HUGS 2021 Lectures on: Experimental Meson Spectroscopy

Prologue: Definitions and Philosophy

- I. A Field Guide to Meson Families
- II. Meson Quantum Numbers
- III. The Quark Model
- IV. Exotic Mesons
- V. Current and Future Experiments

Ryan Mitchell

Senior Scientist Indiana University

(remitche@indiana.edu)

I'm a member of the: BESIII Experiment GlueX Experiment Particle Data Group (which will color these lectures)

HUGS 2021 Lectures on:

▲al Meson Spectroscopy

Jianwei covered some of this material very clearly (the zoom transcript was less clear):

with three full meals, like for example omega minus three.

13:47:34

Australia calls. If they also need the grace day, then they they like to be known as the grandstand they like to be symmetric but we know for the familiar you like to have the overall waveforms to be anti symmetric.

13:47:45

So then if you put those two Republicans together, you have a potential to violate all the politics principle. That means you need another quantum number to help you to distinguish those states.

13:47:55

So that. Exactly.

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rent and Future Experiments

Rvon Mitcholl

strong track your physics, I was taught my lectures, with the discovery of all the headphones, a venture from hadron to the pothole, the potholes to hydro, that's the plan. I'm a member of the: BESIII Experiment GlueX Experiment Particle Data Group (which will color these lectures)

generations **QUARKS** Hadrons: composite particles made from Ι Π Ш quarks (q), antiquarks (\bar{q}) , and gluons (g)electric charge $+\frac{2}{3}$ С t \implies strongly interacting particles U (up) (charm) (top) db 1 S 3 (strange) (bottom) (down) **Baryons:** hadrons with three more quarks q \overline{q} than antiquarks (*e.g. qqq*) **BARYONS** \implies strongly interacting particles, fermions, *baryon number = 1* \bar{q} *q* qMesons: hadrons with equal numbers of conventional baryon pentaquark quarks and antiquarks (e.g. $q\bar{q}$) **MESONS** \implies strongly interacting particles, bosons, *baryon number* = 0 \bar{q} *gg* \bar{q} conventional meson hybrid meson glueball **Spectroscopy:** use the diverse spectrum of hadrons/baryons/mesons to explore the strong \bar{q} \bar{q} \bar{q} q force (QCD) q

tetraquark

meson molecule

baryonium



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Hybrid static potential flux tubes from SU(2) and SU(3) lattice gauge theory

Lasse Müller[®], Owe Philipsen[®], Christian Reisinger, and Marc Wagner[®] Goethe-Universität Frankfurt am Main, Institut für Theoretische Physik, Max-von-Laue-Straße 1, D-60438 Frankfurt am Main, Germany

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We compute chromoelectric and chromomagnetic flux densities for hybrid static potentials in SU(2) and SU(3) lattice gauge theory. In addition to the ordinary static potential with quantum numbers $\Lambda_{\eta}^{e} = \Sigma_{g}^{+}$, we present numerical results for seven hybrid static potentials corresponding to $\Lambda_{\eta}^{(e)} = \Sigma_{u}^{+}, \Sigma_{g}^{-}, \Sigma_{u}^{-}, \Pi_{g}, \Pi_{u}, \Delta_{g}, \Delta_{u}$, where the flux densities of five of them are studied for the first time in this work. We observe hybrid static potential flux tubes, which are significantly different from that of the ordinary static potential. They are reminiscent of vibrating strings, with localized peaks in the flux densities that can be interpreted as valence gluons.



Meson Summary Table

$(S = 0)$ $f^{G}(J^{PC})$ $1^{-}(0^{-})$ $1^{-}(0^{-})$ $0^{+}(0^{-}+)$ $0^{+}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(1^{-}-)$ $0^{-}(1^{-}-)$ $0^{-}(1^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $0^{-}(0^{-}+)$ $1^{-}(0^{-}+)$ $1^{-}(0^{-}+)$ $1^{-}(0^{-}+)$ $1^{-}(0^{-}+)$ $1^{-}(0^{-}+)$ $1^{-}(1^{-}+)$ 1^{-	$\begin{array}{c c} (S=C=B=0) \\ P^C \\ \hline 0^{-} \\ (0^{-}) \\$	$\begin{array}{c} f^{G}(J^{PC}) \\ \hline 1^{-}(2^{-}+) \\ 0^{-}(1^{-}-) \\ 1^{+}(3^{-}-) \\ 1^{+}(1^{-}-) \\ 1^{-}(2^{+}+) \\ 0^{+}(0^{+}+) \\ 0^{+}(0^{+}+) \\ 0^{+}(0^{+}+) \\ 0^{+}(2^{+}+) \\ 1^{-}(2^{-}+) \\ 0^{+}(2^{+}+) \\ 1^{-}(2^{-}+) \\ 1^{-}(2^{-}+) \\ 0^{+}(2^{+}+) \\ 1^{-}(2^{-}+) \\ 0^{+}(2^{+}+) \\ 1^{-}(2^{-}+) \\ 0^{+}(2^{+}+) \\ 0^{+}(2^{+}+) \\ 0^{+}(2^{+}+) \\ 0^{+}(2^{+}+) \\ 0^{+}(2^{+}+) \\ 0^{+}(0^{+}+) \\ 0^{+}$	$(S = \pm 1, C = K^{\pm} + K^{0} $	$= B = 0)$ $f(J^{P})$ $1/2(0^{-})$ $1/2(0^{-})$ $1/2(0^{-})$ $1/2(0^{-})$ $1/2(0^{-})$ $1/2(1^{-})$ $1/2(1^{-})$ $1/2(1^{-})$ $1/2(1^{-})$ $1/2(2^{$	$(C = S = \pm 1)$ $I(J^{P})$ $D_{s}^{\pm} 0(0^{-})$ $D_{s}^{\pm} 0(7^{-})$ $D_{s0}^{\pm}(2317)^{\pm} 0(0^{+})$ $D_{s1}(2460)^{\pm} 0(1^{+})$ $D_{s1}(2536)^{\pm} 0(1^{-})$ $D_{s1}^{\pm}(2700)^{\pm} 0(1^{-})$ $D_{s1}^{\pm}(2860)^{\pm} 0(1^{-})$ $D_{s1}^{\pm}(2860)^{\pm} 0(3^{-})$ $D_{sJ}^{\pm}(3040)^{\pm} 0(7^{-})$ $BOTTOM$ $(B = \pm 1)$ $B^{\pm} 1/2(0^{-})$ $B^{\pm}/B^{0} ADMIXTURE$ $V_{cb} and V_{ub} CKM Matrix Elements$ $B^{*} 1/2(1^{-})$ $B_{1}(5721)^{+} 1/2(1^{+})$ $B_{1}(5721)^{0} 1/2(1^{+})$ $B_{3}(5732) ?(7^{-})$ $B_{2}(5747)^{+} 1/2(2^{+})$	$\begin{array}{c} & \beta(J^{PC}) \\ \bullet \psi(3770) & 0^{-}(1^{-}) \\ \bullet \psi_2(3823) & 0^{-}(2^{-}) \\ \bullet \psi_3(3842) & 0^{-}(3^{-}) \\ \chi_{c0}(3860) & 0^{+}(0^{+}) \\ \bullet \chi_{c1}(3872) & 0^{+}(1^{+}) \\ \bullet \chi_{c1}(3872) & 0^{+}(1^{+}) \\ \bullet \chi_{c2}(3930) & 0^{+}(2^{+}) \\ \chi_{c1}(4100) & 0^{-}(1^{-}) \\ \chi_{c1}(4100) & 0^{+}(1^{+}) \\ \bullet \psi(4160) & 0^{-}(1^{-}) \\ \chi_{c1}(4160) & 1^{-}(2^{-}) \\ \chi_{c1}(4260) & 1^{+}(0^{-}) \\ \chi_{c1}(4270) & 1^{+}(0^{-}) \\ \chi_{c1}(4274) & 0^{+}(1^{+}) \\ \psi(4360) & 0^{-}(1^{-}) \\ \psi(4390) & 0^{-}(1^{-}) \\ \psi(4390) & 0^{-}(1^{-}) \end{array}$
$\begin{array}{c} 1^{-}(0^{-}) \\ 1^{-}(0^{-}) \\ 1^{-}(0^{-}) \\ 0^{+}(0^{-}+) \\ 0^{+}(0^{-}+) \\ 0^{-}(1^{-}+) \\ 0^{-}(1^{-$	$\begin{array}{c} 0^{-} \\$	$\begin{array}{c} 1^{-}(2^{-}+)\\ 0^{-}(1^{-}-)\\ 1^{+}(3^{-}-)\\ 1^{+}(3^{-}-)\\ 1^{+}(1^{-}-)\\ 1^{-}(2^{+}+)\\ 0^{+}(0^{+}+)\\ 0^{+}(0^{+}+)\\ 0^{+}(0^{+}+)\\ 0^{+}(0^{+}+)\\ 0^{+}(2^{+}+)\\ 1^{-}(2^{-}+)\\ 1^{-}(2^{+}+)\\ 1^{-}(2^{+}+)\\ 1^{-}(2^{+}+)\\ 1^{-}(2^{+}+)\\ 0^{+}(2^{+}+)\\ 1^{-}(2^{-}+)\\ 0^{+}(2^{+}+)\\ 0^{+}(2^{+}+)\\ 1^{-}(2^{-}+)\\ 0^{+}(0^{+}+)\\ 0^{+}(0^{+}+)\\ 1^{-}(2^{-}+)\\ 0^{+}(0^{+}+)\\$	• K^{\pm} • K^{0} • K_{S}^{0} • K_{S}^{0} • K_{L}^{0} • $K_{1}^{0}(700)$ • $K_{1}(1270)$ • $K_{1}(1270)$ • $K_{1}(1400)$ • $K_{2}^{*}(1430)$ • $K_{2}^{*}(1430)$ • $K_{2}^{*}(1430)$ • $K_{2}^{*}(1430)$ • $K_{2}^{*}(1430)$ • $K_{2}^{*}(1430)$ • $K_{2}^{*}(1580)$ • $K_{2}^{*}(1580)$ • $K_{2}^{*}(1770)$ • $K_{3}^{*}(1780)$ • $K_{2}^{*}(1820)$ • $K_{2}^{*}(1830)$ • $K_{2}^{*}(1950)$ • $K_{4}^{*}(2045)$ • $K_{2}^{*}(2250)$	$\begin{array}{c} 1/2(0^{-}) \\ 1/2(0^{-}) \\ 1/2(0^{-}) \\ 1/2(0^{-}) \\ 1/2(0^{-}) \\ 1/2(0^{-}) \\ 1/2(1^{-}) \\ 1/2(1^{-}) \\ 1/2(1^{-}) \\ 1/2(1^{-}) \\ 1/2(2^{-}) $	$\begin{array}{c} (J^{-}) \\ D_{S}^{\pm} & 0(0^{-}) \\ D_{S}^{\pm} & 0(?^{2}) \\ D_{s0}^{+}(2317)^{\pm} & 0(0^{+}) \\ D_{s1}(2460)^{\pm} & 0(1^{+}) \\ D_{s1}(2536)^{\pm} & 0(1^{+}) \\ D_{s1}^{+}(2573) & 0(2^{+}) \\ D_{s1}^{+}(260)^{\pm} & 0(1^{-}) \\ D_{s1}^{+}(260)^{\pm} & 0(1^{-}) \\ D_{s3}^{+}(2860)^{\pm} & 0(3^{-}) \\ D_{s3}^{+}(2860)^{\pm} & 0($	• $\psi(3770)$ 0 ⁻ (1 ⁻) • $\psi_2(3823)$ 0 ⁻ (2 ⁻) • $\psi_3(3842)$ 0 ⁻ (3) $\chi_{c0}(3860)$ 0 ⁺ (0 ⁺) • $\chi_{c1}(3872)$ 0 ⁺ (1 ⁺) • $\chi_{c2}(3900)$ 1 ⁺ (1 ⁺) • $\chi_{c2}(3930)$ 0 ⁺ (2 ⁺) • $\chi_{c1}(400)^{\pm}$ 1 ⁻ (? ⁻) • $\chi(4050)^{\pm}$ 1 ⁻ (? ⁻) • $\chi(4050)^{\pm}$ 1 ⁻ (? ⁻) • $\chi(4100)^{\pm}$ 1 ⁻ (? ⁻) • $\chi(4100)^{\pm}$ 1 ⁻ (? ⁻) • $\chi_{c1}(4140)$ 0 ⁺ (1 ⁺) • $\psi(4160)$ 0 ⁻ (1 ⁻) • $\chi(4160)$? ^(???) $Z_{c}(4200)$ 1 ⁺ (1 ⁺) • $\psi(4230)$ 0 ⁻ (1 ⁻) • $\chi_{c1}(4274)$ 0 ⁺ (1 ⁺) • $\chi(4350)$ 0 ⁺ (? ⁺⁺) • $\psi(4360)$ 0 ⁻ (1 ⁻) • $\psi(4390)$ 0 ⁻ (1 ⁻)
$\begin{array}{c} 1 & (0 &) \\ 1^{-}(0 & -+ \\ 0^{+}(0 & ++ \\ 0^{+}(0 & ++ \\ 70) & 1^{+}(1 & \\ 82) & 0^{-}(1 & \\ 82) & 0^{-}(1 & \\ 80) & 0^{+}(0 & ++ \\ 80) & 1^{-}(0 & ++ \\ 80) & 1^{-}(0 & ++ \\ 80) & 1^{-}(0 & ++ \\ 270) & 0^{-}(1 & \\ 235) & 1^{+}(1 & +- \\ 270) & 0^{+}(2 & ++ \\ 270) & 0^{+}(2 & ++ \\ 270) & 0^{+}(2 & ++ \\ 285) & 0^{+}(1 & ++ \\ 285) & 0^{+}(0 & -+ \\ 320) & 1^{-}(2 & ++ \\ 320) & 1^{-}(2 & ++ \\ 370) & 0^{+}(0 & ++ \\ 430) & 1^{-}(1 & -+ \\ 440) & 0^{-}(1 & -+ \\ 420) & 0^{-}(1 & \\ 420) & 0$	$\begin{array}{c} 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 1 & - \\ 0 & - \\ 1 & - \\ 0 & - \\$	$\begin{array}{c} 1 & (2 & -) \\ 0 & -(1 & -) \\ 1 & (3 & -) \\ 1 & (3 & -) \\ 1 & (1 & -) \\ 1 & (2 & +) \\ 0 & +(0 & +) \\ 0 & +(0 & +) \\ 0 & +(0 & +) \\ 0 & +(0 & +) \\ 0 & +(2 & +) \\ 1 & -(2 & +) \\ 1 & -(2 & +) \\ 1 & -(2 & +) \\ 1 & -(2 & +) \\ 1 & -(2 & +) \\ 1 & -(2 & +) \\ 0 & +(2 & +) \\ 1 & -(2 & +) \\ 0 & +(2 & +) \\ 1 & -(2 & +) \\ 0 & +(2 & +) \\ 1 & -(2 & +) \\ 0 & +(2 & +) \\ 0 & +(2 & +) \\ 1 & -(2 & +) \\ 0 & +(0 & +) \\ 0 & +(0 & +) \\ 0 & +(0 & +) \\ 0 & +(0 & +) \\ 0 & +(0 & +) \\ \end{array}$	• K^- • K^0 • K_S^0 • K_L^0 • $K_1^0(700)$ • $K^*(892)$ • $K_1(1270)$ • $K_1(1400)$ • $K_1(1400)$ • $K_2^*(1430)$ • $K_2^*(1430)$ • $K_2^*(1430)$ • $K_2^*(1430)$ • $K_2^*(1580)$ • $K_1(1650)$ • $K_2^*(1680)$ • $K_2^*(1770)$ • $K_3^*(1780)$ • $K_2^*(1780)$ • $K_2^*(1830)$ • $K_2^*(1980)$ • $K_2^*(1980)$ • $K_4^*(2045)$ • $K_2^*(2250)$	$\begin{array}{c} 1/2(0) \\ 1/2(0^{-}) \\ 1/2(0^{-}) \\ 1/2(0^{-}) \\ 1/2(0^{-}) \\ 1/2(1^{-}) \\ 1/2(1^{-}) \\ 1/2(1^{-}) \\ 1/2(1^{-}) \\ 1/2(2^{-}) \\ 1/$	$\begin{array}{c} \mathbf{b}_{\overline{s}} & 0(0^{\circ}) \\ \mathbf{D}_{s}^{\pm} & 0(?^{\circ}) \\ \mathbf{D}_{s0}^{*}(2317)^{\pm} & 0(0^{+}) \\ \mathbf{D}_{s1}(2460)^{\pm} & 0(1^{+}) \\ \mathbf{D}_{s1}(2536)^{\pm} & 0(1^{+}) \\ \mathbf{D}_{s2}^{*}(2573) & 0(2^{+}) \\ \mathbf{D}_{s1}^{*}(2700)^{\pm} & 0(1^{-}) \\ \mathbf{D}_{s1}^{*}(2860)^{\pm} & 0(1^{-}) \\ \mathbf{D}_{s3}^{*}(2860)^{\pm} & 0(3^{-}) \\ \mathbf{D}_{sJ}(3040)^{\pm} & 0(?^{\circ}) \\ \end{array}$ $\begin{array}{c} \mathbf{B}\mathbf{D}TTOM \\ (B = \pm 1) \\ \mathbf{B}^{\pm} & 1/2(0^{-} \\ \mathbf{B}^{0} & 1/2(0^{-} \\ \mathbf{B}^{\pm}/B^{0} A \mathbf{D}\mathbf{M}\mathbf{IXTURE} \\ \mathbf{D}_{s}^{b}/B_{s}^{b}/b \text{-}baryon \\ \mathbf{ADMIXTURE} \\ \mathbf{V}_{cb} \text{ and } V_{ub} \ CKM \ Matrix Elements \\ \mathbf{B}^{*} & 1/2(1^{-} \\ \mathbf{B}_{1}(5721)^{+} & 1/2(1^{+} \\ \mathbf{B}_{1}(5721)^{0} & 1/2(1^{+} \\ \mathbf{B}_{3}^{*}(5732) & ?(?^{\circ}) \\ \mathbf{B}_{2}^{*}(5747)^{+} & 1/2(2^{+} \\ \mathbf{D}_{s}^{*}(5747)^{-} & 1/2($	$\begin{array}{c} \psi_{2}(382) & 0 & (2 \\ \psi_{3}(3842) & 0^{-}(3^{-}) \\ \chi_{c0}(3860) & 0^{+}(0^{+}) \\ & \chi_{c1}(3872) & 0^{+}(1^{+}) \\ & Z_{c}(3900) & 1^{+}(1^{+}) \\ & Z_{c}(3910) & 0^{+}(0/2^{-}) \\ & \chi_{c2}(3930) & 0^{+}(2^{+}) \\ & \chi_{c3}(3940) & ?^{?}(?^{?}) \\ & \chi_{c4}(4020)^{\pm} & 1^{+}(?^{-}) \\ & \psi(4040) & 0^{-}(1^{-}) \\ & \chi(4050)^{\pm} & 1^{-}(?^{?}) \\ & \chi(4050)^{\pm} & 1^{-}(?^{?}) \\ & \chi_{c1}(4140) & 0^{+}(1^{+}) \\ & \psi(4160) & 0^{-}(1^{-}) \\ & \chi_{c1}(4160) & 1^{-}(7^{-}) \\ & \chi_{c1}(4200) & 1^{+}(1^{+}) \\ & \psi(4230) & 0^{-}(1^{-}) \\ & \chi_{c1}(4274) & 0^{+}(1^{+}) \\ & \chi(4350) & 0^{+}(?^{2^{+}}) \\ & \psi(4360) & 0^{-}(1^{-}) \\ & \psi(4390) & 0^{-}(1^{-}) \end{array}$
$\begin{array}{c} 1 & (0 & - + \\ 0^+ & (0^+ + + \\ 0^- & (0^+ + + \\ 1^- & - \\ 82) & 0^- & (1^ \\ 82) & 0^- & (1^ \\ 80) & 0^+ & (0^+ + \\ 80) & 1^- & (0^+ + \\ 80) & 1^- & (0^+ + \\ 180) & 1^- & (0^+ + \\ 180) & 1^- & (1^+ + \\ 180) & 0^+ & (1^+ + \\ 180) & 1^- & (1^- + \\ 180) & 1^- & (0^- + \\ 180) & 1^- & (0^- + \\ 180) & 1^- & (0^- + \\ 180) & 1^- & (0^- + \\ 180) & 1^- & (1^- + \\ 180) & 0^+ & (1^+ + \\ 180) & 0^- & (1^ \\ 1$	$\begin{array}{c} 0 \\ (0^{-+}) \\ (0^{-+}) \\ (0^{++}) \\ (0^{++}) \\ (0^{++}) \\ (0^{++}) \\ (1^{}) \\ (0^{++}) \\ (1^{}) \\ (0^{++}) \\ (1^{}) \\ (0^{++}) \\ (1^{}) \\ (0^{++}) \\ (1^{}) \\ $	$\begin{array}{c} 0 & (1 &) \\ 1^+(3 & -) \\ 1^+(1 & -) \\ 1^-(2 & +) \\ 0^+(0 & +) \\ 0^+(0 & +) \\ 0^+(0 & +) \\ 1^-(0 & +) \\ 0^+(2 & +) \\ 1^-(2 & +) \\ 1^-(2 & +) \\ 1^-(2 & +) \\ 1^-(2 & +) \\ 1^-(2 & +) \\ 1^-(2 & +) \\ 1^-(2 & +) \\ 1^-(2 & +) \\ 1^-(2 & +) \\ 0^+(2 & +) \\ 1^-(2 & +) \\ 0^+(2 & +) \\ 1^-(2 & +) \\ 0^+(0 & +) $	$\begin{array}{c} \kappa \\ \kappa $	$\begin{array}{c} 1/2(0^{-})\\ 1/2(0^{-})\\ 1/2(0^{-})\\ 1/2(1^{-})\\ 1/2(1^{-})\\ 1/2(1^{+})\\ 1/2(1^{-})\\ 1/2(1^{-})\\ 1/2(2^{-})\\$	$\begin{array}{c} \mathbf{D}_{s^{-}}^{-} & 0(?^{+}) \\ \mathbf{D}_{s0}^{+}(2317)^{\pm} & 0(0^{+}) \\ \mathbf{D}_{s1}(2460)^{\pm} & 0(1^{+}) \\ \mathbf{D}_{s1}(2536)^{\pm} & 0(1^{+}) \\ \mathbf{D}_{s2}^{+}(2573) & 0(2^{+}) \\ \mathbf{D}_{s1}^{+}(2660)^{\pm} & 0(1^{-}) \\ \mathbf{D}_{s1}^{+}(2660)^{\pm} & 0(1^{-}) \\ \mathbf{D}_{s1}^{+}(2660)^{\pm} & 0(3^{-}) \\ \mathbf{D}_{sJ}^{+}(3040)^{\pm} & 0(?^{+}) \\ \end{array}$	$\begin{array}{c} \psi_{3}(3642) & 0 & (37) \\ \chi_{C0}(3860) & 0^{+}(0 + \\ \chi_{C1}(3872) & 0^{+}(1 + \\ Z_{C}(3900) & 1^{+}(1 + \\ Z_{C}(3900) & 0^{+}(2 + \\ X(3915) & 0^{+}(0/2 - \\ \chi_{C2}(3930) & 0^{+}(2 + \\ X(3940) & ?^{?}(?^{?}) \\ \chi_{C1}(400) & 0^{-}(1 - \\ X(4005) \pm & 1^{-}(?^{?} + \\ X(4055) \pm & 1^{+}(?^{-} - \\ X(4055) \pm & 1^{+}(?^{-} - \\ X(4055) \pm & 1^{+}(?^{-} - \\ X(4100) \pm & 1^{-}(?^{?} + \\ \chi(4100) \pm & 1^{-}(?^{?} + \\ \chi(4100) \pm & 1^{-}(?^{?} + \\ \chi(4100) + & 1^{-}(?^{?} + \\ \chi(4100) + & 1^{-}(?^{?} + \\ \chi(4160) & 0^{-}(1 - \\ \chi(4160) & ?^{?}(?^{?} + \\ \chi(4160) & 1^{+}(1 + \\ \psi(4230) & 0^{-}(1 - \\ \chi(4250) \pm & 1^{-}(?^{?} + \\ \psi(4260) & 0^{-}(1 - \\ \chi(4250) \pm & 1^{-}(?^{?} + \\ \chi(4350) & 0^{+}(?^{2} + \\ \psi(4360) & 0^{-}(1 - \\ \psi(4390) & 0^{-}(1 - \\ \end{array}$
$\begin{array}{c} 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & - & - \\ 70 & 1 & 1 & - & - \\ 82 & 0 & - & 1 & - & - \\ 58 & 0 & + & 0 & - & + \\ 80 & 0 & + & 0 & + & + \\ 80 & 1 & - & 0 & + & + \\ 920 & 0 & - & 1 & - & - \\ 2235 & 1 & + & 1 & + & - \\ 2260 & 1 & - & (1 & + & + \\ 270) & 0 & - & (1 & + & + \\ 270) & 0 & + & (2 & + & + \\ 285) & 0 & + & (1 & + & + \\ 295) & 0 & + & (0 & - & + \\ 320) & 1 & - & (2 & + & + \\ 320) & 1 & - & (2 & + & + \\ 320) & 1 & - & (2 & + & + \\ 320) & 1 & - & (2 & + & + \\ 4300) & 1 & - & (1 & - & + \\ 4450) & 0 & - & (1 & - & + \\ 420) & 0 & - & (1 & - & - & - \\ 420) & 0 & - & (1 & - & - \\ 420) & 0 & - & (1 & - &$	$\begin{array}{c} \rho_{1}(1) \\ \rho_{2}(1) \\ \rho_{3}(1) \\ \rho_{3$	$\begin{array}{c} 1+(3-)\\ 1+(1-)\\ 1-(2+)\\ 0+(0+)\\ 0+(0+)\\ 1-(0-+)\\ 1-(0-+)\\ 0+(2++)\\ ?^{?}(0-+)\\ 0-(3)\\ 0+(2++)\\ 1-(2-+)\\ 1+(1)\\ 0+(2++)\\ 1-(2++)\\ 1-(0++)\\ 0+(2++)\\ 1-(2++)\\ 0+(2++)\\ 1-(2-+)\\ 0+(0++)$	κ_s κ_1^0 $\kappa_1^{(700)}$ $\kappa_1^{(1270)}$ $\kappa_1^{(1270)}$ $\kappa_1^{(1400)}$ $\kappa_1^{(1410)}$ $\kappa_1^{(1410)}$ $\kappa_1^{(1410)}$ $\kappa_1^{(1410)}$ $\kappa_1^{(1430)}$ $\kappa_1^{(1430)}$ $\kappa_1^{(1650)}$ $\kappa_1^{(1650)}$ $\kappa_1^{(1650)}$ $\kappa_2^{(1770)}$ $\kappa_2^{(1770)}$ $\kappa_2^{(1820)}$ $\kappa_1^{(1820)}$ $\kappa_1^{(1830)}$ $\kappa_2^{(1950)}$ $\kappa_2^{(1950)}$ $\kappa_2^{(2220)}$	$\begin{array}{c} 1/2(0^{-})\\ 1/2(0^{-})\\ 1/2(1^{-})\\ 1/2(1^{-})\\ 1/2(1^{-})\\ 1/2(1^{-})\\ 1/2(1^{-})\\ 1/2(2^{-})\\$	• $D_{s0}(2317)^ 0(0^+)^-$ • $D_{s1}(2460)^{\pm}$ $0(1^+)^-$ • $D_{s1}(2536)^{\pm}$ $0(1^+)^-$ • $D_{s2}^*(2573)$ $0(2^+)^-$ • $D_{s1}^*(2600)^{\pm}$ $0(1^-)^-$ $D_{s1}^*(2660)^{\pm}$ $0(3^-)^-$ $D_{sJ}(3040)^{\pm}$ $0(2^-)^-$ • B^0 $1/2(0^-$ • $B^{\pm}/B^0/B_0^0/b^-$ baryon ADMIXTURE • $B^{\pm}/B^0/B_0^0/b^-$ baryon ADMIXTURE • $B^{\pm}/B^0/B_0^0/b^-$ baryon • B^{\pm}/B	$\begin{array}{c} \chi_{c1}(300) 0 & 0 & 0 \\ \chi_{c1}(3872) & 0^+(1+\\ Z_c(3900) & 1^+(1+\\ Z_c(3900) & 0^+(2+\\ X(3915) & 0^+(0/2) \\ \chi_{c2}(3930) & 0^+(2+\\ X(400) & 1^-(2+\\ X(4100) & 1^-(2+\\ X(4100) & 0^+(1+\\ \psi(4160) & 0^-(1-\\ X(4160) & 2^+(2+\\ X(4160) & 2^+(2+\\ X(4160) & 1^+(2+\\ X(4250) & 1^+(2+\\ X(4250) & 1^-(2+\\ X(4250) & 1^-(2+\\ X(4250) & 1^-(2+\\ \chi(4250) & 0^+(2+\\ \chi(4350) & 0^+(2+\\ \chi(4360) & 0^-(1-\\ \psi(4390) & 0^-(1-\\ \chi(4290) & 0^-(1-\\ \chi(4290$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c} p_1(100) \\ (1) \\ = \partial_2(1700) \\ (1) \\ = \partial_2(1700) \\ = \partial_1(1700) \\ = \partial_1(1700$	$\begin{array}{c} 1 & (1 \\ -) \\ 1 - (2 + +) \\ 0^+ (0 + +) \\ 0^+ (0 + +) \\ 0^+ (0 - +) \\ 1^- (0 - +) \\ 0^+ (2 + +) \\ 0^- (3) \\ 0^+ (2 + +) \\ 1^- (2 - +) \\ 1^- (2 - +) \\ 1^- (2 + +) \\ 1^- (2 + +) \\ 1^- (2 + +) \\ 0^+ (2 + +) \\ 1^- (2 - +) \\ 0^+ (2 + +) \\ 0^+ (0 + +) \\ 0^+ (0 + +) \\ 1^- (2 - +) \\ 0^+ (0 + $	κ_{L} $\kappa_{0}(700)$ $\kappa'(892)$ $\kappa_{1}(1270)$ $\kappa_{1}(1400)$ $\kappa'(1410)$ $\kappa'_{0}(1430)$ $\kappa'_{2}(1580)$ $\kappa(1630)$ $\kappa(1650)$ $\kappa'(1680)$ $\kappa'_{2}(1770)$ $\kappa'_{3}(1780)$ $\kappa'_{2}(1820)$ $\kappa(1830)$ $\kappa'_{2}(1820)$ $\kappa'_{3}(1950)$ $\kappa'_{4}(2045)$ $\kappa'_{4}(2025)$	$\begin{array}{c} 1/2(0^{+}) \\ 1/2(0^{+}) \\ 1/2(1^{-}) \\ 1/2(1^{-}) \\ 1/2(1^{+}) \\ 1/2(1^{-}) \\ 1/2(0^{-}) \\ 1/2(2^{-}) \\ 1/2(2^{-}) \\ 1/2(2^{-}) \\ 1/2(2^{-}) \\ 1/2(2^{-}) \\ 1/2(2^{-}) \\ 1/2(2^{-}) \\ 1/2(0^{-}) \\ 1/2(2^{+}) \\ 1/2(2^{+}) \\ 1/2(2^{+}) \\ 1/2(2^{+}) \\ 1/2(2^{+}) \\ 1/2(2^{+}) \\ 1/2(2^{-}) \\ 1/2(2^{+}) \\ 1/2(2^{-}) \\ 1/2(2^{-}) \\ 1/2(2^{+}) \\ 1/2(2^{-}) $	$\begin{array}{c} \mathbf{b}_{s1}(2400)^{-} & 0(1^{+}) \\ \mathbf{b}_{s1}(2536)^{\pm} & 0(1^{+}) \\ \mathbf{b}_{s2}^{*}(2573) & 0(2^{+}) \\ \mathbf{b}_{s1}^{*}(2700)^{\pm} & 0(1^{-}) \\ \mathbf{b}_{s1}^{*}(2860)^{\pm} & 0(3^{-}) \\ \mathbf{b}_{s3}^{*}(2860)^{\pm} & 0(3^{-}) \\ \mathbf{b}_{s3}^{*}(3040)^{\pm} & 0(?^{2}) \\ \end{array}$	$\begin{array}{c} \sum_{c(3900)} 1^{+}(1+\\ \sum_{c(3900)} 1^{+}(1+\\ \sum_{c(3900)} 1^{+}(1+\\ \sum_{c(3910)} 0^{+}(2+\\ \sum_{c(3940)} 2^{+}(2+\\ \sum_{c(3940)} 2^{+}(2+\\ \sum_{c(3940)} 1^{+}(2+\\ \sum_{c(1410)} 0^{-}(1-\\ \sum_{c(4055)} 1^{+}(2+\\ \sum_{c(14140)} 1^{-}(2+\\ \sum_{c(14140)} 1^{-}(2+\\ \sum_{c(14140)} 1^{-}(2+\\ \sum_{c(14140)} 1^{+}(1+\\ \sum$
$\begin{array}{c} 0 \\ 82 \\ 82 \\ 0^{-}(158) \\ 0^{+}(0-+8) \\ 80 \\ 0^{+}(0++8) \\ 80 \\ 1^{-}(0++8) \\ 920 \\ 0^{-}(12) \\ 1^{-}(1+-2) \\ 1^{-}($	$\begin{array}{c} a \\ (1) \\ (1-$	$\begin{array}{c} 1 & (2 \\ 0 \\ 0 \\ + (0 \\ +) \\ 0^+ (0 \\ -+) \\ 1^- (0 \\ -+) \\ 0^- (2 \\ -+) \\ 0^- (2 \\ -+) \\ 1^- (2 \\ -+) \\ 1^- (2 \\ -+) \\ 1^- (2 \\ -+) \\ 1^- (2 \\ -+) \\ 1^- (2 \\ -+) \\ 1^- (2 \\ -+) \\ 0^+ (2 \\ ++) \\ 1^- (2 \\ -+) \\ 0^+ (0 \\ ++) \\ 0^+ (0 \\ ++) \\ 1^- (2 \\ -+) \\ 0^+ (0 \\ ++) \\ 1^- (2 \\ -+) \\ 0^+ (0 \\ ++) \\ 1^- (2 \\ -+) \\ 0^+ (0 \\ ++) \\ $	$\begin{array}{c} \kappa_{0}(100)\\ \kappa'(892)\\ \kappa'(11270)\\ \kappa'(11270)\\ \kappa'(1410)\\ \kappa'(1410)\\ \kappa'(1410)\\ \kappa'(1410)\\ \kappa'(1410)\\ \kappa'(1410)\\ \kappa'(1430)\\ \kappa'(1430)\\ \kappa'(1630)\\ \kappa'(163$	$\begin{array}{c} 1/2(0^{-})\\ 1/2(1^{-})\\ 1/2(1^{+})\\ 1/2(1^{+})\\ 1/2(0^{-})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(0^{-})\\ 1/2(2^{+})\\ 1/2(2^{+})\\ 1/2(2^{+})\\ 1/2(2^{+})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(2^{+})\\ 1/2(2^{-})\\$	$\begin{array}{c} \mathbf{b}_{s1}(2336)^{-} & 0(1^{+}) \\ \mathbf{D}_{s2}^{*}(2573) & 0(2^{+}) \\ \mathbf{D}_{s1}^{*}(2700)^{\pm} & 0(1^{-}) \\ \mathbf{D}_{s1}^{*}(2860)^{\pm} & 0(1^{-}) \\ \mathbf{D}_{s3}^{*}(2860)^{\pm} & 0(3^{-}) \\ \mathbf{D}_{sJ}(3040)^{\pm} & 0(?^{2}) \\ \hline \\ \mathbf{B}^{0} & \mathbf{D}_{sJ}(20^{-}) \\ \mathbf{B}^{0} & \mathbf{D}_{sJ}(20^{-}) \\ \mathbf{B}^{\pm}/B^{0} & \mathbf{A}_{sJ}(20^{-}) \\ \mathbf{B}^{$	$\begin{array}{c} \lambda(3915) & 0^+(0/2)^-\\ \times \chi_{c2}(3930) & 0^+(2+\\ \chi(3940) & ?^?(?^?)\\ \times \chi(4020)^\pm & 1^+(?^?-\\ \psi(4040) & 0^-(1-\\ \chi(4050)^\pm & 1^-(?^?+\\ \chi(4055)^\pm & 1^+(?^?-\\ \chi(4100)^\pm & 1^-(?^?)\\ \chi_{c1}(4140) & 0^+(1+\\ \psi(4160) & 0^-(1-\\ \chi(4160) & ?^?(?^?)\\ Z_c(4200) & 1^+(1+\\ \psi(4230) & 0^-(1-\\ \chi(4250)^\pm & 1^-(?^?+\\ \psi(4260) & 0^-(1-\\ \chi(4250)^\pm & 1^-(?^?+\\ \psi(4360) & 0^+(1+\\ \chi(4350) & 0^+(?^?+\\ \psi(4390) & 0^-(1-\\ \psi(4390) & 0^-(1-\\ \psi(4390) & 0^-(1-\\ \chi(4290) & 0^-(1-\\ \chi(4390) &$
$\begin{array}{c} 0 + (0 - + + \\ 80) & 0^+(0 + + \\ 80) & 1^-(0 + + \\ 80) & 1^-(0 + + \\ 90) & 1^-(1 \\ 90) & 0^-(1 \\ 90) & 1^-(1 + + \\ 90) & 1^-(1 + + \\ 90) & 1^-(0 - + \\ 90) & 1^-(0 - + \\ 90) & 1^-(0 - + \\ 90) & 1^-(1 - + \\ 90) & 1^$	$\begin{array}{c} 0 & -+ \\ \eta(1760) \\ \eta(1760) \\ \eta(1760) \\ \eta(1760) \\ \eta(1760) \\ \eta(1760) \\ \eta(1800) \\ \eta(1800) \\ \eta(180) \\ \eta(1835) \\ \eta_2(1810) \\ \eta_2(1810) \\ \eta_2(1870) \\ \eta_2(1910) \\ \eta_2(190) \\ \eta_3(1990) \\ \eta_4(1970) \\ \eta_3(1990) \\ \eta_4(1970) \\ \eta_5(1950) \\ \eta_{1} + \eta_{1} \\ \eta_{2}(2005) \\ \eta_{1} + \eta_{2}(2005) \\ \eta_{1} + \eta_{2}(2100) \\ \eta_{2}(190) \\ \eta_{2}(190) \\ \eta_{3}(190) \\ \eta_{4}(190) \\$	$\begin{array}{c} 0+(0-+)\\ 1-(0-+)\\ 0+(2++)\\ ?^{?}(0-+)\\ 0-(3)\\ 0+(2-+)\\ 1-(2-+)\\ 1+(1)\\ 0+(2++)\\ 1-(2++)\\ 1-(0++)\\ 0+(2++)\\ 1-(4++)\\ 1+(3)\\ 1-(2-+)\\ 0+(2++)\\ 0+(2++)\\ 0+(2++)\\ 0+(0++)\\ 0+(0++)\\ 1-(2-+)\\ 0+(0++)\\ 0+$	$\begin{array}{c} \kappa_{1}(02)\\ \kappa_{1}(1270)\\ \kappa_{1}(1400)\\ \kappa_{1}(1400)\\ \kappa_{1}(1400)\\ \kappa_{2}(1430)\\ \kappa_{2}(1430)\\ \kappa_{1}(1650)\\ \kappa_{1}(1650)\\ \kappa_{1}(1650)\\ \kappa_{2}(1770)\\ \kappa_{3}(1780)\\ \kappa_{2}(1770)\\ \kappa_{3}(1780)\\ \kappa_{2}(1820)\\ \kappa_{1}(1830)\\ \kappa_{2}(1820)\\ \kappa_{1}(1830)\\ \kappa_{2}(1950)\\ \kappa_{2}(1980)\\ \kappa_{4}(2045)\\ \kappa_{2}(2220)\\ \end{array}$	$\begin{array}{c} 1/2(1^{-})\\ 1/2(1^{+})\\ 1/2(1^{-})\\ 1/2(0^{-})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(1^{-})\\ 1/2(1^{-})\\ 1/2(2^{-})\\ 1/2(2^{-})\\ 1/2(0^{-})\\ 1/2(2^{+})\\ 1/2(2^{+})\\ 1/2(2^{+})\\ 1/2(2^{-})\\$	$\begin{array}{c} B_{52}(2373) & 0(2^{-}) \\ D_{51}^{*}(2700)^{\pm} & 0(1^{-}) \\ D_{51}^{*}(2860)^{\pm} & 0(1^{-}) \\ D_{53}^{*}(2860)^{\pm} & 0(3^{-}) \\ D_{53}^{*}(3040)^{\pm} & 0(?^{2}) \\ \hline \end{array} \\ \hline \begin{array}{c} BOTTOM \\ (B = \pm 1) \\ \hline \end{array} \\ \hline \\ BOTTOM \\ (B = \pm 1) \\ \hline \end{array} \\ \hline \\ B^{\pm} & 1/2(0^{-} \\ B^{0} & 1/2(0^{-} \\ B^$	$\begin{array}{c} \chi_{c2}(3930) & 0^+(2+) \\ \chi_{c3}(3940) & ?^?(?^?) \\ & \chi(4020)^{\pm} & 1^+(?^?-) \\ & \psi(4040) & 0^-(1-) \\ & \chi(4050)^{\pm} & 1^-(?^?+) \\ & \chi(4055)^{\pm} & 1^+(?^?-) \\ & \chi(4100)^{\pm} & 1^-(?^?) \\ & \chi_{c1}(4140) & 0^+(1+) \\ & \psi(4160) & 0^-(1-) \\ & \chi(4160) & ?^?(?^?) \\ & Z_c(4200) & 1^+(1+) \\ & \psi(4230) & 0^-(1-) \\ & \chi(4250)^{\pm} & 1^-(?^?+) \\ & \psi(4260) & 0^-(1-) \\ & \chi_{c1}(4274) & 0^+(1+) \\ & \chi(4350) & 0^+(?^?+) \\ & \psi(4360) & 0^-(1-) \\ & \psi(4390) & 0^-(1-) \end{array}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c} 0 & + + \\ 0 & +$	$\begin{array}{c} 1-(0-+)\\ 0+(2++)\\ ?^?(0-+)\\ 0-(3)\\ 0+(2-+)\\ 1-(2-+)\\ 1+(1)\\ 0+(2++)\\ 1-(0++)\\ 0+(2++)\\ 1-(0++)\\ 1-(2-+)\\ 0+(2++)\\ 0+(2++)\\ 0+(2++)\\ 0+(2++)\\ 0+(2++)\\ 0+(2++)\\ 1-(2-+)\\ 0+(0++)\\ 0+(0$	$\begin{array}{c} \kappa_1(1210)\\ \kappa_1(1400)\\ \kappa_1(1400)\\ \kappa_2(1430)\\ \kappa_2(1430)\\ \kappa_2(1580)\\ \kappa_1(1650)\\ \kappa_1(1650)\\ \kappa_1(1650)\\ \kappa_2(1770)\\ \kappa_3(1780)\\ \kappa_2(1770)\\ \kappa_3(1780)\\ \kappa_2(1820)\\ \kappa_1(1830)\\ \kappa_2(1820)\\ \kappa_1(1830)\\ \kappa_2(1980)\\ \kappa_2(1980)\\ \kappa_2(2250)\\ \kappa_2(2250)\\ \kappa_2(2250)\\ \kappa_2(2220)\end{array}$	$\begin{array}{c} 1/2(1^+) \\ 1/2(1^-) \\ 1/2(0^+) \\ 1/2(2^+) \\ 1/2(2^-) \\ 1/2(2^-) \\ 1/2(2^-) \\ 1/2(1^-) \\ 1/2(1^-) \\ 1/2(1^-) \\ 1/2(2^-) \\ 1/2(2^-) \\ 1/2(0^+) \\ 1/2(2^+) \\ 1/2(2^+) \\ 1/2(2^+) \\ 1/2(2^-) \end{array}$	$\begin{array}{cccc} B_{31}(2100) & 0(1^{-}) \\ D_{51}^{*}(2860)^{\pm} & 0(1^{-}) \\ D_{53}^{*}(2860)^{\pm} & 0(3^{-}) \\ D_{sJ}(3040)^{\pm} & 0(?^{2}) \\ \hline \\ BOTTOM \\ (B = \pm 1) \\ \bullet B^{\pm} & 1/2(0^{-} \\ B^{0} & 1/2(0^{-} \\ B^{\pm}/B^{0} & ADMIXTURE \\ B^{\pm}/B^{0} & ADMIXTURE \\ B^{\pm}/B^{0} & B_{0}^{0}/b \text{-baryon} \\ ADMIXTURE \\ V_{cb} & and V_{ub} & CKM \text{ Matrix Elements} \\ B^{*} & 1/2(1^{-} \\ B_{1}(5721)^{+} & 1/2(1^{+} \\ B_{1}(5721)^{0} & 1/2(1^{+} \\ B_{3}(5732) & ?(?^{2}) \\ B_{2}^{*}(5747)^{+} & 1/2(2^{+} \\ B_{3}(5747)^{+} & 1/2(2^{+} \\ B_{3}(5747)^{+} & 1/2(2^{+} \\ B_{3}(5747)^{-} & 1/2(2^{$	$\begin{array}{c} \chi(3940) & ??(??)\\ \bullet \chi(4020)^{\pm} & 1^{+}(??^{-}\\ \bullet \psi(4040) & 0^{-}(1^{-}\\ \chi(4050)^{\pm} & 1^{-}(??^{+}\\ \chi(4055)^{\pm} & 1^{+}(?^{-}\\ \chi(4100)^{\pm} & 1^{-}(??^{+})\\ \chi(4100)^{\pm} & 1^{-}(??^{+})\\ \bullet \psi(4160) & 0^{-}(1^{-}\\ \chi(4160) & ??(??)\\ Z_{c}(4200) & 1^{+}(1^{+}\\ \bullet \psi(4230) & 0^{-}(1^{-}\\ R_{c0}(4240) & 1^{+}(0^{-}\\ \chi(4250)^{\pm} & 1^{-}(?^{+})\\ \psi(4260) & 0^{-}(1^{-}\\ \chi(4150) & 0^{+}(?^{+})\\ \psi(4350) & 0^{+}(?^{+})\\ \bullet \psi(4360) & 0^{-}(1^{-}\\ \psi(4390) & 0^{-}(1^{-}\\ \end{array}$
$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c} 0^{+}(2^{+}+)\\ ?^{?}(0^{-}+)\\ 0^{-}(3^{-}-)\\ 0^{+}(2^{-}+)\\ 1^{-}(2^{-}+)\\ 1^{-}(2^{-}+)\\ 1^{-}(0^{+}+)\\ 0^{+}(2^{+}+)\\ 1^{-}(4^{+}+)\\ 1^{-}(2^{-}+)\\ 0^{+}(2^{+}+)\\ 0^{+}(2^{+}+)\\ 0^{+}(4^{+}+)\\ 1^{-}(2^{-}+)\\ 0^{+}(0^{+}+)\\$	• $K^*(1410)$ • $K_0^*(1430)$ • $K_2^*(1430)$ • $K_2^*(1430)$ • $K_2(1580)$ • $K_1(1650)$ • $K_1(1650)$ • $K_1(1650)$ • $K_2(1770)$ • $K_2^*(1770)$ • $K_2^*(1780)$ • $K_2^*(1820)$ • $K_1(1830)$ • $K_2^*(1980)$ • $K_2^*(1980)$ • $K_2^*(2050)$ • $K_2(2250)$	$\begin{array}{c} 1/2(1^-) \\ 1/2(0^+) \\ 1/2(2^+) \\ 1/2(2^-) \\ 1/2(2^-) \\ 1/2(2^-) \\ 1/2(1^-) \\ 1/2(1^-) \\ 1/2(1^-) \\ 1/2(2^-) \\ 1/2(2^-) \\ 1/2(0^-) \\ 1/2(2^+) \\ 1/2(2^+) \\ 1/2(2^+) \\ 1/2(2^-) \end{array}$	$\begin{array}{c} D_{s1}(2360)^{\pm} & 0(3^{-}) \\ D_{s3}^{*}(2860)^{\pm} & 0(3^{-}) \\ D_{sJ}(3040)^{\pm} & 0(?^{2}) \\ \hline \\ & \text{BOTTOM} \\ (B = \pm 1) \\ \hline \\ & B^{\pm} & 1/2(0^{-} \\ B^{0} & 1/2(0^{-} \\ B^{\pm}/B^{0}/B_{s}^{0}/b \text{-baryon} \\ ADMIXTURE \\ V_{cb} \text{ and } V_{ub} \text{ CKM Matrix Elements} \\ B^{*} & 1/2(1^{-} \\ B_{1}(5721)^{+} & 1/2(1^{-} \\ B_{1}(5721)^{0} & 1/2(1^{+} \\ B_{1}(5721)^{0} & 1/2(1^{+} \\ B_{3}(5732) & ?(?^{2}) \\ B_{2}^{*}(5747)^{+} & 1/2(2^{+} \\ D_{3}(5747)^{+} & 1/2(2^{+} \\ D_{3}(5747)^{0} & 1/2(2^{+} \\ D_{3}(5747)^$	• $X(4020)^{\pm}$ 1 ^{+(??- • $\psi(4040)$ 0⁻⁽¹⁻⁾ $X(4050)^{\pm}$ 1^{-(??+ $X(4055)^{\pm}$ 1^{+(?)- $X(4100)^{\pm}$ 1^{-(???)} • $\chi_{c1}(4140)$ 0⁺⁽¹⁺⁾ • $\psi(4160)$ 0⁻⁽¹⁻⁾ X(4160) ?^(???) $Z_{c}(4200)$ 1⁺⁽¹⁺⁾ • $\psi(4230)$ 0⁻⁽¹⁻⁾ $R_{c0}(4240)$ 1⁺⁽⁰⁻⁾ $X(4250)^{\pm}$ 1^{-(??+)} $\psi(4260)$ 0⁻⁽¹⁻⁾ • $\chi_{c1}(4274)$ 0⁺⁽¹⁺⁾ X(4350) 0^{+(?+1)} • $\psi(4360)$ 0⁻⁽¹⁻⁾ $\psi(4390)$ 0⁻⁽¹⁻⁾}}}
$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	$\begin{array}{cccc} (1) & \chi(1835) \\ (1+-) & \phi_3(1850) \\ (1+-) & \phi_3(1850) \\ (1++) & \pi_2(1870) \\ (1++) & \pi_2(1880) \\ (1++) & f_2(1910) \\ (0-+) & a_0(1950) \\ (0-+) & f_2(1950) \\ (1++) & f_2(1950) \\ (1++) & f_2(2010) \\ (1+-) & f_2(2010) \\ (1++) & f_2(205) \\ (1++) & f_2(2010) \\ (1++) & f_2(2010) \\ (1++) & f_2(2010) \\ (1++) & f_2(2100) \\ (1+-) & f_2(210) \\ (1+-) & $	$\begin{array}{c} ??(0-+) \\ 0^{-}(3) \\ 0^{+}(2-+) \\ 1^{-}(2-+) \\ 1^{+}(1) \\ 0^{+}(2++) \\ 1^{-}(0++) \\ 0^{+}(2++) \\ 1^{-}(4++) \\ 1^{+}(3) \\ 1^{-}(2-+) \\ 0^{+}(2++) \\ 0^{+}(2++) \\ 0^{+}(0++) \\ 1^{-}(2-+) \\ 0^{+}(0++) \end{array}$	• $K_0^*(1430)$ • $K_2^*(1430)$ • $K_2^*(1430)$ • $K_2^*(1580)$ • $K_1(1650)$ • $K_1(1650)$ • $K_2^*(1680)$ • $K_2^*(1770)$ • $K_2^*(1770)$ • $K_2^*(1770)$ • $K_2^*(1770)$ • $K_2^*(1770)$ • $K_2^*(1770)$ • $K_2^*(1780)$ • $K_2^*(1980)$ • $K_2^*(1980)$ • $K_2^*(2045)$ • $K_2^*(2020)$	$1/2(0^+)$ $1/2(2^+)$ $1/2(2^-)$ $1/2(2^-)$ $1/2(1^-)$ $1/2(1^-)$ $1/2(2^-)$ $1/2(2^-)$ $1/2(2^-)$ $1/2(0^-)$ $1/2(2^+)$ $1/2(2^+)$ $1/2(2^+)$ $1/2(2^-)$ $1/2(2^+)$ $1/2(2^-)$	$\begin{array}{c} B_{s3}^{-1}(3000)^{\pm} & 0(?^{?}) \\ \hline BOTTOM \\ (B = \pm 1) \\ \bullet B^{\pm} & 1/2(0^{-} \\ \bullet B^{0} & 1/2(0^{-} \\ \bullet B^{\pm}/B^{0} & ADMIXTURE \\ \bullet B^{\pm}/B^{0}/B^{0}_{s}/b^{-}baryon \\ ADMIXTURE \\ V_{cb} \text{ and } V_{ub} \ CKM \ Matrix \ Elements \\ \bullet B^{*} & 1/2(1^{-} \\ \bullet B_{1}(5721)^{+} & 1/2(1^{+} \\ \bullet B_{1}(5721)^{0} & 1/2(1^{+} \\ B_{3}(5732) & ?(?^{?}) \\ \bullet B^{*}_{2}(5747)^{+} & 1/2(2^{+} \\ \bullet B^{*}_{3}(5747)^{+} & 1/2(2^{+} \\ \bullet B^{*}_{3}(5747)^{+} & 1/2(2^{+} \\ \bullet B^{*}_{3}(5747)^{0} & 1/2(2^{+} \\ \bullet B^{$	• $\psi(4040)$ 0 ⁻⁽¹⁻ $X(4050)^{\pm}$ 1 ^{-(?+4)} $X(4055)^{\pm}$ 1 ^{+(?-7)} $X(4100)^{\pm}$ 1 ^{-(???} • $\chi_{c1}(4140)$ 0 ⁺⁽¹⁺⁺⁷⁾ • $\psi(4160)$ 0 ⁻⁽¹⁻⁷⁾ X(4160) ? ^(???) $Z_{c}(4200)$ 1 ⁺⁽¹⁺⁷⁾ • $\psi(4230)$ 0 ⁻⁽¹⁻⁷⁾ $R_{c0}(4240)$ 1 ⁺⁽⁰⁻⁷⁾ $X(4250)^{\pm}$ 1 ^{-(?+4)} $\psi(4260)$ 0 ⁻⁽¹⁻⁷⁾ • $\chi_{c1}(4274)$ 0 ⁺⁽¹⁺¹⁺⁷⁾ X(4350) 0 ^{+(?+4)} • $\psi(4360)$ 0 ⁻⁽¹⁻⁷⁾ $\psi(4390)$ 0 ⁻⁽¹⁻⁷⁾
$\begin{array}{rrrr} 170) & 0^{-}(1+-) \\ 170) & 1^{+}(1+-) \\ 1235) & 1^{+}(1+-) \\ 170) & 0^{+}(2++) \\ 270) & 0^{+}(2++) \\ 285) & 0^{+}(0-+) \\ 300) & 1^{-}(0-+) \\ 300) & 1^{-}(0-+) \\ 320) & 1^{-}(2++) \\ 370) & 0^{+}(0++) \\ 370) & 0^{+}(0++) \\ 4400) & 1^{-}(1-+) \\ 4400) & 1^{-}(1+-) \\ 4400) & 1^{-}(1++) \\ 420) & 0^{+}(1++) \\ 420) & 0^{+}(1) \\ 420) & 0^{-}$	$\begin{array}{ccccc} (1^{+-}) & & \phi_{3}(1850) \\ (1^{+-}) & & \phi_{3}(1850) \\ & & \eta_{2}(1870) \\ (1^{++}) & & \pi_{2}(1880) \\ \rho(1900) \\ (1^{++}) & & f_{2}(1910) \\ (0^{-+}) & & a_{0}(1950) \\ (0^{-+}) & & f_{2}(1950) \\ (1^{++}) & & \sigma_{3}(1990) \\ (1^{++}) & & \pi_{2}(2005) \\ (1^{++}) & & f_{4}(2050) \\ (1^{++}) & & \pi_{2}(2100) \\ (1^{++}) & & \pi_{2}(2100) \\ (1^{++}) & & \sigma_{3}(190) \\ (1^{++}) & & \sigma_{3}(1$	$\begin{array}{c} 0^{-}(3^{-}) \\ 0^{+}(2^{-}+) \\ 1^{-}(2^{-}+) \\ 1^{+}(1^{-}-) \\ 0^{+}(2^{+}+) \\ 1^{-}(0^{+}+) \\ 0^{+}(2^{+}+) \\ 1^{-}(4^{+}+) \\ 1^{+}(3^{-}-) \\ 1^{-}(2^{-}+) \\ 0^{+}(2^{+}+) \\ 0^{+}(0^{+}+) \\ 1^{-}(2^{-}+) \\ 0^{+}(0^{+}+) \\ 0^{+}(0^{+}+) \end{array}$	• $K_2^*(1430)$ • $K_2^*(1430)$ • $K_2(1580)$ • $K_2(1580)$ • $K_1(1630)$ • $K_2(1770)$ • $K_2^*(1780)$ • $K_2^*(1780)$ • $K_2^*(1780)$ • $K_2^*(1820)$ • $K_2^*(1980)$ • $K_2^*(1980)$ • $K_4^*(2045)$ • $K_2^*(2220)$	$1/2(2^+)$ $1/2(0^-)$ $1/2(2^-)$ $1/2(1^+)$ $1/2(1^-)$ $1/2(2^-)$ $1/2(2^-)$ $1/2(0^-)$ $1/2(0^+)$ $1/2(2^+)$ $1/2(2^+)$ $1/2(2^+)$ $1/2(2^-)$	$\begin{array}{c} \text{BOTTOM} \\ (B = \pm 1) \\ \bullet B^{\pm} & 1/2(0^{-} \\ \bullet B^{0} & 1/2(0^{-} \\ \bullet B^{0}/B^{0}_{a}/b^{-}baryon \\ \bullet B^{\pm}/B^{0}/B^{0}_{a}/b^{-}baryon \\ \bullet B^{\pm}/B^{0}/B^{0}_{a}/b^{-}baryon \\ \bullet B^{\pm}/B^{0}/B^{0}_{a}/b^{-}baryon \\ \bullet B^{\pm}/B^{0}_{a}/b^{-}baryon \\ \bullet B^{0}_{a}/b^{-}baryon \\ \bullet B$	$\begin{array}{c} X(4050)^{\pm} & 1^{-}(?^{-1} \\ X(4055)^{\pm} & 1^{+}(?^{-1} \\ X(4105)^{\pm} & 1^{-}(?^{-2} \\ X(4100)^{\pm} & 1^{-}(?^{-2} \\ \psi(4160) & 0^{-}(1^{-1} \\ \psi(4160) & 0^{-}(1^{-1} \\ X(4160) & ?^{-}(?^{-2} \\ Z_c(4200) & 1^{+}(1^{+} \\ \psi(4230) & 0^{-}(1^{-1} \\ R_{c0}(4240) & 1^{+}(0^{-1} \\ X(4250)^{\pm} & 1^{-}(?^{-1} \\ \psi(4260) & 0^{-}(1^{-1} \\ \psi(4250) & 0^{+}(?^{-1} \\ \psi(4350) & 0^{-}(1^{-1} \\ \psi(4390) & 0^{$
$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	$\begin{array}{cccc} (1^{+-}) & & & & & & \\ (1^{++}) & & & & & \\ (1^{++}) & & & & & \\ (2^{++}) & & & & & \\ (2^{++}) & & & & & \\ (1^{++}) & & & & & \\ (1^{++}) & & & & & \\ (1^{++}) & & & & & \\ (1^{+}) & & & & & \\ (1^{+}) & & & & & \\ (1^{+}) & & & & & \\ (1^{+}) & & & & & \\ (1^{+}) & & & \\ (1^{+}) & & \\ (1^{+}) & & \\ (1^{+}) & & \\ (1^{+}) & & \\ (1^{+}) & & & \\ $	$\begin{array}{c} 0^+(2^{-+})\\ 1^-(2^{-+})\\ 1^+(1^{})\\ 0^+(2^{++})\\ 1^-(0^{++})\\ 0^+(2^{++})\\ 1^-(4^{++})\\ 1^+(3^{})\\ 1^-(2^{-+})\\ 0^+(2^{++})\\ 0^+(0^{++})\\ 1^-(2^{-+})\\ 0^+(0^{++})\\ 0^+(0^{++})\\ \end{array}$	K_{1460} $K_{2}(1580)$ $K_{2}(1580)$ $K_{1}(1630)$ $K_{1}(1650)$ $K_{2}(1770)$ $K_{2}(1770)$ $K_{2}(1820)$ K_{1830} $K_{2}(1950)$ $K_{2}^{*}(1980)$ $K_{4}^{*}(2045)$ $K_{2}(2220)$	1/2(0 ⁻) 1/2(2 ⁻) 1/2(1 ⁺) 1/2(1 ⁻) 1/2(2 ⁻) 1/2(2 ⁻) 1/2(2 ⁻) 1/2(0 ⁻) 1/2(0 ⁺) 1/2(2 ⁺) 1/2(2 ⁺) 1/2(4 ⁺) 1/2(2 ⁻)	BOTTOM $(B = \pm 1)$ • B^{\pm} 1/2(0 • B^{0} 1/2(0 • B^{\pm}/B^{0} ADMIXTURE • $B^{\pm}/B^{0}/B^{0}_{2}/b$ -baryon ADMIXTURE V_{cb} and V_{ub} CKM Ma- trix Elements • B^{*} 1/2(1 • $B_{1}(5721)^{+}$ 1/2(1 ⁻⁺ • $B_{1}(5721)^{0}$ 1/2(1 ⁺⁺ • $B_{1}(5721)^{0}$ 1/2(1 ⁺⁺) • $B_{2}^{*}(5747)^{++}$ 1/2(2 ⁺⁺)	$\begin{array}{c} X(4055)^{\pm} & 1^{+}(?^{-} \\ X(4100)^{\pm} & 1^{-}(??^{+} \\ (14100)^{\pm} & 1^{-}(??^{+} \\ \psi(4160) & 0^{-}(1^{-} \\ X(4160) & ?^{+}(??^{+} \\ \zeta_{c}(4200) & 1^{+}(1^{+} \\ \psi(4230) & 0^{-}(1^{-} \\ R_{c0}(4240) & 1^{+}(0^{-} \\ X(4250)^{\pm} & 1^{-}(?^{+} \\ \psi(4260) & 0^{-}(1^{-} \\ \chi_{c1}(4274) & 0^{+}(1^{+} \\ X(4350) & 0^{+}(?^{+} \\ \psi(4360) & 0^{-}(1^{-} \\ \psi(4390) & 0^{-}(1^{-} \\ \end{array}\right)$
$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	$\begin{array}{cccc} (1^{++}) & & \pi_2(1880) \\ (2^{++}) & & \rho(1900) \\ (1^{++}) & & f_2(1910) \\ (0^{-+}) & & a_0(1950) \\ 0^{-+}) & & f_2(1950) \\ 2^{++}) & & a_4(1970) \\ 0^{++}) & & \rho_3(1990) \\ 1^{-+}) & & \pi_2(2005) \\ 0^{-+}) & & f_2(2010) \\ 1^{+-}) & & f_0(2020) \\ 1^{++}) & & \pi_2(2100) \\ 1^{}) & & f_4(2050) \\ 1^{}) & & f_2(2100) \\ 1^{}) & & f_2(210) \\ 1^{$	$1^{-}(2^{-}+)$ $1^{+}(1^{-}-)$ $0^{+}(2^{+}+)$ $1^{-}(0^{+}+)$ $1^{-}(4^{+}+)$ $1^{+}(3^{-}-)$ $1^{-}(2^{-}+)$ $0^{+}(2^{+}+)$ $0^{+}(0^{+}+)$ $1^{-}(2^{-}+)$ $0^{+}(0^{+}+)$ $1^{-}(2^{-}+)$ $0^{+}(0^{+}+)$	$K_2(1580)$ K(1630) $K_1(1650)$ $K^*(1680)$ $K_2(1770)$ $K_3(1780)$ $K_2(1820)$ $K_1(1830)$ $K_2(1820)$ $K_2(1980)$ $K_2^*(1980)$ $K_4^*(2045)$ $K_2(2250)$ $K_2(2220)$	$1/2(2^{-})$ $1/2(?^{+})$ $1/2(1^{+})$ $1/2(1^{-})$ $1/2(2^{-})$ $1/2(2^{-})$ $1/2(0^{-})$ $1/2(0^{+})$ $1/2(2^{+})$ $1/2(2^{+})$ $1/2(2^{-})$ $1/2(2^{-})$	$\begin{array}{c} (B=\pm 1)\\ \bullet B^{\pm} & 1/2(0^{-}\\ \bullet B^{0} & 1/2(0^{-}\\ \bullet B^{\pm}/B^{0} & ADMIXTURE\\ \bullet B^{\pm}/B^{0}/B^{0}_{S}/b^{-}baryon\\ ADMIXTURE\\ V_{cb} & and V_{ub} CKM Matrix Elements\\ \bullet B^{*} & 1/2(1^{-}\\ \bullet B_{1}(5721)^{+} & 1/2(1^{+}\\ \bullet B_{1}(5721)^{0} & 1/2(1^{+}\\ B^{*}_{3}(5732) & ?(?^{?})\\ \bullet B^{*}_{2}(5747)^{+} & 1/2(2^{+}\\ \bullet B^{*}_{3}(5747)^{+} & 1/2(2^{+}\\ \bullet B^{*}_{3}(5747)^{+} & 1/2(2^{+}\\ \bullet B^{*}_{3}(5747)^{0}) & 0 \end{array}$	$\begin{array}{c} X(4100)^{\pm} 1^{-}(??)^{\prime}\\ *\chi_{c1}(4140) 0^{+}(1+)\\ *\psi(4160) 0^{-}(1-)\\ X(4160) ??(??)\\ Z_{c}(4200) 1^{+}(1+)\\ *\psi(4230) 0^{-}(1-)\\ R_{c0}(4240) 1^{+}(0-)\\ X(4250)^{\pm} 1^{-}(?+)\\ \psi(4260) 0^{-}(1-)\\ *\chi_{c1}(4274) 0^{+}(1+)\\ X(4350) 0^{+}(?+)\\ \psi(4360) 0^{-}(1-)\\ \psi(4390) 0^{-}(1-)\end{array}$
$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	$\begin{array}{cccc} (2^{++}) & \rho(1900) \\ (1^{++}) & f_2(1910) \\ a_0(1950) \\ 0^{-+}) & \bullet f_2(1950) \\ 2^{++}) & \bullet a_4(1970) \\ 0^{++}) & \rho_3(1990) \\ 1^{-+}) & \pi_2(2005) \\ 0^{-+}) & \bullet f_2(2010) \\ 1^{+-}) & f_0(2020) \\ 1^{++}) & \pi_2(2100) \\ 1^{}) & \bullet f_4(2050) \\ \pi_2(2100) \\ 1^{}) & f_2(2100) \\ \end{array}$	$\begin{array}{c} 1^+(1^{})\\ 0^+(2^{++})\\ 1^-(0^{++})\\ 0^+(2^{++})\\ 1^-(4^{++})\\ 1^+(3^{})\\ 1^-(2^{-+})\\ 0^+(2^{++})\\ 0^+(0^{++})\\ 0^+(4^{++})\\ 1^-(2^{-+})\\ 0^+(0^{++})\\ 0^+(0^{++})\\ \end{array}$	$\begin{array}{c} \kappa(1630) \\ \kappa_1(1650) \\ \kappa_1(1650) \\ \kappa_2(1770) \\ \kappa_3(1780) \\ \kappa_2(1820) \\ \kappa_1(1830) \\ \kappa_2(1820) \\ \kappa_1(1950) \\ \kappa_2^*(1980) \\ \kappa_4^*(2045) \\ \kappa_2(2250) \\ \kappa_2(2250) \\ \kappa_2(2220) \end{array}$	$1/2(?^{?})$ $1/2(1^{+})$ $1/2(1^{-})$ $1/2(2^{-})$ $1/2(2^{-})$ $1/2(0^{-})$ $1/2(0^{+})$ $1/2(2^{+})$ $1/2(2^{+})$ $1/2(2^{-})$ $1/2(2^{-})$	$\begin{array}{cccc} B^{\pm} & 1/2(0^{-} \\ B^{0} & 1/2(0^{-} \\ B^{\pm}/B^{0} & ADMIXTURE \\ B^{\pm}/B^{0}/B^{0}_{S}/b^{-}baryon \\ ADMIXTURE \\ V_{cb} & and V_{ub} \\ CKM \\ Matrix Elements \\ B^{*} & 1/2(1^{-} \\ B_{1}(5721)^{+} & 1/2(1^{+} \\ B_{1}(5721)^{0} & 1/2(1^{+} \\ B_{1}(5721)^{0} & 1/2(1^{+} \\ B_{1}(5722)^{0} & 2(?^{?}) \\ B^{*}_{2}(5747)^{+} & 1/2(2^{+} \\ B^{*}_{2}(5747)^{+} & 1/2(2^{+} \\ B^{*}_{2}(5747)^{0} & 1/2(2^{+} \\ B^{$	$ \begin{array}{c} \bullet \chi_{c1}(4140) 0^+(1 + \\ \bullet \psi(4160) 0^-(1 - \\ X(4160) ?^?(??) \\ Z_c(4200) 1^+(1 + \\ \bullet \psi(4230) 0^-(1 - \\ R_{c0}(4240) 1^+(0 - \\ X(4250)^{\pm} 1^-(?^{+}) \\ \psi(4260) 0^-(1 - \\ \bullet \chi_{c1}(4274) 0^+(1 + \\ X(4350) 0^+(?^{+}) \\ \bullet \psi(4360) 0^-(1 - \\ \psi(4390) 0^-(1 - \\ \end{array} $
$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	$\begin{array}{c} (1^{++}) \\ (0^{-+}) \\ (0^{-+}) \\ (0^{-+}) \\ (2^{++}) \\ (0^{++}) \\ (1^{$	$\begin{array}{c} 0^+(2^{++})\\ 1^-(0^{++})\\ 0^+(2^{++})\\ 1^-(4^{++})\\ 1^+(3^{})\\ 1^-(2^{-+})\\ 0^+(2^{++})\\ 0^+(0^{++})\\ 0^+(4^{++})\\ 1^-(2^{-+})\\ 0^+(0^{++})\\ 0^+(0^{++})\\ \end{array}$	$\begin{array}{c} \kappa_1(1650) \\ \bullet \ \kappa^*(1680) \\ \bullet \ \kappa_2(1770) \\ \bullet \ \kappa_3(1780) \\ \bullet \ \kappa_2(1820) \\ \kappa(1830) \\ \kappa_0^*(1950) \\ \kappa_2^*(1980) \\ \bullet \ \kappa_4^*(2045) \\ \kappa_2(2250) \\ \kappa_4(2220) \end{array}$	$\begin{array}{c} 1/2(1^+) \\ 1/2(1^-) \\ 1/2(2^-) \\ 1/2(3^-) \\ 1/2(2^-) \\ 1/2(0^-) \\ 1/2(0^+) \\ 1/2(2^+) \\ 1/2(2^+) \\ 1/2(2^-) \\ 1/2(2^-) \end{array}$	• B^0 1/2(0 ⁻ • B^{\pm}/B^0 ADMIXTURE • $B^{\pm}/B^0/B_5^0/b$ -baryon ADMIXTURE · V_{cb} and V_{ub} CKM Matrix Elements • B^* 1/2(1 ⁻ • $B_1(5721)^+$ 1/2(1 ⁺ • $B_1(5721)^0$ 1/2(1 ⁺ • $B_1(5721)^0$ 1/2(1 ⁺ • $B_1(5721)^0$ 1/2(1 ⁺ • $B_2(5747)^+$ 1/2(2 ⁺) • $B_2^*(5747)^+$ 1/2(2 ⁺)	$ \begin{array}{c} \bullet \psi(4160) & 0^{-}(1^{-}) \\ X(4160) & ?^{?}(?^{?}) \\ Z_{c}(4200) & 1^{+}(1^{+}) \\ \bullet \psi(4230) & 0^{-}(1^{-}) \\ R_{c0}(4240) & 1^{+}(0^{-}) \\ X(4250)^{\pm} & 1^{-}(?^{+}) \\ \psi(4260) & 0^{-}(1^{-}) \\ \bullet \chi_{c1}(4274) & 0^{+}(1^{+}) \\ X(4350) & 0^{+}(?^{+}) \\ \bullet \psi(4360) & 0^{-}(1^{-}) \\ \psi(4390) & 0^{-}(1^{-}) \end{array} $
$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	$\begin{array}{c} 0 & - & + \\ 0 & - & + \\ 0 & - & + \\ 2 & + & + \\ 0 & + & + \\ 1 & - & + \\$	$1^{-}(0^{+}+)$ $0^{+}(2^{+}+)$ $1^{-}(4^{+}+)$ $1^{+}(3^{-}-)$ $1^{-}(2^{-}+)$ $0^{+}(2^{+}+)$ $0^{+}(0^{+}+)$ $0^{+}(4^{+}+)$ $1^{-}(2^{-}+)$ $0^{+}(0^{+}+)$	• $K^*(1680)$ • $K_2(1770)$ • $K_3^*(1780)$ • $K_2(1820)$ K(1830) $K_0^*(1950)$ $K_2^*(1980)$ • $K_4^*(2045)$ $K_2(2250)$ $K_2(2250)$	$\begin{array}{c} 1/2(1^{-})\\ 1/2(2^{-})\\ 1/2(3^{-})\\ 1/2(2^{-})\\ 1/2(0^{-})\\ 1/2(0^{+})\\ 1/2(2^{+})\\ 1/2(2^{+})\\ 1/2(2^{-})\\$	• B^{\pm}/B^{0} ADMIXTURE • $B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon ADMIXTURE V_{cb} and V_{ub} CKM Matrix Elements • B^{*} 1/2(1 • $B_{1}(5721)^{+}$ 1/2(1 ⁺ • $B_{1}(5721)^{0}$ 1/2(1 ⁺ • $B_{1}(5721)^{0}$ 1/2(1 ⁺ • $B_{1}(5722)^{0}$ 1/2(1 ⁺ • $B_{1}(5722)^{0}$ 1/2(1 ⁺) • $B_{2}^{*}(5747)^{+}$ 1/2(2 ⁺)	$\begin{array}{c} X(4160) & ?^{(2,1)}\\ Z_{c}(4200) & 1^{+}(1^{+})\\ \bullet \psi(4230) & 0^{-}(1^{-})\\ R_{c0}(4240) & 1^{+}(0^{-})\\ X(4250)^{\pm} & 1^{-}(?^{+})\\ \psi(4260) & 0^{-}(1^{-})\\ \bullet \chi_{c1}(4274) & 0^{+}(1^{+})\\ X(4350) & 0^{+}(?^{+})\\ \bullet \psi(4360) & 0^{-}(1^{-})\\ \psi(4390) & 0^{-}(1^{-})\end{array}$
$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	$\begin{array}{c} 0 & - \\ 0 & - \\ 2 & + \\ 0 & + \\ 1 & - \\$	$\begin{array}{c} 0^+(2^{++}) \\ 1^-(4^{++}) \\ 1^+(3^{}) \\ 1^-(2^{-+}) \\ 0^+(2^{++}) \\ 0^+(0^{++}) \\ 0^+(4^{++}) \\ 1^-(2^{-+}) \\ 0^+(0^{++}) \end{array}$	• $K_2(1770)$ • $K_3^*(1780)$ • $K_2(1820)$ K(1830) $K_0^*(1950)$ $K_2^*(1980)$ • $K_4^*(2045)$ $K_2(2250)$ $K_2(2250)$	$\begin{array}{c} 1/2(2^{-})\\ 1/2(3^{-})\\ 1/2(2^{-})\\ 1/2(0^{-})\\ 1/2(0^{+})\\ 1/2(2^{+})\\ 1/2(2^{+})\\ 1/2(4^{+})\\ 1/2(2^{-})\\$	• $B^{\pm}/B^0/B^0_s/b$ -baryon ADMIXTURE V_{cb} and V_{ub} CKM Ma- trix Elements • B^* 1/2(1 • $B_1(5721)^+$ 1/2(1 ⁺ • $B_1(5721)^0$ 1/2(1 ⁺ $B_1(5721)^0$ 1/2(1 ⁺ $B_1(5732)$?(? ²) • $B_2^*(5747)^+$ 1/2(2 ⁺	$\begin{array}{c} \mathcal{L}_{c}(4200) & 1^{+}(1^{+}) \\ \bullet \psi(4230) & 0^{-}(1^{-}) \\ \mathcal{R}_{c0}(4240) & 1^{+}(0^{-}) \\ \chi(4250)^{\pm} & 1^{-}(?^{+}) \\ \psi(4260) & 0^{-}(1^{-}) \\ \bullet \chi_{c1}(4274) & 0^{+}(1^{+}) \\ \chi(4350) & 0^{+}(?^{+}) \\ \bullet \psi(4360) & 0^{-}(1^{-}) \\ \psi(4390) & 0^{-}(1^{-}) \end{array}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c} \bullet a_4(1970) \\ (0^{++}) \\ 1^{-+}) \\ (1^{-+}) \\ (0^{-+}) \\ (1^{+-}) \\ (1^{+-}) \\ (1^{++}) \\ (1$	$1^{-}(4^{+}+)$ $1^{+}(3^{-}-)$ $1^{-}(2^{-}+)$ $0^{+}(2^{+}+)$ $0^{+}(0^{+}+)$ $1^{-}(2^{-}+)$ $0^{+}(0^{+}+)$	• $K_3^*(1780)$ • $K_2(1820)$ K(1830) $K_0^*(1950)$ $K_2^*(1980)$ • $K_4^*(2045)$ $K_2(2250)$ $K_2(2250)$	$\frac{1/2(3^{-})}{1/2(2^{-})}$ $\frac{1/2(0^{-})}{1/2(0^{+})}$ $\frac{1/2(2^{+})}{1/2(4^{+})}$ $\frac{1/2(2^{-})}{1/2(2^{-})}$	ADMIXTORE V_{cb} and V_{ub} CKM Ma- trix Elements B^* 1/2(1 ⁻ $B_1(5721)^+$ 1/2(1 ⁺ $B_1(5721)^0$ 1/2(1 ⁺ $B_j(5732)$?(? [?]) $B_2^*(5747)^+$ 1/2(2 ⁺ $D_2(5747)^+$ 1/2(2 ⁺)	$ \begin{array}{c} \bullet \psi(4230) & 0 & (1) \\ R_{c0}(4240) & 1^+(0^-) \\ X(4250)^{\pm} & 1^-(?^+) \\ \psi(4260) & 0^-(1^-) \\ \bullet \chi_{c1}(4274) & 0^+(1^+) \\ X(4350) & 0^+(?^+) \\ \bullet \psi(4360) & 0^-(1^-) \\ \psi(4390) & 0^-(1^-) \end{array} $
$\begin{array}{cccc} 370) & 0^+(0^+)^+\\ 1400) & 1^-(1^-)^+\\ 1405) & 0^+(0^-)^+\\ 1415) & 0^-(1^+)^-\\ 1420) & 1^-(1^+)^+\\ 1420) & 0^+(1^+)^+\\ 1420) & 0^-(1^-)^-\\ 14000 & 0^+(1^+)^+\\ 14000 & 0^-(1^+)^-\\ 14000 & 0^+(1^+)^+\\ 14000 & 0^-(1^+)^-\\ 14000 & 0^+(1^+)^+\\ 14000 & 0^-(1^+)^-\\ 14000 & 0^+(1^+)^+\\ 14000 & 0^-(1^+)^-\\ 14000 & 0^+(1^+)^+\\ 14000 & 0^-(1^+)^-\\ 14000 & 0^+(1^+)^+\\ 1400 & 0^+(1^+)^+\\ 1400 & 0^+(1^+)$	$\begin{array}{c} \rho_{3}(1990) \\ \pi_{2}(2005) \\ \eta_{4}(1-+) \\ \pi_{2}(2005) \\ \pi_{2}(2010) \\ \pi_{4}(2050) \\ \pi_{4}(2050) \\ \pi_{4}(2100) \\ \pi_{2}(2100) \\ \pi_{4}(2100) \end{array}$	$ \begin{array}{c} 1^{+}(3^{-}) \\ 1^{-}(2^{-+}) \\ 0^{+}(2^{++}) \\ 0^{+}(0^{++}) \\ 0^{+}(4^{++}) \\ 1^{-}(2^{-+}) \\ 0^{+}(0^{++}) \end{array} $	• $K_2(1820)$ K(1830) $K_0^*(1950)$ $K_2^*(1980)$ • $K_4^*(2045)$ $K_2(2250)$ $K_2(2250)$	$\frac{1/2(2^{-})}{1/2(0^{-})}$ $\frac{1/2(0^{+})}{1/2(2^{+})}$ $\frac{1/2(4^{+})}{1/2(2^{-})}$	$\begin{array}{c} v_{cb} \mbox{ and } v_{ub} cital trial cital trial cital trial cital trial cital trial cital c$	$\begin{pmatrix} \mathcal{R}_{c0}(4240) & 1^+(0) \\ \mathcal{X}(4250)^{\pm} & 1^-(?^{+}) \\ \psi(4260) & 0^-(1^-) \\ \bullet \chi_{c1}(4274) & 0^+(1^+) \\ \mathcal{X}(4350) & 0^+(?^{+}) \\ \bullet \psi(4360) & 0^-(1^-) \\ \psi(4390) & 0^-(1^-) \\ \end{pmatrix}$
$\begin{array}{cccc} 1400) & 1 & (1 & & \\ 1405) & 0^+(0 & - & + \\ .415) & 0^-(1 & + & - \\ .420) & 1^-(1 & + & + \\ .420) & 0^+(1 & + & + \\ .420) & 0^-(1 & - & - \\ \end{array}$	$\begin{array}{c} \pi_{2}(2005) \\ \pi_{2}(2010) \\ \pi_{1}(1+-) \\ \pi_{2}(2010) \\ \pi_{1}(2020) \\ \pi_{2}(2100) \\ \pi_{2}(2100) \\ \pi_{2}(2100) \\ \pi_{2}(2100) \end{array}$	$ \begin{array}{c} 1 & (2 \\ 0^{+}(2^{++}) \\ 0^{+}(0^{++}) \\ 0^{+}(4^{++}) \\ 1^{-}(2^{-+}) \\ 0^{+}(0^{++}) \end{array} $	$ \begin{array}{c} \mathcal{K}(1830) \\ \mathcal{K}_{0}^{*}(1950) \\ \mathcal{K}_{2}^{*}(1980) \\ \bullet \mathcal{K}_{4}^{*}(2045) \\ \mathcal{K}_{2}(2250) \\ \mathcal{K}_{4}(2220) \end{array} $	$1/2(0^{-})$ $1/2(0^{+})$ $1/2(2^{+})$ $1/2(4^{+})$ $1/2(2^{-})$	$ \begin{array}{c} \bullet B^* & 1/2(1^- \\ \bullet B_1(5721)^+ & 1/2(1^+ \\ \bullet B_1(5721)^0 & 1/2(1^+ \\ B_j(5732) & ?(?^2) \\ \bullet B_2^*(5747)^+ & 1/2(2^+ \\ P_3(5747)^+ & 1/2(2^+ \\$	$\begin{array}{c} \chi(4250)^{-} & 1 & (?^{+})^{+} \\ \psi(4260) & 0^{-}(1^{-})^{+} \\ \bullet \chi_{c1}(4274) & 0^{+}(1^{+})^{+} \\ \chi(4350) & 0^{+}(?^{+})^{+} \\ \bullet \psi(4360) & 0^{-}(1^{-})^{-} \\ \psi(4390) & 0^{-}(1^{-})^{+} \end{array}$
$\begin{array}{c} 415) & 0^{+}(0 \\ 415) & 0^{-}(1 + $	$ \begin{array}{c} \bullet & f_2(2010) \\ f_1(1) & f_0(2020) \\ 1(1++) & \bullet & f_4(2050) \\ 1(1++) & \pi_2(2100) \\ 1(1) & \bullet & f_4(2100) \end{array} $	$ \begin{array}{c} 0^+(2^{++}) \\ 0^+(0^{++}) \\ 0^+(4^{++}) \\ 1^-(2^{-+}) \\ 0^+(0^{++}) \end{array} $	$ \begin{array}{c} \kappa_0^*(1950) \\ \kappa_2^*(1980) \\ \bullet \kappa_4^*(2045) \\ \kappa_2(2250) \\ \kappa_2(2250) \end{array} $	$1/2(0^+)$ $1/2(2^+)$ $1/2(4^+)$ $1/2(2^-)$	• $B_1(5721)^+$ 1/2(1+ • $B_1(5721)^0$ 1/2(1+ $B_j^*(5732)$?(??) • $B_2^*(5747)^+$ 1/2(2+	$\begin{pmatrix} \psi(4200) & 0 & (1 \\ + \chi_{c1}(4274) & 0^+(1 + \\ X(4350) & 0^+(? + \\ \psi(4360) & 0^-(1 - \\ \psi(4390) & 0^-(1 - \\ \end{pmatrix}$
$\begin{array}{c} 443) & 0 & (1 \\ 420) & 1^{-}(1^{+} + \\ 420) & 0^{+}(1^{+} + \\ 420) & 0^{-}(1^{-} - \end{array}$	$ \begin{array}{c} 1 \\ (1^{+}+) \\ 1^{+}+) \\ 1^{-}- \end{array} \right \begin{array}{c} r_{0}(2020) \\ \bullet f_{4}(2050) \\ \pi_{2}(2100) \\ f_{5}(2100) \end{array} $	$0^{+}(0^{++})$ $1^{-}(2^{-+})$ $0^{+}(0^{++})$	$K_2^*(1980)$ • $K_4^*(2045)$ $K_2(2250)$ $K_2(2250)$	$1/2(2^+)$ $1/2(4^+)$ $1/2(2^-)$	• $B_1(5721)^0$ 1/2(1+ $B_j^*(5732)$?(??) • $B_2^*(5747)^+$ 1/2(2+ $D_2^*(5747)^0$ 1/2(2+	$\begin{pmatrix} \bullet \chi_{C1}(4214) & \bullet (1 \\ X(4350) & \bullet^+(?^{?+}) \\ \bullet \psi(4360) & \bullet^-(1^{-}) \\ \psi(4390) & \bullet^-(1^{-}) \\ \end{pmatrix}$
$\begin{array}{c} 420) & 1 & (1 \\ 420) & 0^+(1^{++}) \\ 420) & 0^-(1^{}) \end{array}$	(1^{++}) $\pi_2(2100)$ $\pi_2(2100)$	$1^{-}(2^{-+})$ $0^{+}(0^{++})$	• $K_4^*(2045)$ $K_2(2250)$ $K_2(2220)$	$1/2(4^+)$ $1/2(2^-)$	$B_{J}^{*}(5732)$?(?') • $B_{2}^{*}(5747)^{+}$ 1/2(2 ⁺	$\begin{pmatrix} & \chi(4300) & 0 & (1 \\ & \psi(4360) & 0^{-}(1 \\ & \psi(4390) & 0^{-}(1 \\ & & \end{pmatrix}$
$(120) 0^{-}(1^{-})$	(1) $f_{0}(2100)$	$0^{+}(0^{++})$	$K_2(2250)$	$1/2(2^{-})$	• $B_2^*(5747)^+$ 1/2(2 ⁺	$\psi(4390) = 0^{-1}(1-1)^{-1}$
			K-(2220)			
$(430) 0^+(2^{++})$	$f_2(2150)$	$0^{+}(2^{++})$	r(3(2520)	1/2(3 ⁺)	• $B_2^*(5/47)^3$ 1/2(2 ⁺	• $\psi(4415) = 0^{-}(1^{-})$
(450) $1^{-}(0^{++})$	$\rho(2150) = \rho(2150)$	$1^{+}(1^{-})$	$K_5^*(2380)$	$1/2(5^{-})$	$B_{J}(5840)^{+}$ 1/2(? ¹)	• $Z_{c}(4430)$ 1 ⁺ (1 ⁺
450) 1+(1	$(1^{}) \bullet \phi(2170)$	$0^{-}(1^{-})$	$K_4(2500)$	$\frac{1}{2(4)}$	$B_{J}(5840)^{\circ} = 1/2(?)$	$\chi_{c0}(4500) 0^+(0^+$
$(0^{+})^{-}$	(0^{-+}) $f_0(2200)$	$0^{+}(0^{++})$	K(3100)	?·(?··)	• $B_{J}(5970)^{\dagger} = 1/2(?^{\circ})$	 ψ(4660) 0⁻(1⁻
500) 0 ⁺ (0 ⁺⁺	$(0^{++}) f_J(2220)$	0+(2++	CHARM	/IED	• <i>B</i> J(5970) ² 1/2(!)	$\chi_{c0}(4700) 0^+(0^+$
510) $0^+(1^{++})$	(1++)	or 4 ^{+ +})	(<i>C</i> = ±	=1)	BOTTOM, STRANGE	
.525) 0+(2++	$(2^{++}) \eta(2225)$	0+(0-+)	● <i>D</i> [±]	$1/2(0^{-})$	$(B = \pm 1, S = \mp 1)$	$(+ \text{ possibly pon-} a\overline{a} \text{ st})$
565) $0^+(2^{++})$	$(2^{++}) \rho_3(2250)$	1+(3)	• D ⁰	$1/2(0^{-})$	• B_{S}^{0} 0(0 ⁻)	
570) 1+(1	$(1^{}) \bullet f_2(2300)$	$0^+(2^{++})$	• D*(2007) ⁰	$1/2(1^{-})$	• B_{s}^{*} 0(1 ⁻)	• $\eta_b(1S) = 0^+(0)^-$
$0^{-}(1^{+-})$	(1^{+-}) $f_4(2300)$	$0^+(4^{++})$	● <i>D</i> *(2010) [±]	$1/2(1^{-})$	$X(5568)^{\pm}$?(??)	$\bullet I(15) = 0 (1)$
$1^{-}(1^{-+})$	$\begin{pmatrix} 1 - + \\ 1 + + \end{pmatrix} = f_0(2330)$	$0^+(0^+)$	• $D_0^*(2300)^0$	1/2(0+)	• $B_{s1}(5830)^0$ 0(1 ⁺)	• $\chi_{b0}(1P)$ 0 (0
(640) 1 (1 ' '	$(2 + +) = f_2(2340)$	$0^{+}(2^{+})^{+})$ $1^{+}(5^{-})^{-}$	$D_0^*(2300)^{\pm}$	$1/2(0^+)$	• $B_{s2}^*(5840)^0$ $0(2^+)$	$h_{h}(1P) = 0^{-}(1^{+})^{-}$
(2^{+}) (2^{+})	(2^{-1}) $\rho_5(230)$ (2^{-1}) $f_c(2510)$	$0^+(6^{++})$	• $D_1(2420)^0$	$1/2(1^+)$	$B^*_{s,J}(5850)$?(? [!])	• $\chi_{b2}(1P) = 0^+(2^+)^+$
$(2^{+})^{-} (2^{-})^{-} (1^{-})^{-}$	(2^{-1}) (2^{-1})	0 (0)	$D_1(2420)^{\pm}$	1/2(?)	BOTTOM CHARMED	$n_{b}(2S) = 0^{+}(0^{-})^{-}$
$(1670) 0^{-}(3^{-})$	OTHER	RLIGHT	$D_1(2430)^0$	$1/2(1^+)$	$(B = C = \pm 1)$	• T(25) 0-(1-
	Further Sta	ates	• $D_2^*(2460)^\circ$	$1/2(2^{+})$	• B ⁺ 0(0 ⁻)	• $T_2(1D)$ 0 ⁻ (2 ⁻
			• $D_2^*(2460)^{\pm}$	$1/2(2^{+})$	$B_{c}(25)^{\pm} 0(0^{-})$	• $\chi_{b0}(2P)$ 0 ⁺ (0 ⁺
			$D(2550)^{\circ}$	1/2(?)	0(0)	• $\chi_{b1}(2P)$ 0+(1+
			$D_{j}^{*}(2600)$	1/2(?)	, c c	$h_b(2P) = 0^-(1^+)^{-1}$
			$D^{*}(2640)^{\pm}$	1/2(?)	$(+ \text{ possibly non} - q \overline{q} \text{ state})$	5) • $\chi_{b2}(2P)$ 0 ⁺ (2 ⁺
			D*(2740)*	1/2(?)	• $\eta_c(1S)$ 0 ⁺ (0 ⁻⁺	• $\Upsilon(3S)$ 0 ⁻ (1 ⁻
			$D_3(2150)$	$\frac{1}{2}(3)$	• J/ψ(1S) 0 ⁻ (1) • $\chi_{b1}(3P)$ 0 ⁺ (1 ⁺
			D(3000)*	1/2(?`)	• $\chi_{c0}(1P)$ 0 ⁺ (0 ⁺⁺) • $\chi_{b2}(3P)$ 0 ⁺ (2 ⁺
					• $\chi_{c1}(1P)$ 0 ⁺ (1 ⁺⁺) • $\Upsilon(4S)$ 0 ⁻ (1 ⁻
					• $h_c(1P)$ 0 ⁻ (1 ⁺⁻) • $Z_b(10610)$ 1 ⁺ (1 ⁺
					• $\chi_{c2}(1P)$ 0 ⁺ (2 ⁺⁺) • $Z_b(10650)$ 1 ⁺ (1 ⁺
		_			• $\eta_c(2S)$ 0 ⁺ (0 ⁻⁺) $7(10753)$?: $(1 - 20(10053))$
				$D(2550)^{0}$ $D_{J}^{*}(2600)$ $D^{*}(2640)^{\pm}$ $D(2740)^{0}$ $D_{3}^{*}(2750)$ $D(3000)^{0}$	Data Group (PDG)	$D(2550)^{0} 1/2(?) \\ D_{j}(2600) 1/2(?) \\ D_{j}(2600)^{\pm} 1/2(?) \\ D(2740)^{0} 1/2(?) \\ D_{3}(2750) 1/2(3^{-}) \\ D(3000)^{0} 1/2(?) \\ D(300)^{0} 1/2(?) \\ D(3000)^{0} 1/2(?) \\ D(3000)^{0} $



Meson Summary Table

See also the table of suggested $q\overline{q}$ quark-model assignments in the Quark Model section.

• Indicates particles that appear in the preceding Meson Summary Table. We do not regard the other entries as being established.

	LIGHT UN			STRAN	IGE	CHARMED,	STRANGE	c c con	tinued
	$I^{G}(J^{PC})$	_ <i>D</i> _ 0) 	J ^G (J ^{PC})	() = ±1, 0 -	_ <i>U</i> _ 0) <i>I</i> (<i>J</i> ^P)	(0 = 5 =	1) (J ^P)	• v/(2770)	n(3)
• <i>m</i> [±]	$1^{-}(0^{-})$	• <i>m</i> -(1670)	$\frac{1-(2-+)}{1-(2-+)}$	• K±	1/2(0-)	• D [±]	$0(0^{-})$	• ψ(3770)	0(1)
• π • π ⁰	$1^{-}(0^{-}+)$	• #2(1070) • #(1680)	$1 (2^{-1})$ $0^{-}(1^{-})$	• K ⁰	$1/2(0^{-})$	• D _s	$0(0^{\circ})$	• $\psi_2(3023)$	$0^{-}(2^{-})$
• n	$0^{+}(0^{-}+)$	• $\phi(1000)$	$1^{+}(3^{-})$	• K ⁰	$1/2(0^{-})$	• D_s • D^* (2217)±	0(:)	$v_{co}(3860)$	$0^{+}(0^{+}+)$
• $f_0(500)$	$0^{+}(0^{+}+)$	• $\rho(1700)$	$1^{+}(1^{-})$	• K ⁰	$1/2(0^{-1})$	$D_{s0}(2317)$	$0(0^{-})$	• $\chi_{c1}(3872)$	$0^{+}(1^{++})$
 ρ(770) 	$1^{+}(1^{-})$	• $a_{1}(1700)$	$1^{-}(2^{++})$	• $K_{0}^{*}(700)$	$1/2(0^+)$	• $D_{s1}(2400)$ • $D_{s1}(2536)^{\pm}$	$0(1^+)$	• $Z_c(3900)$	$1^{+}(1^{+}-)$
• ω(782)	$0^{-}(1^{-})$	• $f_0(1710)$	$0^{+}(0^{+}+)$	• K*(892)	$1/2(1^{-})$	• $D_{s1}^{*}(2573)$	$0(1^{+})$	• X(3915)	$0^{+}(0/2^{+}+)$
 η'(958) 	$0^{+}(0^{-}+)$	η(1760)	$0^{+}(0^{-}+)$	• $K_1(1270)$	$1/2(1^+)$	• $D_{s_2}^*(2700)^{\pm}$	$0(2^{-})$	• $\chi_{c2}(3930)$	$0^{+}(2^{++})$
• f ₀ (980)	$0^{+}(0^{+}+)$	• π(1800)	$1^{-(0^{-+})}$	• $K_1(1400)$	$1/2(1^+)$	$D_{s1}^{*}(2860)^{\pm}$	$0(1^{-})$	X(3940)	? [?] (? ^{??})
• <i>a</i> ₀ (980)	$1^{-}(0^{++})$	$f_2(1810)$	$0^+(2^{++})$	• K*(1410)	$1/2(1^{-})$	$D_{s1}^{*}(2860)^{\pm}$	$0(3^{-})$	• X(4020) [±]	$1^{+}(?^{?-})$
• ϕ (1020)	0-(1)	X(1835)	? [?] (0 ⁻⁺)	• K ₀ (1430)	$1/2(0^+)$	$D_{s3}(2000)^{\pm}$	$0(3^{?})$	 ψ(4040) 	$0^{-}(1^{})$
• $h_1(1170)$	$0^{-}(1^{+})$	• $\phi_3(1850)$	0-(3)	• K [*] ₂ (1430)	$1/2(2^+)$	235(0010)	U(.)	$X(4050)^{\pm}$	$1^{-}(?^{\prime+})$
• $b_1(1235)$	$1^+(1^{+-})$	• η ₂ (1870)	0+(2 - +)	K(1460)	$1/2(0^{-})$	BOTT	OM	$X(4055)^{\pm}$	$1^{+}(?^{!-})$
• $a_1(1260)$	$1^{-}(1^{++})$	• π ₂ (1880)	$1^{-}(2^{-+})$	$K_2(1580)$	$1/2(2^{-})$	(<i>B</i> = =	±1)	X(4100) [±]	$1^{-}(?^{::})$
• $f_2(1270)$	$0^+(2^{++})$	$\rho(1900)$	$1^+(1^{})$	K(1630)	1/2(??)	• B [±]	1/2(0 ⁻)	• $\chi_{c1}(4140)$	$0^+(1^+)$
• $f_1(1285)$	$0^{+}(1^{++})$	$f_2(1910)$	$0^+(2^++)$	$K_1(1650)$	$1/2(1^+)$	• B ⁰	1/2(0)	• $\psi(4160)$	0 (1)
• η(1295)	$0^{+}(0^{-+})$	$a_0(1950)$	$1^{-}(0^{++})$	• K*(1680)	$1/2(1^{-})$	• B^{\pm}/B^0 ADN	MIXTURE	X (4160)	(()
$\bullet \pi(1300)$	$1 (0^{+})$ 1 - (2 + +)	• $T_2(1950)$	$0^{+}(2^{++})$	• $K_2(1770)$	$1/2(2^{-})$		/ b-baryon	$Z_{c}(4200)$	$1^{+}(1^{+})$ $0^{-}(1^{-})$
• $a_2(1320)$ • $f_2(1370)$	1(2++)	• $a_4(1970)$	1 (4 + 1) 1 + (2 - 1)	• $K_3^*(1780)$	1/2(3 ⁻)	V_{ch} and V_{uh}	CKM Ma-	• $\psi(4230)$	$1^{+}(0^{-})$
$\bullet \pi_0(1370)$	$1^{-}(1^{-+})$	$p_3(1990)$	$1^{-}(3^{-}+)$	• K ₂ (1820)	$1/2(2^{-})$	trix Element	S	$X(4250)^{\pm}$	$1^{-}(2^{?+})$
• $n(1405)$	$0^{+}(0^{-}+)$	• $f_{0}(2003)$	$0^{+}(2^{+})$	K(1830)	$1/2(0^{-})$	• B*	$1/2(1^{-})$	$\psi(4260)$	$0^{-}(1^{-})$
• $h_1(1415)$	$0^{-}(1^{+})$	$f_0(2020)$	$0^{+}(0^{+}+)$	$K_0^*(1950)$	$1/2(0^{+})$	• $B_1(5721)^+$	$1/2(1^{+})$	• $\chi_{c1}(4274)$	$0^{+}(1^{++})$
$a_1(1420)$	$1^{-}(1^{+})$	• $f_4(2050)$	$0^{+}(4^{++})$	K [*] ₂ (1980)	$1/2(2^{+})$	• B ₁ (5/21) ^o	$\frac{1}{2(1^{+})}$	X(4350)	$0^{+(?^{?+})}$
• $f_1(1420)$	$0^{+}(1^{+}+)$	$\pi_2(2100)$	$1^{-}(2^{-+})$	• K ₄ (2045)	1/2(4 ')	$B_{j}(5/32)$!(!`) 1.(2(2 ⁺)	 ψ(4360) 	$0^{-}(1^{-})$
• ω(1420)	$0^{-}(1^{-})$	$f_0(2100)$	0+(0++)	$K_2(2250)$	1/2(2)	• $B_2(5/47)^{+}$	$1/2(2^+)$ $1/2(2^+)$	ψ (4390)	$0^{-}(1^{-})$
$f_2(1430)$	$0^{+}(2^{+}+)$	$f_2(2150)$	$0^{+}(2^{++})$	K*(2320)	$1/2(5^{-})$	• $B_2(5/47)^\circ$	$1/2(2^{+})$ $1/2(2^{?})$	 ψ(4415) 	$0^{-}(1^{})$
• <i>a</i> ₀ (1450)	$1^{-}(0^{++})$	ρ(2150)	$1^{+}(1^{-})$	K ₅ (2300)	1/2(5) $1/2(4^{-})$	B _J (5840) ⁺	$\frac{1}{2}(?)$	• <i>Z_c</i> (4430)	$1^{+}(1^{+-})$
 ρ(1450) 	$1^+(1^{})$	 φ(2170) 	0-(1)	K(3100)	$\frac{1}{2(4)}$	$B_{J}(5040)^{2}$	$\frac{1}{2}(?)$ $\frac{1}{2}(?)$	χ _{c0} (4500)	0+(0++)
 η(1475) 	0+(0 - +)	$f_0(2200)$	0+(0++)	N(3100)	. (.)	• B ₁ (5970) ⁰	$\frac{1}{2}(?)$	 ψ(4660) 	0-(1)
• $f_0(1500)$	$0^+(0^{++})$	f_(2220)	0+(2++	CHARM	/IED	- 25(0510)	1/2(.)	$\chi_{c0}(4700)$	0+(0++)
$f_1(1510)$	$0^+(1^{++})$	(2225)	or 4^{++}	(<i>C</i> = ±	=1)	BOTTOM, S	STRANGE	h	<u></u>
• $f'_2(1525)$	$0^+(2^{++})$	$\eta(2225)$	$0^+(0^-+)$ $1^+(2^)$	• D±	$1/2(0^{-})$	$(B = \pm 1, 3)$	S = ∓1)	(+ possibly no	on-qq states)
$T_2(1565)$	$0^{+}(2^{++})$ $1^{+}(1^{-})$	$\rho_3(2250)$	$1^{+}(3^{-})$	• D ⁰	$1/2(0^{-})$	• B_s^0	0(0-)	• n ₄ (15)	$0^{+}(0^{-}+)$
$\rho(1570)$	$1^{+}(1^{-})$	• $I_2(2300)$ f.(2300)	$0^{+}(2^{+})$	• D*(2007) ⁰	$1/2(1^{-})$	• B_s*	$0(1^{-})$	• $\Upsilon(15)$	$0^{-}(1^{-})$
$\pi_1(1595)$	$1^{-}(1^{-}+)$	$f_4(2300)$	$0^{+}(0^{+}+)$	• D*(2010) [±]	$1/2(1^{-})$	X(5568) [±]	?(?')	• $\chi_{10}(1P)$	$0^{+}(0^{++})$
• $a_1(1640)$	$1^{-}(1^{+}+)$	• $f_0(2340)$	$0^+(2^{++})$	• $D_0^*(2300)^*$	$1/2(0^{+})$	• $B_{s1}(5830)^{\circ}$	$0(1^+)$	• $\chi_{b1}(1P)$	$0^{+}(1^{++})$
$f_{1}(1640)$	$0^{+}(2^{+}+)$	$\rho_{\rm E}(2350)$	$1^{+}(5^{-})$	$D_0^{-}(2300)^{\perp}$	$1/2(0^{+})$	• B [*] ₅₂ (5840) ^o	$0(2^{+})$	• $h_b(1P)$	$0^{-(1+-)}$
• m(1645)	$0^{+}(2^{-}+)$	$f_{6}(2510)$	$0^{+}(6^{++})$	• $D_1(2420)^\circ$	1/2(1') 1/2(2?)	$B_{sJ}^{*}(5850)$?(?:)	• $\chi_{b2}(1P)$	$0^{+}(2^{++})$
• ω(1650)	$0^{-}(1^{-})$	0()	- (-)	$D_1(2420)^-$	$\frac{1}{2}(1^{+})$	BOTTOM, C	HARMED	$\eta_b(2S)$	$0^{+}(0^{-+})$
• ω ₃ (1670)	$0^{-}(3^{-}-)$	OTHEF	R LIGHT	$D_1(2430)$	$\frac{1}{2}(1)$ $\frac{1}{2}(2^{+})$	(<i>B</i> = <i>C</i> =	= ±1)	 <i>↑</i>(2S) 	0-(1)
	, , , , , , , , , , , , , , , , , , ,	Further St	ates	$D_2(2400)^{\pm}$	$\frac{1}{2(2^{+})}$	• B_c^+	0(0-)	• $\Upsilon_2(1D)$	0-(2)
				$D(2550)^0$	$\frac{1}{2(2^{\circ})}$	$B_c(2S)^{\pm}$	$0(0^{-})$	• χ _{b0} (2P)	0+(0++)
				D*(2600)	$\frac{1}{2(?^{?})}$			• $\chi_{b1}(2P)$	$0^+(1^{++})$
				$D^{*}(2640)^{\pm}$	$1/2(?^{?})$	CC (⊥ possibly por	$-a\overline{a}$ states)	$h_b(2P)$	$0^{-}(1^{+})$
				$D(2740)^{0}$	$1/2(?^{?})$		r q q statcs)	• $\chi_{b2}(2P)$	$0^{+}(2^{++})$
				$D_{2}^{*}(2750)$	$1/2(3^{-})$	• $\eta_c(15)$	$0^+(0^-+)$	• 7 (35)	0(1)
				D(3000)0	$1/2(?^{?})$	• $J/\psi(1S)$	0(1)	• $\chi_{b1}(3P)$	$0^{+}(2^{+}+)$
				, ,		• $\chi_{c0}(1P)$	$0^+(0^+)$	• $\chi_{b2}(SP)$ • $\Upsilon(AS)$	$0^{-}(1^{-})$
						$\chi_{c1}(1P)$	$0^{-}(1^{+})$	• 7 ₆ (10610)	$1^{+}(1^{+})$
						• $\chi_{c}(1P)$	$0^{+}(2^{+})$	• $Z_b(10010)$	$1^{+}(1^{+})$
						• nc(25)	$0^{+}(0^{-}+)$	$\gamma(10050)$	$?^{?}(1)$
ticle D	Data G	oun (l	PDG)			• \u03cb(25)	$0^{-}(1^{-})$	 <i>γ</i>(10860) 	$0^{-}(1^{-})$
	vala UI	oup (I	DU			, (2)	()	• r(11020)	$0^{-}(1^{-})$
lacon	Cumme	owy To	hla					. ,	, ,
leson ,	Summ	ary ra	lole						

Pa

Baryon Summary Table

This short table gives the name, the quantum numbers (where known), and the status of baryons in the Review. Only the baryons with 3- or 4-star status are included in the Baryon Summary Table. Due to insufficient data or uncertain interpretation, the other entries in the table are not established baryons. The names with masses are of baryons that decay strongly. The spin-parity J^P (when known) is given with each particle. For the strongly decaying particles, the J^P values are considered to be part of the names.

	1 /0+	****	4(1000)	2/0+ ****	<u>5</u> +	1 /0+	****	-0	1 /0+	****	-++		***
ρ	1/2	****	$\Delta(1232)$	3/2 ****		1/2	****	=` 	1/2	****	= cc		ጥጥጥ
n	1/2	****	$\Delta(1600)$	3/2 ****	2°	1/2	****	=	1/2	****	40	1 /0+	***
/V(1440)	1/2	****	$\Delta(1620)$	1/2 ****	Σ_	1/2	****	=(1530)	3/21	****	Λ _Ď	1/2'	
N(1520)	3/2	****	$\Delta(1700)$	3/2 ****	$\Sigma(1385)$	3/2+	****	=(1620)		*	$\Lambda_{b}(5912)^{\circ}$	1/2	***
N(1535)	$1/2^{-}$	****	$\Delta(1750)$	1/2+ *	$\Sigma(1580)$	3/2-	*	$\Xi(1690)$		***	$\Lambda_{b}(5920)^{0}$	3/2	***
N(1650)	$1/2^{-}$	****	Δ (1900)	1/2 ***	$\Sigma(1620)$	$1/2^{-}$	*	$\Xi(1820)$	$3/2^{-}$	***	$\Lambda_{b}(6146)^{0}$	3/2+	***
N(1675)	5/2	****	Δ (1905)	5/2+ ****	$\Sigma(1660)$	$1/2^{+}$	***	$\Xi(1950)$	- 2	***	$\Lambda_b(6152)^0$	5/2+	***
N(1680)	$5/2^{+}$	****	Δ (1910)	1/2+ ****	$\Sigma(1670)$	$3/2^{-}$	****	Ξ(2030)	$\geq \frac{5}{2}$	***	Σ_b	$1/2^{+}$	***
N(1700)	3/2-	***	$\Delta(1920)$	3/2+ ***	$\Sigma(1750)$	$1/2^{-}$	***	$\Xi(2120)$		*	Σ_b^*	$3/2^{+}$	***
N(1710)	$1/2^{+}$	****	⊿(1930)	5/2" ***	Σ(1775)	$5/2^{-}$	****	Ξ(2250)		**	$\Sigma_b(6097)^+$		***
N(1720)	3/2+	****	⊿(1940)	3/2 **	$\Sigma(1780)$	3/2+	*	Ξ(2370)		**	$\Sigma_{b}(6097)^{-}$		***
N(1860)	$5/2^{+}$	**	$\Delta(1950)$	7/2 ⁺ ****	$\Sigma(1880)$	$1/2^{+}$	**	Ξ(2500)		*	Ξ_{b}^{0}, Ξ_{b}^{-}	$1/2^{+}$	***
N(1875)	$3/2^{-}$	***	<i>∆</i> (2000)	5/2+ **	Σ(1900)	$1/2^{-}$	**				$\Xi_{b}^{\prime}(5935)^{-}$	$1/2^{+}$	***
N(1880)	$1/2^{+}$	***	<i>∆</i> (2150)	$1/2^{-}$ *	$\Sigma(1910)$	$3/2^{-}$	***	Ω^{-}	$3/2^{+}$	****	$\Xi_{b}(5945)^{0}$	$3/2^{+}$	***
N(1895)	$1/2^{-}$	****	<i>∆</i> (2200)	7/2 ⁻ ***	Σ(1915)	$5/2^{+}$	****	$\Omega(2012)^{-}$?-	***	$\bar{\Xi_{h}}(5955)^{-}$	$3/2^{+}$	***
N(1900)	$3/2^{+}$	****	<i>∆</i> (2300)	9/2+ **	Σ(1940)	$3/2^{+}$	*	$\Omega(2250)^{-}$		***	$\Xi_{h}(6227)$	'	***
N(1990)	$7/2^{+}$	**	$\Delta(2350)$	5/2 *	Σ(2010)	$3/2^{-}$	*	$\Omega(2380)^{-}$		**	Ω_{L}^{-}	$1/2^{+}$	***
N(2000)	$5/2^{+}$	**	<i>∆</i> (2390)	7/2+ *	$\Sigma(2030)$	$7/2^{+}$	****	$\Omega(2470)^{-}$		**	D	/	
N(2040)	3/2+	*	$\Delta(2400)$	9/2 **	Σ(2070)	$5/2^{+}$	*	. ,			$P_{c}(4312)^{+}$		*
N(2060)	5/2-	***	$\Delta(2420)$	11/2 ⁺ ****	Σ(2080)	3/2+	*	Λ_{c}^{+}	$1/2^{+}$	****	$P_{c}(4380)^{+}$		*
N(2100)	$1/2^{+}$	***	$\Delta(2750)$	13/2- **	Σ(2100)	$7/2^{-}$	*	$\Lambda_{c}(2595)^{+}$	$1/2^{-}$	***	$P_{c}(4440)^{+}$		*
N(2120)	$3/2^{-}$	***	$\Delta(2950)$	15/2+ **	$\Sigma(2160)$	$1/2^{-}$	*	$\Lambda_{c}(2625)^{+}$	3/2-	***	$P_{c}(4457)^{+}$		*
N(2190)	$7/2^{-}$	****	_()	/ _	$\Sigma(2230)$	$3/2^+$	*	$\Lambda_{c}(2765)^{+}$	'	*	()		
N(2220)	9/2+	****	Λ	1/2+ ****	$\Sigma(2250)$	0/2	***	$\Lambda_{c}(2860)^{+}$	$3/2^{+}$	***			
N(2250)	9/2-	****	Λ	1/2- **	$\Sigma(2455)$		**	$\Lambda_{c}(2880)^{+}$	$5/2^+$	***			
N(2300)	$\frac{1}{2^+}$	**	$\Lambda(1405)$	1/2 ****	$\Sigma(2620)$		**	$\Lambda_{c}(2940)^{+}$	$3/2^{-}$	***			
N(2570)	5/2-	**	$\Lambda(1520)$	3/2 ****	$\Sigma(3000)$		*	$\Sigma_{2}(2455)$	$1/2^+$	****			
N(2600)	11/2	***	$\Lambda(1600)$	1/2 ⁺ ****	$\Sigma(3170)$		*	$\Sigma_{2}(2520)$	$\frac{1}{2}$	***			
N(2700)	13/2	**	$\Lambda(1670)$	1/2 ****	2(31/0)			Σ (2800)	5/2	***			
10(2100)	13/2		$\Lambda(1690)$	3/2 ****				$\frac{2}{z+}$	$1/2^{+}$	***			
			$\Lambda(1710)$	1/2+ *				-c =0	1/2+	****			
			$\Lambda(1800)$	1/2 ***				$\frac{-c}{-c}$	1/2	***			
			$\Lambda(1000)$	1/2 1/2 ⁺ ***				= c	1/2 '	***			
			A(1020)	т/2 Б/0+ ****				$=_{c}^{\prime 0}$	1/2	***			
			A(1020)	5/2 E/0 ⁻ ****				$\Xi_c(2645)$	3/2+	***			
			A(1000)	$\frac{3}{2} + \frac{3}{2}$				$\Xi_{c}(2790)$	$1/2^{-}$	***			
			A(2000)	1/2 *				$\Xi_c(2815)$	$3/2^{-}$	***			
			/(2000)	1/2 *				$\Xi_{c}(2930)$		**			
			/1(2050)	3/2 *				$\Xi_c(2970)$		***			
			/(2070)	3/2 *				$\Xi_{c}(3055)$		***			
			/(2080)	5/2 *				$\Xi_{c}(3080)$		***			
			/1(2085)	7/2 ***				$\Xi_{c}(3123)$		*			
			/(2100)	1/2 ****				Ω_c^0	$1/2^{+}$	***			
			A(2110)	5/2 ***				$\Omega_{c}(2770)^{0}$	3/2+	***			
			/1(2325)	3/2 *				$\Omega_{c}(3000)^{0}$		***			
			/1(2350)	9/2 ⁺ ***				$\Omega_c(3050)^0$		***			
			A(2585)	**				$\Omega_{c}(3065)^{0}$		***			
								$\Omega_{c}(3090)^{0}$		***			
								$Q_{c}(3120)^{0}$		***			

**** Existence is certain, and properties are at least fairly well explored.

*** Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, etc. are not well determined.

** Evidence of existence is only fair.

* Evidence of existence is poor.

Particle Data Group (PDG) Baryon Summary Table

"All science is either physics or stamp collecting." — *Ernest Rutherford (apocryphal)*

But:

(1) diversity is interesting

(2) hadrons provide a toolkit to address particular questions

(3) general principles can be inferred from patterns

\implies spectroscopy is stamp collecting (which is a good thing)

Hadron contributions to fundamental physics

Patterns of hadron multiplets

 \implies the existence of quarks with flavors and colors

Non-observation of hadrons with color (including quarks) \implies color confinement

Patterns of excited hadrons

 \implies shape of the $q\bar{q}$ and qq potentials, including spin effects

Searches for exotic hadrons

 \implies tests of our ability to understand and use QCD

Patterns of hadron weak decays

 \implies parity violation, *CP* violation, structure of the CKM matrix

Diverse collection of hadrons

 \implies opportunities to search for new physics (e.g. $B^+ \rightarrow K^+ \mu^+ \mu^-$ and $B^+ \rightarrow K^+ e^+ e^-$)



[PDG quark model review]

HUGS 2021 Lectures on: Experimental Meson Spectroscopy

Prologue: Definitions and Philosophy

- I. A Field Guide to Meson Families
- II. Meson Quantum Numbers
- III. The Quark Model
- IV. Exotic Mesons
- V. Current and Future Experiments

LECTURE I. A Field Guide to Meson Families

- IA. Introduction to Meson Families
- IB. A Few Basic Principles Determining Meson Behavior
- IC. A Tour of Meson Families
 - * the K^+ family * the K^0 family * the π^0 family * the J/ψ family * the ρ family * the $Z_c(3900)$ family

IA. Introduction to Meson Families

			<i>ρ</i> (1	700)	ω(1650)	<i>φ</i> (1	.680)	ψ(37	70)	Υ(4 <i>S</i>)	
			$a_2(1$	320)	$f_2($	1270)	$f'_{2}(1$.525)	$\chi_{c2}(1$	<i>P</i>)	χ_{b2}	(1 <i>P</i>)	
			$a_1(1)$	260)	$f_1($	1285)	$f_1(1$.420)	$\chi_{c1}(1$	<i>P</i>)	χ_{b1}	(1 <i>P</i>)	
	\bar{d}		$a_0(1$	450)	$f_0($	1370)	$f_0(1$	710)	$\chi_{c0}(1$	<i>P</i>)	χ_{b0}	(1 <i>P</i>)	
SK			$b_1(1)$	235)	$h_1($	1170)	$h_1(1)$	1415)	$h_c(1)$	<i>P</i>)	$h_b($	1 <i>P</i>)	
JAF	<i>и</i>	excited states	$\rho(7$	770)	ω((782)	<i>φ</i> (1	.020)	$J/\psi(1)$	1 <i>S</i>)	Υ(1 <i>S</i>)	
lQl	\overline{S}	ground state	π^0	π^+	η	$\eta \mid \eta'$	η	$\mid \eta'$	$\eta_c(1)$	<i>S</i>)	$\eta_b($	(1 <i>S</i>)	
NT					_								
A	\overline{C}	<i>K</i> *(16	80)					D_{s1}^*					
	\bar{b}	$K_{2}^{*}(14)$	30)		$D_2^*(2)$	2460)		D^*_{s2}					
		$K_{1}(14)$	00)		$\frac{1}{2}D_{1}(2)$	2430)	dā	D_{s1}					
	$1^{-(-)} \rho(1')$	$K_0^*(14)$	30)	C	$D_0^*(2)$	2300)	<u>as</u>	D_{s0}^{*}	517)				
	$2^{+(+)} a_2(1)$	$K_1(12)$	70)		$D_{1}(2$	2420)		$D_{s1}(2$	460)+	$B_{1}(57)$	721)	$B_{s1}(58)$	$(830)^{0}$
	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	K*(89	92)	D*(20	$(07)^0$	<i>D</i> *(20]	$(0)^{+}$	D	*+ s	B	k	B_{s}^{i}	*0
excited	$1^{+(-)} b_1(1)$	K^0	K^+	D	0	D^+		Ľ	P_s^+	B^0	B^+	B	0
states ground	$\frac{1^{-(-)}}{0^{-(+)}} \frac{\rho(7)}{\pi^0}$									LL			~
state	$J^{P(C)}$			_			_						_
_		$Z_c(4020)^+ \rightarrow$	$\pi^+ h_c$	$Z_{c}(44)$	$(30)^+ \rightarrow$	$\pi^+\psi(2S)$	$Z_b($	$10650)^+ \rightarrow$	$\pi^+ h_b, \pi^+ \Upsilon$	X	$(2900)^0 \rightarrow$	D^+K^-	
	<i>K</i> *(1680)	$Z_c(3900)^+ \rightarrow$	$\pi^+ J/\psi$	$Z_{cs}(4$	000)+ -	$\rightarrow K^+ J/\psi$	$Z_b()$	$10610)^+ \rightarrow$	$\pi^+ h_b, \pi^+ \Upsilon$	$T_{cc\bar{c}\bar{c}}$	(6900) –	$\rightarrow J/\psi J/\psi$	
	$\frac{K_2^*(1430)}{K_2(1400)}$												
_	$K_1(1400)$	D ₁ (2430)											

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IA. Introduction to Meson Families

						LIADI	<u> </u>										
					$\rho(1$.700)	ω(1	1650)	φ (1	680)) $\psi(.)$	3770)	$\Upsilon(4)$	(4S)			
			d	l	$a_2(2)$	1320)	$f_2(1)$	1270)	$f'_{2}(1)$	525)) χ_{c2}	(1P)	$\chi_{b2}($	(1P)			
	-	0.1	1 /		$a_1(1)$	1260)	$f_1(1)$	1285)	$f_1(1)$	420)) χ_{c1}	(1P)	$\chi_{b1}($	1 <i>P</i>)			
\mathbf{S}	d	$ \pi^\circ $	$\eta \mid \eta'$	π	$a_0(1)$	1450)	$f_0(1)$	1370)	$f_0(1)$	(710)) χ_{c0}	(1P)	a $\chi_{b0}($	1 <i>P</i>)			
ZK	ī		π^{-}	π^0	$b_1(1)$	1235)	$h_1($	1170)	$h_1($	1415) h_c	(1P)	$h_b(1)$	1 <i>P</i>)			
JAI					ρ(΄	770)	ω((782)	$\phi(1)$	020)) J/y	v(1S)	Γ $\Upsilon(1)$	(S) cay	ys)		
IQU	\overline{S}	1	K^0	K	π^0	π^+	η	η' η'	η	η'	η_c	(1S)	$\prod_{1=2}^{1} \eta_b(1)$	1S)	$\begin{array}{c} \Upsilon(t) \\ \gamma \chi_{b2} \end{array}$	4 <i>S</i>) (1 <i>P</i>)	
NN	Ē	I	\sum_{K}	(168	.0 80)	<u>–</u>		Ilse	D	$\begin{bmatrix} a_1(1) \\ D_s^{\aleph} \end{bmatrix}$	$f_1(1) = \frac{f_1(1)}{f_1(1)}$	$\begin{array}{c c} 285 \\ \hline f_1(\\ \hline f_1 $	1420) 1710)	$\chi_{c1}(1P)$	χ_{b1}	(1P) $(1P)$ $(1P)$	
	\bar{b}		B^0 K	$\frac{14}{2}$	30)		$D_{2}^{*}(2$	2460)		D_{s}^*	*(2						
		7	Ķ	$\zeta_{1}(140)$)0)		$_{-}D_{1}(2$,430),	1-	D_s	1(2330) _			17	- - [
•	$1^{-(-)} \rho(17)$	$\begin{array}{c} ua, \\ \hline 00) \end{array}$	$\frac{uu}{\omega} K$	$Z_{0}^{*}(14)$	30)		$\frac{c}{D_{0}^{*}(2)}$	2300)	as		$(2317)^{+}$, da	<u>CS</u> /(<i>db</i>	, <i>ub</i> ∏	sb	1
	$2^{+(+)} a_2(13)$	20)	$f_2(\mathbf{k})$	$\frac{0}{127}$	70)		$D_1(2)$	(420)		D_{s}	$(2460)^+$	$B_1(5)$	721)	$B_{a1}(583)$	$(30)^0$	$B_{s2}^*(5840)^0$	
	$\begin{array}{c c} 1^{+(+)} & a_1(12) \\ 0^{+(+)} & a_0(14) \end{array}$.60)	$\frac{f_1(1)}{f_0(1)}$	K*(89	(2)	D*(20	$(07)^0$	D*(20	$(10)^{+}$	4	$\overline{D_s^{*+}}$		*	B_{s}^{*0}			
excited	$1^{+(-)} b_1(12)$	(35)	$h_1($	K^0	(+)	D	0	D^+		2	D_s^+	B^0	B^+	$B_{\rm s}^0$		$B_{s1}(5830)^0$	
states	$1^{-(-)} \rho(77)$	/0)	ω(702) φ	(1020)			1(15)	X *(892)	D*(2007)*1	D*(2010)'			B*	B_s^{*0}	
ground state	$0^{-(+)} \boxed{\pi^{\circ}}$	π'	$\eta \mid \eta'$		$\eta \mid \eta'$	$\eta_c(1)$	<i>S</i>)	$\eta_b(1S)$	<i>K</i> ⁰	K ⁺	D^0	D^+	D_s			B_s^0	
	$J^{-(c)}$															$(0)^0 \to D^+ K$	_
	<i>K</i> *(1680)									3 9 0017	$\rightarrow \pi^{+} II$ in		$1)^{+} \rightarrow \pi^{+}h$	π^{+}		$J(00) \rightarrow J/\psi J$	/ψ
	$K_{2}^{*}(1430)$	L	$D_2^*(2460)$)	$D^*_{s^2}$	$(2573)^+$	<i>B</i> *(57	47) <i>B</i> *(5840) ⁰	5700)	π στφ	26(1001)		b, n			
	<i>K</i> ₁ (1400)	I	$D_1(2430)$)	D_{s1}	(2536)+		<u>s2</u>								12	,

IA. Introduction to Meson Families

				цари	<u>n</u>								1	
			ρ(1	700)	<i>ω</i> (1650)) q	<i>þ</i> (168	0)	ψ(37	70)	Υ((4S)		
		d	$l a_2(1)$	320)	$f_2(1270)$)) f	^c / ₂ (152	5)	$\chi_{c2}(1)$	(P)	χ_{b2}	(1 <i>P</i>)		
	_	0	$a_1(1)$.260)	$f_1(1285)$	5) f	$r_1(142)$	0)	$\chi_{c1}(1)$	(P)	χ_{b1}	(1 <i>P</i>)	(8)	
\mathbf{S}	d	$\pi^{0} \eta \eta$	$\pi a_0(1)$	450)	$f_0(1370)$)) <i>f</i>	$f_0(171)$	0)	$\chi_{c0}(1)$	(P)	χ_{b0}	(1 <i>P</i>))	
RK	ū	π^{-}	π^0 $b_1(1)$.235)	$h_1(1170)$	D) h	n ₁ (141	.5)	$h_c(1)$	<i>P</i>)	$h_b($	(1 <i>P</i>)		
JA]			$\rho($	770)	<i>ω</i> (782)	<i>þ</i> (102	.0)	$J/\psi($	1 <i>S</i>)	Υ((1S)	cays)	
IQL	\overline{S}	<i>K</i> ⁰	$K \pi^0$	π^+	$\eta \mid \eta'$		η η	/))	$\eta_c(1)$	S)	$\eta_b($	(1 <i>S</i>)) $\Upsilon($	(4S) (1P)
ANT	Ē	D^{-}	50 K*(1680)	<u>n</u> -	Ilve	. 1		$D_{s1}^{*}(2)$	$f_1(128)$	$\begin{array}{c c} f_1(1) \\ f_1(1) \\ f_2(1) \\ f_3(1) \\ f_4(1) \\ f_4$	420) 710)	$\chi_{c1}(1P)$		(1P) $(1P)$ $(1P)$
	$ar{b}$	B^0	$K_2^*(1430)$	Ì	$D_2^*(2460)$)		$D_{s2}^{*}(2)$	573) ⁺	$B_2^*(5)$	747)	$B_{s2}^{*}(5)$	840) ⁰	1S) 1S)
	$1^{-(-)}$ $\rho(170)$	$u\bar{d}, u\bar{u}$	$X_{\frac{1}{d}, \frac{1400}{ss}}$ $X_{2}^{*}(1430)$	c _	$D_1(2430)$ $D_2^*(2300)$)	$\frac{d\bar{s}}{d\bar{s}}$	$D_{s0}^{*}(2)$	$\frac{c\bar{u}, c}{317}$	d	<u></u>		d̄b, ūb	sb
Ī	$2^{+(+)}$ $a_2(132)$	$f_2(1)$ $f_2(1)$	$K_1(1270)$		$D_1(2420)$)	4 1	$D_{s1}(24)$	460)+	$B_1(57)$	/21)	$B_{s1}(5)$	830) ⁰	$B_{s2}^{*}(5840)^{0}$
	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	50) $f_1($ 50) $f_0($	K*(892)	D*(200	$(07)^0 D^*$	$(2010)^{-1}$	+ _2	D_s	*+ s	B°	k	B	*0 s	
excited	$1^{+(-)} b_1(123)$	$h_1($	$K^0 K^+$	D^{0})	D^+	2	D	+ s	B^0	B^+	B	$\frac{0}{s}$	$B_{s1}(5830)^0$
ground	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\frac{\omega}{\pi^+} \frac{\omega}{\eta \mid \eta}$	$\frac{\varphi(1020)}{\eta \mid \eta'}$	$\frac{J/\psi(1)}{\eta_c(1S)}$	$\frac{1}{\eta_b}$	13) / 15) /	$K^{+}(892)$ $K^{0} K^{+}$		$(2007)^{\circ} D^{\circ}$	$\frac{(2010)^{+}}{D^{+}}$	D_s	+	B^{*} B^{0} B^{+}	$\frac{B_s}{B_s}$
state	J ^{P(C)} K*(1680)	$\frac{Z_c(4)}{Z_c(39)}$	$(020)^+ \rightarrow \pi^+ h_c$ $(00)^+ \rightarrow \pi^+ J/\psi$		$(0)^+ \to \pi^+ \psi(2)$ $(0)^+ \to K^+ J$	2S)	$Z_b(106)$ $Z_b(106)$	$(50)^+ \rightarrow (10)^+ \rightarrow$	$\frac{\pi^+ h_b, \pi^+ \Upsilon}{\pi^+ h_b, \pi^+ \Upsilon}$	X(Z)	2900) ⁰	$\rightarrow D^+ K^-$ $\rightarrow J/\psi J/\psi$	$\frac{X(290)}{\sum_{cc\bar{c}\bar{c}}(69)}$	$(00)^0 \rightarrow D^+ K^-$ $(000) \rightarrow J/\psi J$
	<i>K</i> [*] ₂ (1430)	$D_2^*(246)$	D_{s2}^{*}	(2373)	$B_2^*(5747)$	$B_{s2}^{*}(5840)$	$))^{0}$							•••
	<i>K</i> ₁ (1400)	$D_1(243)$	D_{s1}	$(2536)^+$										13

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Four basic principles determining meson behavior:

1. For a particle A at rest decaying to particles 1, 2, 3, ...,

$$m_A = E_A = \sum_i E_i = \sum_i \sqrt{m_i^2 + p_i^2} \ge \sum_i m_i$$

- 2. Flavor quantum numbers are conserved by the strong and electromagnetic forces, but not by the weak force.
- 3. When allowed,

strong decays dominate electromagnetic decays, and electromagnetic decays dominate weak decays.

4. Strong decays without $q\bar{q}$ annihilation are usually preferred over decays with $q\bar{q}$ annihilation (OZI suppression).

IB. Basic Principles Determining Meson Behavior **ELECTROMAGNETIC** Four basic principles determining meson behavior: $Q_a e \gamma^{\mu}$ 1. For a particle A at rest decaying to particles 1, 2, 3, ..., $m_A = E_A = \sum E_i = \sum \sqrt{m_i^2 + p_i^2} \ge \sum m_i$ **STRONG** 2. Flavor quantum numbers are conserved by the qstrong and electromagnetic forces, but not by the -ig_T weak force. sht. 3. When allowed, strong decays dominate electromagnetic decays, $\sim \sim \sim$ and electromagnetic decays dominate weak decays 4. Strong decays without $q\bar{q}$ annihilation are usually. preferred over decays with $q\bar{q}$ annihilation $\sqrt{\sqrt{2}}$ (OZI suppression).

IB. Basic Principles Determining Meson Behavior **ELECTROMAGNETIC** Four basic principles determining meson behavior: q $i Q_a e \gamma^{\mu}$ 1. For a particle A at rest decaying to particles 1, 2, 3, ..., $m_A = E_A = \sum E_i = \sum \sqrt{m_i^2 + p_i^2} \ge \sum m_i$ **STRONG** 2. Flavor quantum numbers are conserved by the 220 qstrong and electromagnetic forces, but not by the $-ig_s T_{ii}$ weak force. 500 \implies all SM interactions conserve baryon number $\sim \sim \sim$ $B = \frac{1}{3} \sum_{f} \left(N_{q_f} - N_{\bar{q}_f} \right)$ Q_0 \implies electromagnetic and strong interactions con quark flavors (e.g. strangeness, charm, bøttopiness) $F = \pm \left(N_{q_f} - N_{\bar{q}_f} \right)$

Four basic principles determining meson behavior:

1. For a particle A at rest decaying to particles 1, 2, 3, ...,

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 π^+ (decays weakly): $\tau_{\pi^+} = 2.6 \times 10^{-8} \text{ s}$ $c\tau_{\pi^+} = 7.8 \text{ m}$

 π^{0} (decays electromagnetically): $\tau_{\pi^{0}} = 8.5 \times 10^{-17} \text{ s}$ $c\tau_{\pi^{0}} = 26 \text{ nm}$

$$\rho$$
(770) (decays strongly):
 $\tau_{\rho} = \frac{1}{\Gamma} = \frac{1}{150 \text{ MeV}} = 4.4 \times 10^{-24} \text{ s}$
 $c\tau_{\rho} = 1.3 \text{ fm}$





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$$\rho(770)$$
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 $c\tau_{\rho} = 1.3 \text{ fm}$



IC. A Tour of Meson Families: **the** *K*⁺ **family**

			ρ(1	700) a	0(1650)	<i>φ</i> (1	680)	$\psi(37)$	70)	Υ((4S)		
		d	$l a_2(1$	320) f ₂	(1270)	$f'_{2}(1$	525)	$\chi_{c2}($	1 <i>P</i>)	χ_{b2}	(1 <i>P</i>))	
		0	$a_1(1)$	260) <i>f</i> ₁	(1285)	$f_1(1$	420)	$\chi_{c1}($	(P)	χ_{b1}	(1P)	g)	
	\bar{d}	$\pi^0 \eta \eta$	' $\pi a_0(1)$	450) <i>f</i> ₀	(1370)	$f_0(1$	710)	$\chi_{c0}($	(P)	χ_{b0}	(1P))	
SK	ū	π^{-}	$\pi^0 b_1(1)$	235) <i>h</i> ₁	(1170)	$h_1(1)$.415)	$h_c(1)$	<i>P</i>)	$h_b($	(1 <i>P</i>)		
JAF	u	Л	$\rho(7)$	770) 0	v(782)	φ(1	020)	J/ψ((1 <i>S</i>)	Υ((1 <i>S</i>)	cays)	
IQU	\overline{S}	K^0	$K \pi^0$	π^+	$\eta \mid \eta'$	η	$ \eta' $	$\eta_c(1)$	(S)	$\eta_b($	(1S)	$\gamma($	(1 <i>P</i>)
ANT	Ē		5 0 K*(1680)	D-	Ilve	<i>D</i> -	$a_1(1260)$ $D_{s1}^*(2)$	$f_1(128)$	$\begin{array}{c c} \hline & & \\ \hline & & \\ \hline \\ \hline$	420) 710)	$\chi_{c1}(1P)$		(1 <i>P</i>) (1 <i>P</i>) (1 <i>P</i>)
	\bar{b}	B^0	$K_2^*(1430)$	D ₂ *	(2460)		$D_{s2}^{*}(2)$	$(573)^+$	$B_2^*(5)$	747)	$B_{s2}^{*}(58)$	340) ⁰ ((1 <i>S</i>) 1 <i>S</i>)
	$1^{-(-)}$ $\rho(170)$	$u\bar{d}, u\bar{u}, \bar{d}$	$K_{0}^{1}(1400)$	$\frac{c\bar{c}D_1}{D_0^*}$	(24301) (2300)	$-d\bar{s}$	$D_{s1}^{*\bar{s}}$	$(317)^{+}$	ā	<u> </u>	(<i>d̄b,ūb</i>	sb
	$2^{+(+)} a_2(132)$	$f_2(1)$	$K_1(1270)$	D_1	(2420)		$D_{s1}(2$	460)+	$B_1(57)$	/21)	$B_{s1}(58)$	830) ⁰	$B_{s2}^*(5840)^0$
	$\begin{array}{c c} 1^{+(1)} & a_1(120) \\ 0^{+(+)} & a_0(145) \end{array}$	50) $f_1(1)$ 50) $f_0(1)$	K*(892)	D*(2007)	$^{0} \mid D^{*}(20)$	10)+	D	*+ s	B°	ĸ	B_s^*	*0 -	
excited	$1^{+(-)} b_1(123)$	$h_1($	$K^0 \mid K^+ \mid 2$	D^0	D^+	2	L	P_s^+	B^0	B^+		0 s	$B_{s1}(5830)^0$
states ground	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\frac{\omega}{\pi^+} \frac{\omega}{\eta \mid \eta}$	$\frac{\varphi(1020)}{\eta \mid \eta'}$	$\frac{J/\psi(1S)}{\eta_c(1S)}$	$\eta_b(1S)$	$K^{*}(8)$	$\frac{D^*}{K^+}$	$\frac{(2007)^{\circ}}{D^0}$	*(2010)* D ⁺	D_s	+ E	B^{*} B^{0} B^{+}	$\frac{B_s^0}{B_s^0}$
state	$J^{P(C)}$	$Z_c(4)$	$(020)^+ \rightarrow \pi^+ h_c$	$Z_c(4430)^+$	$\rightarrow \pi^+ \psi(2S)$	$Z_b(1)$	l0650) ⁺ →	$\pi^+ h_b, \pi^+ \Upsilon$	X(2	2900) ⁰ →	$\rightarrow D^+K^-$	X(290	$(0)^0 \rightarrow D^+ K$
	<i>K</i> *(1680)	$Z_{c}(39)$	$(00)^+ \to \pi^+ J/\psi$	$Z_{cs}(4000)^{+}$	$\to K^+ J/\psi$	$Z_b(1)$	$(0610)^+ \rightarrow$	$\pi^+ h_b, \pi^+ \Upsilon$	$T_{cc\bar{c}\bar{c}}$	(6900) -	$\rightarrow J/\psi J/\psi$		····
-	$K_2^*(1430)$	$D_2^*(246)$	$\frac{D_{s2}}{D}$	$(2575)^+$ $B_2^*(2536)^+$	5747) $B_{s2}^{*}(5)$	5840) ⁰							
	$K_1(1400)$	$D_1(243)$	D_{s1}	(2350)									21

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IC. A Tour of Meson Families: **the** *K*⁺ **family**

IC. A Tour of Meson Families: the *K*⁰ family

					IIADI	<u> </u>								-		
				$\rho(1$	700)	ω(1650)	$\phi(1)$	(680)	ψ(3΄	770)	Ύ	(4S)			
		d		$l a_2(2)$	1320)	<i>f</i> ₂ (1270)	$f'_{2}(1)$	1525)	$\chi_{c2}($	(1 <i>P</i>)	χ_{b2}	(1P)			
	_	0		$a_1(1)$	1260)	$f_1($	1285)	$f_1(1)$	(420)	$\chi_{c1}($	(1 <i>P</i>)	χ_{b1}	(1 <i>P</i>)	<i>(g)</i>		
	\bar{d}	$\pi^0 \eta$	$\eta' \mid \sigma$	$a_0(1)$	1450)	$f_0($	1370)	$f_0(1)$	(710)	$\chi_{c0}($	(1 <i>P</i>)	χ_{b0}	(1P))		
SK	ū	π^{-}	π^0	$b_1(1)$	1235)	$h_1($	1170)	$h_1($	1415)	$h_c($	1 <i>P</i>)	h_b	(1 <i>P</i>)			
JAF		<i><i><i>T</i>(</i></i>		ρ(΄	770)	ω	(782)	$\phi(1)$	1020)	J/ψ	(1S)	Ϋ́	(1S)	cays)		
Ŋ	\overline{S}	K^0	l	π^0	π^+	r r	η η'	η	$\mid \eta'$	$\eta_c($	1 <i>S</i>)	η_b	(1 <i>S</i>)		(4S)	
ANT	Ē	D^{-}	K*(10	5 0 580)			Ilse	<i>D</i> -	$a_1(1260)$ $D_{s1}^*(2)$	$f_1(12)$ $f_1(12)$ $f_2(12)$ $f_1(12)$	$\begin{array}{c} 100 \\ 85) \\ f_1(1) \\ f_$	420) 710)	$\frac{\chi_{c2}(1P)}{\chi_{c1}(1P)}$	χ_{b1}	$(1P) \\ (1P) \\ (1P) \\ (1P) $	
	\bar{b}	B^0	$K_2^*(14)$ $K_1(14)$	430) 400)		$D_2^*(2)$	2460) 2430)		$D_{s2}^{*}(2)$	$(2573)^+$ $(2536)^+$	$B_{2}^{*}(5)$	747)	$B_{s2}^{*}(5)$	(840) ⁰	(1S) (1S)	
•	$1^{-(-)} \rho(170)$	(1) (1) (1)	$\frac{dd^{2}}{K_{0}^{*}(14)}$	430)	<i>C</i>	$D_0^*(2)$	2300)	ds	D_{s0}^{*s}	$(2317)^{+}$		<u> </u>	7(<u>db,ub</u>	sb	
	$2^{+(+)} a_2(132)$	20) $f_2(1)$	$K_1(12)$	270)		$D_1(2)$	2420)		$^{4} D_{s1}(2)$	2460)+	$B_1(57)$	721)	$B_{s1}(5$	$(830)^0$	$B_{s2}^{*}(5840)$	0
	$1^{+(+)}$ $a_1(126)$ $0^{+(+)}$ $a_0(145)$	$f_{1}(1) = f_{1}(1)$	K*(8	92)	D*(20	$(007)^0$	<i>D</i> *(20	$(10)^{+}$) ^{*+}	B^{2}	*	B B	*0 -		
excited	$1^{+(-)} b_1(123)$	$h_1($	K^0	<i>K</i> ⁺	L) ⁰	D^+		2 <i>I</i>	D_s^+	B^0	B^+	H E	B_s^0	$B_{s1}(5830)$	0
states ground	$\begin{array}{c c} 1^{-(-)} & \rho(770) \\ 0^{-(+)} & \pi^0 \end{array}$	$\frac{\partial}{\sigma^+} \frac{\omega}{\eta}$	(82) η'	$\frac{\varphi(1020)}{\eta \mid \eta'}$	$\eta_c(1$	15) S)	$\frac{1(1S)}{\eta_b(1S)}$	$K^{*}($	(K^+)	$\frac{(2007)^{\circ} L}{D^0}$	$D^{*(2010)^{+}}$	D_s	+ 5	B^{*} B^{0} B^{+}	$\frac{B_s^{*0}}{B_s^0}$	
state	$J^{P(C)}$											L			(0,0)	17.
Г	<i>K</i> *(1680)	Z_c	$\frac{(4020)^+}{3900)^+} \rightarrow$	$\rightarrow \pi^+ h_c$ $\rightarrow \pi^+ J/\psi$	$\frac{Z_c(44)}{Z_{cs}(44)}$	$(-30)^+ \rightarrow (-300)^+ -$	$\pi^+ \psi(2S)$ $\rightarrow K^+ J/\psi$	$Z_b($	$10650)^+ - 10610)^+ - 10610)^+ - 10610)^+ - 10610)^+ - 1061000000000000000000000000000000000$	$\rightarrow \pi^+ h_b, \pi^+ \Upsilon$ $\rightarrow \pi^+ h_b, \pi^+ \Upsilon$	X(z)	2900) ⁰ -	$\rightarrow D^+ K^-$ $\rightarrow J/\psi J/\psi$	$\frac{X(29)}{c_{cc\bar{c}}}$	$(00)^\circ \rightarrow D^+ I$ $(00)^\circ \rightarrow J/\psi$	۲ رJ
	K [*] ₂ (1430)	$D_{2}^{*}(24)$	160)		(2373)	<i>B</i> *(57	$(47) B^*($	5840) ⁰			-				••••	
	<i>K</i> ₁ (1400)	$D_1(24)$	30)	D_{s1}	(2536)+	2,007	s2¢								2	5

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IC. A Tour of Meson Families: the *K*⁰ family

Mixing also means the K_S^0 and K_L^0 can have slightly different masses, which controls the rate of $K^0 - \overline{K}^0$ oscillations (and similarly for D^0 , B^0 , and B_s^0).

Start with a K^0 at t = 0. The K_S^0 and K_L^0 components evolve differently:

 $|K(t)\rangle = e^{-iHt} |K^{0}\rangle$ $= e^{-iHt} \frac{1}{\sqrt{2}} \left[|K_{S}^{0}\rangle + |K_{L}^{0}\rangle \right]$ $= \frac{1}{\sqrt{2}} \left[e^{-im_{S}t - \frac{1}{2}\Gamma_{S}t} |K_{S}^{0}\rangle + e^{-im_{L}t - \frac{1}{2}\Gamma_{L}t} |K_{L}^{0}\rangle \right]$

So that the probability of finding a K^0 at time *t* oscillates:

$$< K^{0} | K(t) > = \frac{1}{2} \left[e^{-im_{S}t - \frac{1}{2}\Gamma_{S}t} + e^{-im_{L}t - \frac{1}{2}\Gamma_{L}t} \right]$$
$$P_{K^{0}}(t) = \frac{1}{4} \left[e^{-\Gamma_{S}t} + e^{-\Gamma_{L}t} + 2e^{-\frac{1}{2}(\Gamma_{S} + \Gamma_{L})t} \cos((m_{L} - m_{S})t) \right]$$

Experimentally, K^0 and \bar{K}^0 can be distinguished using semi-leptonic decays, since $K^0 \to \pi^- e^+ \nu_e$ and $\bar{K}^0 \to \pi^+ e^- \bar{\nu}_e$.

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THE EUROPEAN PHYSICAL JOURNAL C

\mathcal{T} -violation and \mathcal{CPT} -invariance measurements in the CPLEAR experiment: a detailed description of the analysis of neutral-kaon decays to $e\pi\nu$

The CPLEAR Collaboration

 $m_L - m_S = 3.5 \times 10^{-12} \text{ MeV} = 5.3 \text{ ns}^{-1}$

IC. A Tour of Meson Family

Mixing also means the K_S^0 and K_L^0 can have slightly different masses, which controls the rate of $K^0 - \overline{K}^0$ oscillations (and similarly for D^0 , B^0 , and B_s^0).

Start with a K^0 at t = 0. The K_S^0 and K_L^0 components evolve differently:

$$\begin{split} |K(t)\rangle &= e^{-iHt} |K^{0}\rangle \\ &= e^{-iHt} \frac{1}{\sqrt{2}} \left[|K_{S}^{0}\rangle + |K_{L}^{0}\rangle \right] \\ &= \frac{1}{\sqrt{2}} \left[e^{-im_{S}t - \frac{1}{2}\Gamma_{S}t} |K_{S}^{0}\rangle + e^{-im_{L}t - \frac{1}{2}\Gamma_{L}t} |K_{L}^{0}\rangle \right] \end{split}$$

So that the probability of finding a K^0 at time *t* oscillates:

$$< K^{0} | K(t) > = \frac{1}{2} \left[e^{-im_{S}t - \frac{1}{2}\Gamma_{S}t} + e^{-im_{L}t - \frac{1}{2}\Gamma_{L}t} \right]$$
$$P_{K^{0}}(t) = \frac{1}{4} \left[e^{-\Gamma_{S}t} + e^{-\Gamma_{L}t} + 2e^{-\frac{1}{2}(\Gamma_{S} + \Gamma_{L})t} \cos((m_{L} - m_{S})t) \right]$$

There are similar phenomena for the D^0 , B^0 , and B_s^0 , with different lifetimes and mass differences.

 $m_H - m_L = 1.17 \times 10^{-8} \text{ MeV} = 17.8 \text{ ps}^{-1}$

				илли	2							1	
			$\rho(1$	700)	ω(1650)) <i>¢</i>	(1680)	ψ(37	770)	Υ((4S)		
		d	$l a_2(1)$	320)	$f_2(1270)$	f_2	(1525)	$\chi_{c2}($	1 <i>P</i>)	χ_{b2}	(1 <i>P</i>)		
		0	$a_1(1)$	260)	$f_1(1285)$	5) f_1	(1420)	$\chi_{c1}($	1 <i>P</i>)	χ_{b1}	(1 <i>P</i>)	(g)	
7	\bar{d}	$\pi^0 \eta \eta'$	$\pi a_0(1)$	450)	$f_0(1370)$)) f_0	(1710)	$\chi_{c0}($	1 <i>P</i>) _c	χ_{b0}	(1 <i>P</i>))	
SK	ū	π^{-}	$\pi^0 b_1(1)$	235)	$h_1(1170)$)) h	₁ (1415)	$h_c(1)$	$ P\rangle$	$h_b($	(1 <i>P</i>)		
JAF	<i>u</i>	π	$\rho()$	770)	<i>ω</i> (782)) _ ¢	(1020)	. J/ψ((1S)	Υ((1 <i>S</i>)	cays)	
	\overline{S}	K^0	$K \pi^0$	π^+	$\eta \mid \eta'$		$\eta \mid \eta'$	$\eta_c(1)$	(S)	$\eta_b($	(1 <i>S</i>)) $\Upsilon($	(1P)
E				/ r			$a_1(126)$	$\begin{array}{c} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ f_1(128) \\ f_1(128) \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ $	$\begin{array}{c} f_{1}(1) \\ f_{2}(1) \\ f_{3}(1) \\ f_{1}(1) \\ f_{2}(1) \\ f_{3}(1) \\ f_{3$	420)	$\frac{\chi_{c2}(1P)}{\chi_{c1}(1P)}$	χ_{b2}	(1P)
A	\bar{c}	D^{-}	×(1680)	<u></u>			$D_{s1}^{*}(2)$	2700)+		<u>710) ľ</u>	- <u>~ (1 D)</u>		(1P)
	Ī	\mathbf{p}_0	$X_{2}^{*}(1430)$		$D_{2}^{*}(2460)$)	$D_{s2}^{*}(2)$	2573)+	$\frac{1}{2} B*(5)$	747)	$B^*(5)$	840) ⁰ ((117) 1S)
	D		$\frac{2}{(1400)}$		$\frac{2}{D_1(2430)}$)	$D_{s1}(2)$	2536)+	$\frac{D_2(0)}{1}$,	<u>s2</u> (0)	<u> </u>	1 <i>S</i>)
•	$1^{-(-)}$ 0(170)	$ud, u\overline{u}, \overline{d}$	(1430)	cā	$D^{*}(2300)$	<u>b</u> ($\frac{1}{1} \frac{1}{1} \frac{1}$	$(2317)^{+}$	d	C3		<i>d̄b,ūb</i>	sb
Ĩ	$2^{+(+)} a_2(132)$	$f_2(1)$	$(1270)^{0}$		D(2420))	$A D_{-1}$	$2460)^{+}$	B (57	721)	$R_{1}(5)$	830)0	$B_{s2}^{*}(5840)^{0}$
	$1^{+(+)}$ $a_1(126)$	$\begin{array}{c} f_{1}(1) \\ f_{1}(1) \\ f_{2}(1) \\ f_{3}(1) \\ f_{3$	(1270)	D*(20)	$D_1(2+20)$	$\frac{1}{(2010)^{-1}}$)*+	(21) k	$D_{s1}(3)$	*0	
avaitad	$\begin{array}{c c} 0^{+(+)} & a_0(143) \\ 1^{+(-)} & b_1(123) \end{array}$	$f_0(1 - 1) = f_0(1 - 1) = f_0$	$\mathbf{v}^{0} \mathbf{v}^{+} \mathbf{v}^{+}$	D*(200	0 D	(2010) n+		<u>s</u>) +	D	D+		s 0	$B_{1}(5830)^{0}$
states	$1^{-(-)} \rho(770)$	$)) \qquad $	$\frac{\mathbf{A}}{2} \frac{\mathbf{A}}{\mathbf{\phi}(1020)}$.5) 1(.			S *(2007)°⊺D	*(2010)'			S B*	$\frac{B_{s1}^{*0}}{B_s^{*0}}$
ground state	$0^{-(+)}$ π^0 π^0	τ^+ $\eta \mid \eta'$	΄ η Ι η΄	$\eta_c(1S)$	S) $\eta_b($	1 <i>S</i>) <i>K</i>	K^0 K^+	D^0	D^+	D_s^+	F	$B^0 \mid B^+$	B_s^0
5	$J^{P(C)}$	$Z_c(40)$	$(20)^+ \rightarrow \pi^+ h_c$	$Z_{c}(443)$	$(30)^+ \to \pi^+ \psi(2)$	2S)	$Z_{b}(10650)^{+}$ –	$\rightarrow \pi^+ h_b, \pi^+ \Upsilon$	X	2900) ⁰ →	$\rightarrow D^+K^-$	X(290	$(00)^0 \to D^+ K$
Γ	<i>K</i> *(1680)	$Z_c(390)$	$(00)^+ \rightarrow \pi^+ J/\psi$	$Z_{cs}(40)$	$(000)^+ \rightarrow K^+ J$	/ψ	$Z_b(10610)^+ -$	$\rightarrow \pi^+ h_b, \pi^+ \Upsilon$	$T_{cc\bar{c}\bar{c}}$	(6900) -	$\rightarrow J/\psi J/\psi$	<u>cccc</u> (69	$(900) \rightarrow J/\psi_J$
	<i>K</i> [*] ₂ (1430)	$D_2^*(2460)$	$D) \qquad D_{s2}^{*}$	$(2373)^{\circ}$	$B_{2}^{*}(5747)$	$B_{s2}^{*}(5840)$	0						
	<i>K</i> ₁ (1400)	D ₁ (2430	D_{s1}	(2536) ⁺	2	32							32

/ψ

Properties of the π^0 , η , and η' :

* mixtures of *u*, *d*, and *s* quarks:

$$\begin{aligned} |\pi^{0}\rangle &= \frac{1}{\sqrt{2}} \left[|u\bar{u}\rangle - |d\bar{d}\rangle \right] \\ |\eta\rangle &\approx \frac{1}{\sqrt{6}} \left[|u\bar{u}\rangle + |d\bar{d}\rangle - 2|s\bar{s}\rangle \right] \\ |\eta'\rangle &\approx \frac{1}{\sqrt{3}} \left[|u\bar{u}\rangle + |d\bar{d}\rangle + |s\bar{s}\rangle \right] \end{aligned}$$

- * the π^0 decays only electromagnetically ($\pi^0 \rightarrow \gamma \gamma$ dominant) with a lifetime of 8.5 × 10⁻¹⁷ s ($c\tau = 26$ nm) corresponding to $\Gamma_{\pi^0} = 7.7$ eV.
- * the η and η' are also narrow (but not as narrow as the π^0): $\Gamma_{\eta} = 1.3 \text{ keV}$ and $\Gamma_{\eta'} = 190 \text{ keV}$
- * important for chiral symmetry breaking, fundamental QCD calculations, searches for new physics, etc.
- * also important as decay products from other particles

						<u> </u>										
				<i>ρ</i> (1	700)	ω(1650)	<i>φ</i> (1	680)	ψ(37	70)	Υ((4S)			
		d		$l a_2(1)$	320)	$f_2($	1270)	$f'_{2}(1$	525)	$\chi_{c2}($	1 <i>P</i>)	χ_{b2}	(1P)			
		0		$a_1(1)$.260)	$f_1($	1285)	$f_1(1$	(420)	$\chi_{c1}($	1 <i>P</i>)	χ_{b1}	(1 <i>P</i>)	<i>.g)</i>		
	\bar{d}	$\pi^0 \eta$	n'	$\pi a_0(1)$	450)	$f_0($	1370)	$f_0(1$	710)	$\chi_{c0}($	(1P)	χ_{b0}	(1 <i>P</i>))		
SK	ū	π^{-}	π^0	$b_1(1)$.235)	$h_1($	(1170)	$h_1(1)$	(415)	$h_c(1)$. <i>P</i>)	$h_b($	(1 <i>P</i>)			
JAI	<i>и</i>	<i>n</i>		$\rho(7)$	770)	ω	(782)	<i>φ</i> (1	.020)	$J/\psi($	(1 <i>S</i>)	Υ((1S)	cays)		
IQU	\overline{S}	<i>K</i> ⁰		$K \pi^0$	π^+	ľ	η η'	η	Ι η'	$\eta_c(1)$	S)	η_b	(1 <i>S</i>)	γ	(4S) $(1P)$	
ANT	Ē	D^{-}	<i>K</i> *(1	50 680)	- <u>ת</u>		Ibu	<i></i>	$a_1(1260)$ $D_{s1}^*(2)$	$f_1(128)$	$\begin{array}{c c} & & & \\ \hline 35) & & f_1(1) \\ \hline 70 & & f(1) \\ \hline 7 & & f(1) \\ \hline 7 & & \end{array}$	420) 710)	$\frac{\chi_{c1}(1P)}{\chi_{c1}(1P)}$) χ_{b1}	(1P) $(1P)$ $(1P)$	
	\bar{b}	B^0	$K_{2}^{*}(1)$	430)		$D_2^{*}(2)$	2460)		$D_{s2}^{*}(2)$	2573) ⁺	$B_2^*(5)$	747)	$B_{s2}^{*}(5)$	840) ⁰	(1 <i>S</i>) (1 <i>S</i>)	
•	$1^{-(-)}$ $o(170)$	$u\bar{d}, u\bar{u},$	$K^*(1)$	430)	<i>C</i>	$\frac{D_1}{c}$	2300	<u> </u>	$D_{s1}^{*}(2)$	$(317)^{\frac{c\bar{u},c}{4}}$	ā	<u></u> CS	7(dīb, uīb	sb	
Ī	$2^{+(+)}$ $a_2(13)$	$f_{20} = \frac{f_{2}(1)}{f_{2}(1)}$	$\frac{K_{1}}{K_{1}}$	270)		$D_{1}(2)$	2420)		$D_{s1}(2$	460)+	$B_{1}(57)$	721)	$B_{s1}(5$	830) ⁰	$B_{s2}^{*}(5840)$)0
	$\begin{array}{c c} 1^{+(+)} & a_1(12) \\ 0^{+(+)} & a_0(14) \end{array}$	$ \begin{array}{c c} 60) & f_1(1) \\ \hline 50) & f_0(1) \end{array} $	<i>K</i> *(8	392))	D*(20	$(07)^0$	<i>D</i> *(20	10)+		*+ s	B^{1}	*	B B	*0 s		
excited	$1^{+(-)} b_1(12)$	$h_1($	<i>K</i> ⁰	<i>K</i> ⁺	D)0	D^+		L	O_s^+	B^0	B^+	l E	B_s^0	$B_{s1}(5830)$)0
states ground	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\frac{0}{\pi^+} \frac{\omega}{\eta}$	02) η'	$\frac{\varphi(1020)}{\eta \mid \eta'}$	$\eta_c(1)$	$\frac{13}{S}$	$\eta_b(1S)$	$K^{*}(\mathbf{k})$	$\frac{(592)}{K^+}$	$\frac{(2007)^{\circ}}{D^{0}}$	*(2010) ⁺ D ⁺	D_s	+	B^{*} B^{0} B^{+}	$\frac{B_s^0}{B_s^0}$	
state	$J^{P(C)}$						-							X(29)	$(D)^0 \rightarrow D^+$	K-
Г	<i>K</i> *(1680)	$Z_c(z)$	$(4020)^+$ · · · · · · · · · · · · · · · · · · ·	$ \rightarrow \pi^+ h_c $ $ \rightarrow \pi^+ J/\psi $	$\frac{Z_c(44)}{Z_{cs}(44)}$	$\frac{30)^+ \rightarrow}{000)^+}$		$Z_b($	$\frac{10650)^+ \rightarrow}{10610)^+ \rightarrow}$	$\cdot \pi^+ h_b, \pi^+ \Upsilon$ $\cdot \pi^+ h_b, \pi^+ \Upsilon$	X()	$(6900)^0 -$	$\rightarrow D^+ K^-$ $\rightarrow J/\psi J/\psi$	$-\frac{1}{cc\bar{c}\bar{c}}(6)$	$(900) \rightarrow J/\psi$	μJ
	<i>K</i> [*] ₂ (1430)	D*(24	·60)		(2373)"	$B_{2}^{*}(57)$	747) $ B^*_{-2}(:$	5840) ⁰								
	<i>K</i> ₁ (1400)	$D_{1}(24)$	30)	D_{s1}	(2536)+		52								3	37

/ψ

	IC	C. A	Tour	of M	e <u>n</u>	Fam		the <i>J</i>	ψ far	nily	
		d	1	$\rho(1700)^{-70}$ $a_2(1320)$	$\psi(3770)$ \overline{c} $\psi(3770)$ \overline{c} $\psi(3770)$ \overline{c} $\psi(3770)$ \overline{c} $\psi(3770)$ \overline{c}		\overline{d} π^+ \overline{d} π^+ π^0	ψ(3770)		c D^+ D^+	
\mathbf{N}	đ	$\pi^0 \eta $	η' π	$a_1(1260)$ $a_0(1450)$	f_(1370)	$f_0(1)$	π^-				
IARK	ū	π^{-}	π^0	$b_1(1235) \over ho(770)$	$(\psi(3770))$ 82)	$\frac{1}{2000}$	41			u π^+	
TIOU		<i>K</i> ⁰	K	π^0 π^+	ψ(3770)	10000 11 10000 11		J/ψ \bar{c}	00000	d d d d d π^0	S) P)
AN	Ē	D^-	Б 0 <i>К</i> *(168())		0000 D -	s (K ⁻)70		-1202021	d \bar{u} π^-	P) P)
	\bar{b}	B^0	$K_2^*(1430)$ $K_1(1400)$)))) -	$D_2^*(2460)$ $D_1(2430)$		$D_{s2}^{*}(25)$ $D_{s1}^{*}(25)$,			S) S)
↑	$1^{-(-)} \rho(170)$	$u\bar{d}, u\bar{u}$ $00) \qquad \omega(1)$	$K_0^*(1430)$		$D_0^*(\overline{2300})$		$D_{s0}^{*}(23)$	<u>cū, c</u> d)+		<u></u>	sb
	$ \begin{array}{c} 2^{+(1)} & a_2(13) \\ 1^{+(+)} & a_1(12) \\ 0^{+(+)} & a_0(14) \end{array} $	$\begin{array}{c} 20) & f_2(1) \\ \hline 60) & f_1(2) \\ \hline 50) & f_0(1) \end{array}$	$K_1(1270)$ $K^*(892)$	$D) = \frac{1}{2}$ $D = \frac{1}{2} D^{*}(20)$	$\frac{D_1(2420)}{(07)^0 \mid D^*(27)}$	2010)+	$D_{s1}(2460)$	$B_1(5)^+$ $B_1(5)^ B_1(5)^-$	721) <i>B</i> _{s1}	$\frac{1}{B_s^{*0}}$	$B_{s2}^{*}(5840)^{\circ}$
excited states	$1^{+(-)} \begin{array}{c} b_1(12) \\ 1^{-(-)} \end{array} \\ \rho(77)$	$ \begin{array}{c} 35) \\ 0 \\ 0 \end{array} b_{1}(1) \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0$	$K^0 K^-$		$D^0 \qquad L$)+ [2)	D_{s}^{+0}	()°TD*(2010)'	B^+	B_s^0	$\frac{B_{s1}(5830)^0}{B_s^{*0}}$
ground state	$0^{-(+)}$ π^0 $J^{P(C)}$	π ⁺ η	η' η	$\eta' = \eta_c(1)$	S) $\eta_b(1)$	S) K ⁰	K ⁺ D ⁰	D ⁺	D_s^+	B ⁰ B ⁺	$\begin{array}{c} B_s^0 \\ \hline 00)^0 \to D^+ K^- \end{array}$
	<i>K</i> *(1680)	$\frac{Z_c}{Z_c}$	$(4020)^+ \to \pi^+$ $(4020)^+ \to \pi^+$	$\begin{array}{c c} h_c & Z_c(44) \\ I/\psi & Z_{cs}(4) \\ I/\psi &$	$30)^+ \to \pi^+ \psi(2k)$ $000)^+ \to K^+ J/k$	$\begin{array}{c} S \\ \psi \\ \end{array} \\ \begin{array}{c} Z_b \\ Z_b \end{array} $	$10650)^+ \to \pi^+ h_b$ $10610)^+ \to \pi^+ h_b$	$\begin{array}{c c} \pi^+ \Upsilon & X \\ \hline & & \\ \pi^+ \Upsilon & T_{cc\bar{c}} \end{array}$	$(2900)^0 \to D^+ K$ $_{\overline{c}}(6900) \to J/\psi.$	J/ψ	$(900) \rightarrow J/\psi J/\psi$
	$K_2^{-(1430)}$ $K_1(1400)$	$D_2^*(2 - D_1)^*(2 -$	430)	$D_{s2}(2575)^+$ $D_{s1}(2536)^+$	B ₂ *(5747)	$B_{s2}^{*}(5840)^{\circ}$					38

Excited meson states below open-flavor thresholds:

- * have suppressed strong decays
 - \implies they are relatively narrow
 - ⇒ electromagnetic transitions are accessible
- * can be considered the positronium of the strong force
- * potential models work well

						<u> </u>								•		
				$\rho(1$	700)	ω(1650)	<i>φ</i> (1	.680)	ψ(37	770)	Υ((4S)			
		d		$l a_2(1)$	1320)	$f_2($	1270)	$f'_{2}(1)$	525)	$\chi_{c2}($	1 <i>P</i>)	χ_{b2}	(1 <i>P</i>)			
	_	0		$a_1(1)$	1260)	$f_1($	1285)	$f_1(1)$.420)	$\chi_{c1}($	1 <i>P</i>)	χ_{b1}	(1 <i>P</i>)	<i>(</i> g)		
\mathbf{S}	\overline{d}	$\pi^0 \eta $	η'	$\pi a_0(1)$	1450)	$f_0($	1370)	$f_0(1$.710)	$\chi_{c0}($	1 <i>P</i>)	χ_{b0}	(1 <i>P</i>))		
RK	ū	π^{-}	π^0	$b_1(1)$	1235)	<i>h</i> ₁ ((1170)	$h_1(2)$	(415)	$h_c(1)$	(<i>P</i>)	$h_b($	(1 <i>P</i>)			
JAJ				$\rho($	770)	ω	(782)	<i>φ</i> (1	.020)	$J/\psi($	(1S)	Υ((1S)	cays)		
IQL	\overline{S}	<i>K</i> ⁰		$K \pi^0$	π^+	, r	η η'	η	$\mid \eta' \mid$	$\eta_c(1)$	(S)	η_b	(1S)	$\sum_{n=1}^{\infty} \frac{\gamma_n}{\gamma_{h2}}$	(4S) (1P)	
ANT	Ē	D^{-}		50	, -ת		Ibu	<u></u>	$a_1(1260)$ $D^*(2)$	$f_1(128)$	$\begin{array}{c c} \hline & & \\ \hline & & \\ \hline \\ \hline \\ \hline \\ \hline \\ \hline \\ \hline \\$.420) 710)	$\chi_{c1}(1P)$	$\begin{array}{c} \chi_{b1} \\ \chi_{b1} \\ \chi_{0} \end{array}$	(1 <i>P</i>) (1 <i>P</i>)	
			$\frac{K^{*}(1)}{K^{*}(1)}$	(680)				_	$D_{s1}^{(2)}$	(573)+	7			,(,((1P)	
	\bar{b}	B^0	$K_2^*(1)$	(430)		$D_{2}^{*}(2)$	2460)		$D_{s2}(2)$	(373) (573)	$B_{2}^{*}(5')$	747)	$B_{s2}^{*}(5)$	840)	(1S)	
		uā, uū,	$K_1(1)$	400)	C	$\overline{c}D_1(2)$	2430) bb	$d\bar{s}$	$D_{s1}(2$	(536)'	d	C.S	;	dīb, uīb	sb	
↑	$1^{-(-)} \rho(170)$	$\omega(1)$	$K_0^*(1)$	(430)		$D_0^*(2)$	2300)		$D_{s0}^{*}(2$.317)*						
	$2^{+(+)}$ $a_2(132)$ $1^{+(+)}$ $a_3(120)$	$f_2(1) = f_2(1)$	$K_{1}(1$	270)		$D_1(2)$	2420)	-	$D_{s1}(2$	460)+	$B_{1}(57)$	721)	$B_{s1}(5)$	830) ⁰	$B_{s2}^{*}(5840)$	0
	$\begin{array}{c c} 1 & a_1(12) \\ 0^{+(+)} & a_0(14) \end{array}$	50) $f_0(1)$	<i>K</i> *(892)	D*(20	$(07)^0$	l D*(20	10)+		s*+	B^{2}	*		s*0 s		_
excited	$1^{+(-)} b_1(122)$	$h_1($	K^0	K^+	D	0	D^+		L	O_s^+	B^0	B^+		B_{s}^{0}	$B_{s1}(5830)$	0
states ground	$1^{-(-)}$ $\rho(7/)$ $\rho^{-(+)}$ π^{0}	$\frac{\omega}{\pi^+} n$	$\binom{02}{n'}$	$\frac{\varphi(1020)}{n \mid n'}$	$J/\psi($	(S)	$n_{L}(1S)$	$K^{*}(\mathbf{k})$	$\frac{K^+}{K^+}$	$\frac{(2007)^{\circ}}{D^0}$	$(2010)^+$	D_s	+	B^{*} B^{0} B^{+}	$\frac{B_s^{+0}}{B^0}$	
state	$J^{P(C)}$. 1	414		5)					D					
_		Z_c	$(4020)^+$	$\rightarrow \pi^+ h_c$	Z _c (44	30) ⁺ →	$\pi^+\psi(2S)$	$Z_b($	$10650)^+ \rightarrow$	$\cdot \pi^+ h_b, \pi^+ \Upsilon$	X	$(2900)^0 -$	$\rightarrow D^+K^-$	X(290	$(0)^{\circ} \rightarrow D^+ I$ $(0)^{\circ} \rightarrow J/u$	K v.J
	<i>K</i> *(1680)	$Z_c($	3900) ⁺ ·	$\rightarrow \pi^+ J/\psi$	$Z_{cs}(4$	000)+ -	$\rightarrow K^+ J/\psi$	$Z_b($	$10610)^+ \rightarrow$	$\cdot \pi^+ h_b, \pi^+ \Upsilon$		(6900) -	$\rightarrow J/\psi J/\psi$			
	$K_2^*(1430)$	$D_2^*(24)$	160)	D_{s2}^{*}	$(2575)^{+}$ $(2536)^{+}$	$B_{2}^{*}(57)$	$(147) B^*_{s2}(147)$	5840) ⁰								12
	$\Lambda_1(1400)$	$D_{1}(22)$	+30)	ν_{s1}	(2000)										4	5

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Precision measurement of the branching fractions of $J/\psi \rightarrow \pi^+\pi^-\pi^0$ and $\psi' \rightarrow \pi^+\pi^-\pi^0$

BESIII Collaboration / Physics Letters B 710 (2012) 594–599

Precision measurement of the branching fractions of $J/\psi \rightarrow \pi^+\pi^-\pi^0$ and $\psi' \rightarrow \pi^+\pi^-\pi^0$

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IC. A Tour of Meson Families: the $Z_c(3900)$ family

					<u>n</u>									
			ρ(1700)		$\omega(1650)$) • $\phi($	1680)	ψ(37	70)	Υ((4S)			
		d	<i>l a</i> ₂ (1320)		$f_2(1270)$) $f'_{2}($	1525)	$\chi_{c2}(1P)$		$\chi_{b2}(1P)$)		
ANTIQUARKS	_	0	<i>a</i> ₁ (1260)		$f_1(1285)$) $f_1($	1420)	$\chi_{c1}(1P)$		$\chi_{b1}(1P)$		<i>g)</i>		
	\bar{d}	$\pi^0 \eta \eta'$	$\pi a_0(1450)$		$f_0(1370)$) $f_0($	1710)	$\chi_{c0}(1P)$ $h_c(1P)$		$\frac{\chi_{b0}(1P)}{h_b(1P)}$)		
	ū	π^{-}	π^0 $b_1(1235)$		$h_1(1170)$) $h_1($	1415)							
			$\rho(7)$	70)	<i>ω</i> (782)	φ(1020)	$J/\psi(1S)$		$\Upsilon(1S)$		cays)		
	\overline{S}	K^0	$K \pi^0$	π^+	$\eta \mid \eta'$	P	η η'	$\eta_c(1)$	S)	$\eta_b($	(1S)	$\frac{1}{2} \frac{\Upsilon(1)}{\chi_{h2}}$	$\frac{4S}{(1P)}$	
	Ē	D^{-} $\overline{K^{*}(1680)}$		<u>–</u>	- Ibu		$a_1(126)$ $D_{s1}^*(2)$	$\frac{f_1(1285)}{700} + \frac{f_1(1285)}{7}$		$\frac{\chi_{c1}(1P)}{\chi_{c1}(1P)}$			(1P) $(1P)$ $1P)$	
	$ar{b}$	\bar{b} $B^0 \frac{K_2^*(1430)}{K_1(1400)}$		$D_2^*(2460)$ $D_1(2430)$			$D_{s2}^{*}(2573)^{+}$ $D_{s1}^{*}(2536)^{+}$			$B_2^*(5747)$ $B_{s2}^*(5840)^0$			1S) 1S)	
Î	$1^{-(-)} \begin{array}{c c} ud, u\bar{u}, dd, \\ \mu & \mu \\ 1^{-(-)} \end{array} \\ \omega(1700) \\ $		(1430)		$\frac{1}{D_0^*(2300)}$	$b = d\bar{s}$	$D_{s0}^{*\bar{s}}(2)$	$317)^{+}$		$\frac{cs}{d}$		<i>db,ub</i>	sb	
	$2^{+(+)} a_2(132)$	$\frac{f_2(1)}{f_2(1)}$	$K_1(1270)$	$D_1(2420)$ $D^*(2007)^0 \mid D^*(202)$			$^{4} D_{s1}(2)$	2460)+	$B_1(57)$	/21)	$B_{s1}(58)$	830) ⁰	$B_{s2}^{*}(5840)^{0}$	0
	$\begin{array}{c c} 1^{+(+)} & a_1(126) \\ 0^{+(+)} & a_0(145) \end{array}$	$f_{1}(1) = f_{1}(1) $	K*(892)			2010)+	$\frac{1}{2}$ L	s^{*+} B		* 8 B		*0		
excited $1^{+(-)}$ $b_1($		$h_1($	K^0 K^+	D^0) L)+	2 <i>I</i>	D_s^+	B^0	B^+	B_s^0		$B_{s1}(5830)^0$	
states ground	$1^{(+)} \rho(7)$ $0^{-(+)} \pi^0$	$\frac{\omega(782)}{\tau^{+}} \qquad \eta \mid \eta'$	$\frac{\varphi(1020)}{\eta \mid \eta'}$	$\eta_c(1S)$	$\eta_b(1)$	$\frac{K^0}{K^0}$	892) D ² K ⁺	$\frac{D^0}{D^0}$	$\frac{(2010)}{D^+}$	D_s	+	B^{*} B^{0} B^{+}	$\frac{B_s^{\circ}}{B_s^{\circ}}$	
state	$J^{P(C)}$										$\Box X(290)$	$(0)^0 \rightarrow D^+ k$	7-	
	$Z_{c}(4020)$		$\frac{(20)^+ \rightarrow \pi^+ h_c}{(20)^+ + I'}$	$Z_{c}(443)$	$\frac{0}{2}^{+} \rightarrow \pi^{+} \psi(2S)$	S) Z_b	$(10650)^+ \rightarrow$	$\rightarrow \pi^+ h_b, \pi^+ \Upsilon$		$X(2900)^0 \to D^+ K^-$			$\overline{D}(00) \rightarrow J/\psi$	J
-	$\frac{K^{*}(1680)}{L_{c}^{*}(1420)} \rightarrow \pi^{+}J/\psi$		J_{0}) $\rightarrow \pi^{*} J \psi$	$Z_{cs}(4000)^{+} \to K^{+}J/\psi$			$Z_b(10610)^+ \to \bar{\pi}^+ h_b, \pi^+ \Upsilon$			$T_{cc\bar{c}\bar{c}}(0900) \rightarrow J/\psi J/\psi$				
	$K_2^*(1430) = D_2^*(2460) = D_{s2}^*(2460)$			$\frac{2373}{2536}$	$B_2^*(5747) = B_2^*(5840)^0$									0
	$A_1(1400)$ $D_1(2430)$ L			2550)									43	ð

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IC. A Tour of Meson Families: the $Z_c(3900)$ family

IC. A Tour of Meson Families: the $Z_c(3900)$ family

 $Z_c(3900)^+ \rightarrow \pi^+ J/\psi \implies minimal quark content is c \bar{c} u \bar{d}$

HUGS 2021 Lectures on: Experimental Meson Spectroscopy

Prologue: Definitions and Philosophy

- I. A Field Guide to Meson Families
- II. Meson Quantum Numbers
- III. The Quark Model
- IV. Exotic Mesons
- V. Current and Future Experiments

LECTURE I. A Field Guide to Meson Families

- IA. Introduction to Meson Families
- IB. A Few Basic Principles Determining Meson Behavior
- IC. A Tour of Meson Families
 - * the K^+ family * the K^0 family * the π^0 family * the J/ψ family * the ρ family * the $Z_c(3900)$ family

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LECTURE I. A Field Guide to Meson Families

Mesons are hadrons made from equal numbers of quarks and antiquarks.

The gross behavior of a meson is determined by whether it decays weakly (*e.g. the* K^+ *and* K^0), electromagnetically (*e.g. the* π^0), or strongly (*e.g. the* J/ψ *and* ρ):

* and if weakly, whether it can mix with its antiparticle (*e.g. the* K^0) or not (*e.g. the* K^+).

* and if strongly, if it's above open-flavor threshold (*e.g. the* ρ) or not (*e.g. the* J/ψ).

There are also meson candidates with exotic flavors that are hard to classify (*e.g. the* $Z_c(3900)$).