QCD and the strange baryon spectrum





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Strange quark in QCD

Strong interaction is governed by QCD

$$\mathscr{L}_{\text{QCD}} = -\frac{1}{4} G^a_{\mu\nu} G^{\mu\nu}_a + \bar{q}_\alpha (i\gamma^\mu D^{\alpha\beta}_\mu - m_q \delta^{\alpha\beta}) q_\beta$$

- nonperturbative at low energy (confinement, SCSB)

Quark mass scale and QCD symmetries



s quark at intermediate —> rich/complicated hadron spectrum

Observed hadrons (2018)

PDG 2018 edition

http://pdg.lbl.gov/

$ \begin{bmatrix} r \\ 1/2^{+} & r \\ M(260) & 3/2^{+} & r \\ M(260) & 1/2^{+} & r \\ M(260) & 5/2^{+} & r \\$	n	1/2+ ****	A(1232)	3/2+ ****	Σ^+	1/2+ **	* =0	$1/2^{+}$	****	A ⁺	$1/2^{+}$	****		LIGHT UN	FLAVORED = B = 0		STRA	NGE = B = 0	CHARMED, S	STRANGE	C	π
$ \begin{array}{c} \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	n	1/2+ ****	$\Delta(1202)$	3/2+ ***	Σ^0	1/2+ **	* =-	$\frac{1}{2^+}$	****	$\Lambda_{-}(2595)+$	1/2	***		$P(\hat{F}^{C})$	/	$f^{\mathcal{C}}(f^{\mathcal{C}})$	(, -	(<i>P</i>)	<	(Ĵ ^P)	• nc(15)	$0^{+}(0^{-}+)$
$ \begin{array}{c} \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	 N(1440)	1/2+ ****	$\Delta(1600)$	1/2 ****	Σ-	1/2+ **	* =(1530)	$\frac{1}{3}/2^+$	****	$\Lambda_{C}(2555)^{+}$	3/2-	***	• π^{\pm}	$1^{-}(0^{-})$	 φ(1680) 	0-(1)	• K [±]	1/2(0-)	 D[±]₅ 	0(0-)	 J/ψ(1S) 	0-(1)
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	N(1520)	3/2 ****	$\Delta(1020)$	3/2 ****	Σ(1385)	3/2+ **	* =(1620)	5/2	*	$\Lambda_{c}(2025)$	5/2	*	• π ⁰	1-(0-+)	 ρ₃(1690) 	1+(3)	• K ⁰	1/2(0-)	• D_{s}^{*\pm}	0(? [?])	• $\chi_{c0}(1P)$	$0^{+}(0^{+}^{+})$
$ \begin{array}{c} A(150) & 1/2^{-1} & ext \\ A(150) & 1/2^{-1} &$	N(1535)	1/2 ****	$\Delta(1750)$	1/2+ *	$\Sigma(1480)$	5/Z *	=(1620)		***	$\Lambda_{c}(2700)$ +	5/2±	***	• η • f (Ε00)	$0^+(0^{-+})$	 ρ(1700) 	$1^+(1^{})$ $1^-(2^{++})$	• K ⁰	1/2(0 ⁻)	• $D_{s0}^*(2317)^{\pm}$	0(0+)	• $\chi_{c1}(1P)$	$0^+(1^+)^+$ $2^{?}(1^+)^-$
$ \begin{array}{c} \begin{array}{c} \begin{array}{c} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 $	N(1555)	1/2 ****	$\Delta(1750)$ $\Lambda(1000)$	1/2 **	$\Sigma(1560)$	**	=(1000)	3/2-	***	$\Lambda_{C}(2000)^{+}$	5/2	***	• n(500) • n(770)	$1^{+}(1^{-})$	$\bullet f_0(1710)$	$0^{+}(0^{+}^{+})$	• K [*] _L K*(800)	1/2(0)	 D_{s1}(2460)[±] D_s(2536)[±] 	$0(1^+)$ $0(1^+)$	• $\chi_{C}(1P)$	$0^{+}(2^{+})$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	N(1675)	1/2 E/0 ****	$\Delta(1000)$	E/2+ ****	$\Sigma(1500)$	o/o− *	=(1020)	5/2	***	$T_{c}(2940)^{-1}$	1 /0+	****	• ω(782)	$0^{-}(1^{-}-)$	$\eta(1760)$	0+(0-+)	• K*(892)	$1/2(0^{-})$	• D _{S1} (2550) • D _{C2} (2573)	$0(2^{\circ})$	• η _c (25)	0 ⁺ (0 ⁻ +)
$ \begin{array}{c} \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	N(1675)	5/2 E/0+ ****	$\Delta(1900)$	5/2 1/2 ⁺ ****	$\Sigma(1500)$	3/2 1/0- *	=(1950)	< 5 ?	***	$\Sigma_{C}(2455)$	2/2+	***	• η′(958)	0+(0 - +)	 π(1800) 	1-(0-+)	• K ₁ (1270)	$1/2(1^+)$	• D ³² ₅₁ (2700) [±]	$0(1^{-})$	 ψ(2S) 	0-(1)
$ \begin{array}{c} \pi(230) & 3/2^{-} & \ast \\ \pi(270) & 3/2^{+} & \ast \\ \pi(270) & 3/2^{$	N(1600)	5/2 *	$\Delta(1910)$	2/2+ ***	$\Sigma(1020)$	1/2 ***	=(2030)	$\leq \frac{1}{2}$	*	$\Sigma_{C}(2520)$	3/2 '	***	• f ₀ (980)	$0^+(0^{++})$ $1^-(0^{++})$	$f_2(1810)$	$0^+(2^+)$	• K ₁ (1400)	$1/2(1^+)$	$D_{s,J}^{*}(2860)^{\pm}$	0(??)	 ψ(3770) χ(3823) 	$\frac{0^{-}(1^{-})}{2^{?}(2^{?}-)}$
$ \begin{array}{c} n_{1700} & j_{2^{+}} & \cdots & \lambda_{1800} & j_{2^{-}} & \cdots & \lambda_{1800} & j_{2^{+}} & \cdots & \lambda_{1800} & j_$	N(1005)	2/0- ***	$\Delta(1920)$	J/Z E/2 ***	$\Sigma(1000)$ $\Sigma(1670)$	2/2 **	* =(2120)		т 44	$\frac{2}{-+}$ (2800)	1 /0+	***	• a ₀ (500) • $\phi(1020)$	$0^{-}(1^{-})$	X(1840)	??(???)	 K*(1410) K*(1430) 	$\frac{1}{2(1)}$ $\frac{1}{2(0^+)}$	$D_{sJ}(3040)^{\pm}$	0(?:)	• X(3872)	$0^{+}(1^{+})$
$ \begin{array}{c} n(125) 1/2 + *** \\ n(126) 1/2 + *** \\ n(126$	N(1700)	3/2 1/0+ ***	$\Delta(1930)$	5/2 2/2- **	$\Sigma(1070)$	3/2 **	=(2250)		**	- <u>c</u>	1/2 '	ттт 	 h₁(1170) 	0-(1+-)	 φ₃(1850) 	0-(3)	 K₀(1430) K₃(1430) 	$1/2(0^{+})$	BOTT	ОМ	• X(3900) [±]	?(1+)
$ \begin{array}{c} m(120) & j/2^{+} & \# \\ m(180) & j/2^{+} & \# \\ m(280) & j/2^{$	N(1710)	1/2 ****	∆(1940) 4(1050)	3/2 **	$\Sigma(1690)$	2/0+ *	=(2370)		**	$=_{c}^{0}$	1/2-	***	 b₁(1235) 	$1^+(1^{+-})$	$\eta_2(1870)$	0+(2-+)	K(1460)	1/2(0-)	(B = ±	⊧1)	X(3900) ⁰	?(? [?])
$ \begin{array}{c} n(190) \ 5/2^{-1} & = \ 2(100) \ 1/2^{-1} & = \ 2(110) \ 1/2^{-1} & = $	N(1720)	3/2 ****	$\Delta(1950)$	1/2 ****	$\Sigma(1750)$	3/2 *	=(2500)		*	$=_{c}^{r+}$	$1/2^{+}$	***	 a1(1260) f(1270) 	$1^{-}(1^{++})$	 π₂(1880) (1000) 	$1^{-}(2^{-+})$ $1^{+}(1^{})$	$K_2(1580)$	1/2(2-)	• B [±]	$1/2(0^{-})$	• $\chi_{c0}(3915)$ • $\chi_{c0}(2P)$	$0^+(0^++)$
$ \begin{array}{c} \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	/V(1860)	5/2 **	$\Delta(2000)$	5/2 **	$\Sigma(1750)$	1/2 ***	0-	a /a+	4444	$=_{c}^{0}$	$1/2^+$	***	• fi(1285)	$0^{+}(1^{++})$	$f_{c}(1900)$	$0^{+}(2^{+})$	K (1630) K (1650)	$\frac{1}{2}(?^{\circ})$ $\frac{1}{2}(1^{\pm})$	• B±/B° ADN	/IXTURE	X(3940)	? [?] (? [?] ?)
$ \begin{array}{c} \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	N(1875)	3/2 ***	$\Delta(2150)$	1/2 *	$\Sigma(1770)$	1/2 *	Ω ⁻	3/2 1	****	$\Xi_{c}(2645)$	3/2+	***	 η(1295) 	0+(0 - +)	 f₂(1950) 	0+(2++)	• K*(1680)	$1/2(1^{-})$ $1/2(1^{-})$	• B [±] /B ⁰ /B ⁰ _s /	b-baryon	X(4020)±	?(? [?])
$ \begin{array}{c} \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	N(1880)	1/2* **	$\Delta(2200)$	7/2 *	$\Sigma(1775)$	5/2 ***	* Ω(2250) [−]		***	$\Xi_{c}(2790)$	$1/2^{-}$	***	 π(1300) 	$1^{-}(0^{-+})$	$\rho_3(1990)$	1+(3)	• K ₂ (1770)	1/2(2-)	ADMIXTUR	E CKM Mæ	 ψ(4040) ψ(4050)⁺ 	$0^{-}(1^{-})$
$ \begin{array}{c} & M(390) & 3/2^{-+} *** \\ M(390) & 3/2^{-+} *** \\ M(200) & 5/2^{-+} ** \\ M(200) & 5/2^{-+} ** \\ M(200) & 3/2^{++} \\ M(200) & 3/2^{++} \\ M(200) & 3/2^{++} \\ M(200) & 3/2^{++} \\ M(200) & 1/2^{-+} \\ M(200) & 1/2^{-+} \\ M(200) & 1/2^{-+} \\ M(200) & 1/2^{-+} \\ M(200) & 1/2^{++} \\ M(200) & 1/2^{++} \\ M(210) & 3/2^{-+} \\ M(210) & 3/2^{-+} \\ M(220) & 1/2^{++} \\ M(200) & 1/2^{++} \\ F(190) & 3/2^{-+} \\ F(100) & 1/2^{-+} \\ F($	N(1895)	1/2 **	$\Delta(2300)$	9/2⊤ **	$\Sigma(1840)$	3/2⊤ *	$\Omega(2380)^{-1}$		**	$\Xi_{c}(2815)$	$3/2^{-}$	***	 ∂2(1320) €(1370) 	$1(2^{++})$ $0^{+}(0^{++})$	 f₂(2010) f₂(2000) 	$0^+(2^++)$ $0^+(0^++)$	• K ₃ (1780)	1/2(3-)	trix Elements	5	$X(4050)^{-1}$ X(4140)	((?))
$ \begin{array}{c} M(300) & 7/2^{-7} * * \\ M(200) & 3/2^{-7} * \\ M(200) & 1/2^{-7} * \\ M(200)$	N(1900)	3/2* ***	$\Delta(2350)$	5/2 *	$\Sigma(1880)$	1/2 **	Ω(2470) ⁻		**	$\Xi_{c}(2930)$		*	$h_1(1380)$	$?^{-}(1^{+})$	• a4(2040)	$1^{-}(4^{++})$	K ₂ (1820) K(1820)	$1/2(2^{-})$ $1/2(0^{-})$	• B*	$\frac{1}{2}(1)$	 ψ(4160) 	$0^{-}(1^{-})$
$ \begin{array}{c} n(200) & 5/2^{-\pi} * * \\ n(2400) & 1/2^{+} * * \\ n(2100) & 1/2^{+} * * \\ n(2200) & 1/2^{+} * * \\ n(2300) & 1/2^{+} $	N(1990)	7/2+ **	$\Delta(2390)$	7/2**	$\Sigma(1900)$	1/2 *				$\Xi_{c}(2980)$		***	 π₁(1400) 	$1^{-}(1^{-+})$	• f ₄ (2050)	0+(4++)	K*(1950)	$1/2(0^{+})$ $1/2(0^{+})$	• B1(5721) ⁰	$1/2(1^{+})$	X(4160)	??(???)
$ \begin{array}{c} & M(200) & 3/2^{-*} \\ M(200) & 1/2^{+} \\ M(210) & 1/2^{+} \\ M(210) & 1/2^{+} \\ M(220) & 3/2^{-} \\ M(220) & 1/2^{-} \\ M(220) & 3/2^{-} \\ M(220) & 1/2^{-} \\ M($	N(2000)	5/2+ **	<i>∆</i> (2400)	9/2 **	Σ(1915)	5/2 ***	*			$\Xi_{c}(3055)$		***	 η(1405) (1400) 	$0^+(0^{-+})$	$\pi_2(2100)$	$1^{-}(2^{-+})$	K [*] ₂ (1980)	1/2(2+)	B [*] _J (5732)	?(? [?])	X(4230)	$?^{!}(1^{})$
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	N(2040)	3/2+ *	<i>∆</i> (2420)	11/2+ ****	Σ(1940)	3/2+ *				$\Xi_{c}(3080)$		***	• ħ(1420) • ∞(1420)	$0^{-}(1^{-})$	$f_0(2100)$ $f_0(2150)$	$0^+(0^+)$	• K ₄ [*] (2045)	1/2(4+)	 B[*]₂(5747)⁺ 	1/2(2+)	$X(4240)^{\pm}$ $X(4250)^{\pm}$?(U) 7(7 [?])
$ \begin{array}{c} & \Lambda(2100) & 1/2^{+} * \\ \Lambda(2120) & 3/2^{-} * * \\ \Lambda(2200) & 7/2^{-} * * \\ \Lambda(2200) & 7/2^{-} * * \\ \Lambda(2200) & 7/2^{-} * * \\ \Lambda(2200) & 1/2^{-} * \\ \Lambda($	N(2060)	5/2 **	$\Delta(2750)$	13/2 **	Σ(1940)	3/2" **				$\Xi_{c}(3123)$		*	f5(1430)	$0^{+}(2^{+})$	$\rho(2150)$	$1^{+}(1^{})$	$K_2(2250)$	$1/2(2^{-})$	• B ₂ (5747) ⁰	1/2(2 ⁺)	• X(4260)	??(1)
$ \begin{array}{c} & \mathcal{M}(2120) & 3/2^{-} *** \\ \mathcal{M}(210) & 3/2^{-} *** \\ \mathcal{M}(210) & 7/2^{+} **** \\ \mathcal{M}(220) & 9/2^{+} **** \\ \mathcal{M}(220) & 9/2^{-} **** \\ \mathcal{M}(220) & 3/2^{+} *** \\ \mathcal{M}(220) & 1/2^{-} *** \\ \mathcal{M}(220) & 1/2^{-} *** \\ \mathcal{M}(250) & 3/2^{-} *** \\ \mathcal{M}(250) & 3/2^{-} *** \\ \mathcal{M}(250) & 3/2^{-} *** \\ \mathcal{M}(250) & 1/2^{-} *** \\ \mathcal$	N(2100)	$1/2^{+}$ *	$\Delta(2950)$	15/2+ **	Σ(2000)	1/2 *				Ω_{c}^{0}	$1/2^{+}$	***	• a ₀ (1450)	$1^{-}(0^{++})$	 φ(2170) 	0-(1)	K [*] (2320)	$1/2(3^{-1})$ $1/2(5^{-1})$	• B(5970) ⁰	?(? [?])	X(4350)	$0^{+}(?^{?+})$
$ \begin{array}{c} & \mathcal{N}(2190) & 7/2^{-} & \ast \ast \ast \ast \\ \mathcal{N}(2200) & 9/2^{+} & \ast \ast \ast \ast \\ \mathcal{N}(2200) & 9/2^{+} & \ast \ast \ast \ast \\ \mathcal{N}(2200) & 9/2^{-} & \ast \ast \ast \ast \\ \mathcal{N}(2300) & 1/2^{+} & \ast \end{aligned} \\ \mathcal{N}(2300) & 1/2^{+} & \ast \ast \\ \mathcal{N}(2300) & 1/2^{+} & \ast \ast \end{aligned} \\ \mathcal{N}(2300) & 1/2^{+} & \ast \end{aligned} \\ \mathcal{N}(2300) & 1/2^$	N(2120)	3/2" **			Σ(2030)	7/2+ **	*			$\Omega_{c}(2770)^{0}$	$3/2^{+}$	***	 ρ(1450) (1475) 	$1^+(1^{})$	$f_0(2200)$	$0^+(0^{++})$	K4(2500)	1/2(4-)	DOTTOM C	TDANCE	• X(4360)	$?(1^{-})$
$ \begin{array}{c} & \sum_{n(2220) \\ (2220) \\ (2220) \\ (2250) \\ (2270$	N(2190)	7/2 ****	Λ	1/2+ ****	$\Sigma(2070)$	5/2+ *				,	'		 η(1475) ƒ(1500) 	$0^{+}(0^{+})$	n(2225)	$0^{+}(0^{-}+)$	⁴ K(3100)	??(? ^{??})	$(B = \pm 1, 5)$	$5 = \mp 1$	 ψ(4415) X(4430)[±] 	?(1 ⁺)
$ \begin{array}{c} \sqrt{(2250)} & 9/2^{-} & **** \\ \sqrt{(1600)} & 1/2^{+} & *** \\ \sqrt{(1600)} & 1/2^{+} & *** \\ \sqrt{(1600)} & 1/2^{+} & *** \\ \sqrt{(1600)} & 1/2^{-} & ** \\ \sqrt{(1600)} & 1/2^{-} & ** \\ \sqrt{(1600)} & 1/2^{-} & 1$	N(2220)	9/2+ ****	<i>N</i> (1405)	1/2 ****	Σ(2080)	3/2+ **				<u>=</u> +		*	f1(1510)	$0^{+}(1^{++})$	ρ ₃ (2250)	1+(3)	CHAR	MED	• B ⁰ _c	0(0-)	• X(4660)	??(1)
$ \begin{array}{c} \sqrt{(2300)} & 1/2^{+} *** \\ \sqrt{(1600)} & 1/2^{+} *** \\ \sqrt{(1600)} & 1/2^{-} *** \\ \sqrt{(1670)} & 1/2^{-} *** \\ \sqrt{(1600)} & 1/2^{-} *** \\ \sqrt{(1710)} & 1/2^{+} ** \\ \sqrt{(1710)} & 1/2^{+} ** \\ \sqrt{(1710)} & 1/2^{+} ** \\ \sqrt{(1800)} & 1/2^{-} *** \\ \sqrt{(1800)} & 3/2^{+} *** \\ \sqrt{(1800)} & 3/2^{+} *** \\ \sqrt{(2000)} & 3/2^{+} *** \\ \sqrt{(2000)} & 3/2^{+} *** \\ \sqrt{(2000)} & 3/2^{-} *** \\ \sqrt{(2100)} & 7/2^{+} * \\ \sqrt{(2100)} & \sqrt{(210)} \\ \sqrt{(2100)} & \sqrt{(210)} \\ \sqrt{(2100)} & \sqrt{(210)} \\ \sqrt{(2100)} & \sqrt{(210)} \\ \sqrt{(225)} & \sqrt{(210)} \\ \sqrt{(210)} $	N(2250)	9/2 ****	<i>Л</i> (1520)	3/2 ****	Σ(2100)	7/2" *				cc.			• $f'_2(1525)$	0+(2++)	 f₂(2300) 	0+(2++)	(C =	±1)	• B_s*	$0(1^{-})$	ŀ	5
$ \begin{array}{c} \sqrt{2570} & 5/2^{-} & *** \\ \sqrt{1670} & 1/2^{-} & **** \\ \sqrt{1680} & 3/2^{-} & **** \\ \sqrt{1680} & 1/2^{-} & **** \\ \sqrt{1680} & 1/2^{-} & **** \\ \sqrt{1680} & 1/2^{-} & *** \\ \sqrt{1680} & 5/2^{-} & **** \\ \sqrt{1680}$	N(2300)	1/2+ **	<i>Л</i> (1600)	1/2+ ***	Σ(2250)	**:				Λ_{h}^{0}	$1/2^{+}$	***	$f_2(1565)$	$0^+(2^++)$ $1^+(1^)$	$f_4(2300)$	$0^+(4^{++})$	• D [±]	1/2(0 ⁻)	 B_{s1}(5830)⁰ 	$0(1^+)$	nb(15)	$\frac{0}{0^{+}(0^{-}+)}$
$ \begin{array}{c} \sqrt{2600} & 11/2^{-***} \\ \sqrt{12700} & 13/2^{+} ** \\ \sqrt{1120} & 1/2^{-} & 1/2^{+} & 1/2^{+} \\ \sqrt{1120} & 1/2^{-} & 1/2^{+} & 1/2^{+} & 1/2^{+} \\ \sqrt{1120} & 1/2^{-} & 1/2^{+} & 1/2^{+} \\ \sqrt{1120} & 1/2^{-} & 1/2^{+} & 1/2^{+} & 1/2^{+} \\ \sqrt{1120} & 1/2^{-} & 1/2^{+} & 1/2^{+} \\ \sqrt{1120} & 1/2^{-} & 1/2^{+} & 1/2^{+} & 1/2^{+} \\ \sqrt{1120} & 1/2^{-} & 1/2^{+} & 1/2^{+} & 1/2^{+} \\ \sqrt{1120} & 1/2^{-} & 1/2^{+} & 1/2^{+} & 1/2^{+} \\ \sqrt{1120} & 1/2^{-} & 1/2^{+} & 1/2^{+} & 1/2^{+} \\ \sqrt{1120} & 1/2^{-} & 1/2^{+} & 1/2^{+} & 1/2^{+} & 1/2^{+} & 1/2^{+} \\ \sqrt{1120} & 1/2^{+} & 1/2^{+} & $	N(2570)	5/2 **	<i>Л</i> (1670)	1/2 ****	Σ(2455)	**				$\Lambda_{b}(5912)^{0}$	$1/2^{-}$	***	h(1570)	$0^{-}(1^{+})$	• f2340)	$0^{+}(2^{++})$	• D*(2007)0	1/2(0) 1/2(1-)	• B [*] ₅₂ (5840) ⁰ R [*] (5950)	0(2 ⁺) 2(2 ²)	• T(15)	0-(1)
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	N(2600)	11/2" ***	Л(1690)	3/2 ****	Σ(2620)	**				$\Lambda_{b}(5920)^{0}$	$3/2^{-}$	***	 π₁(1600) 	1-(1-+)	ρ ₅ (2350)	1+(5)	 D*(2007) D*(2010)[±] 	$1/2(1^{-})$	B _{sJ} (3630)	:(:)	• $\chi_{b0}(1P)$	0+(0++)
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	N(2700)	13/2+ **	<i>Л</i> (1710)	1/2+ *	Σ(3000)	*				Σ_{h}	$1/2^{+}$	***	a1(1640)	$1^{-}(1^{++})$	a ₆ (2450)	$1^{-}(6^{++})$	 D[*]₀(2400)⁰ 	1/2(0+)	BOTTOM, C	HARMED	• $\chi_{b1}(1P)$	$0^+(1^{++})$
$\begin{array}{c c c c c c c c c c c c c c c c c c c $			<i>I</i> (1800)	1/2 ***	Σ	*				Σ_{h}^{*}	$3/2^{+}$	***	$t_2(1640)$	$0^+(2^++)$ $0^+(2^-+)$	and the second second	0'(6'')	$D_0^*(2400)^{\pm}$	1/2(0+)	(D = C =	0(0-)	• η _b (1P) • χ _{to} (1P)	$0^{+}(2^{+})$
$\begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \left(1220 \right) & 5/2^{+} & **** \\ \left(1230 \right) & 5/2^{-} & **** \\ \left(1230 \right) & 5/2^{-} & **** \\ \left(1230 \right) & 3/2^{+} & **** \\ \left(1230 \right) & 3/2^{+} & *** \\ \left(1230 \right) & 3/2^{+} & *** \\ \left(1220 \right) & 7/2^{+} & * \\ \left(1220 \right) & 7/2^{+} & 1 \\ \left(12$			<i>A</i> (1810)	1/2+ ***						=0 =-	$1/2^+$	***	• ω(1650)	0-(1	0	1T	• D ₁ (2420) ^o	$1/2(1^+)$	$B_c(2S)^{\pm}$??(???)	$\eta_b(2S)$	0+(0 - +)
$ \begin{array}{ c c c c c c } \hline & & & & & & & & & & & & & & & & & & $			A(1820)	5/2+ ****						$= b^{\prime} = b^{\prime}$ = $(5935)^{-1}$	1/2+	***	 ω₃(1670) 	0 ⁻ (7			$D_1(2420)$ $D_1(2430)^0$	$1/2(1^+)$. (.)	 <i>γ</i>(25) 	0-(1)
$\begin{array}{c c c c c c c c c c c c c c c c c c c $			A(1830)	5/2 ****						$= \frac{1}{6}(0,000)$	3/2+	***	 π₂(1670) 	1-(• $D_2^*(2460)^0$	1/2(2+)			• T(1D)	$0^{-}(2^{-})$
$\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 &$			A(1890)	3/2+ ****						$=b(5945)^{-}$	- 3/2 ·	***			1		 D₂⁺(2460)[±] 	1/2(2+)			• $\chi_{E0}(2P)$ • $\chi_{E1}(2P)$	$0^{+}(0^{+})$
$\begin{bmatrix} 12_{b} & 1/2 & *** \\ 1/(200) & 3/2^{-} & * \\ 1/(210) & 1/2(7) \\ 1/(210) & 1/2(7) \\ 1/(230) & 155 \text{ baryons} \end{bmatrix} \begin{bmatrix} 12_{b} & 1/2 & *** \\ $			A(2000)	*						$=_{b}(3933)$	3/2 ·	***					D(2550) ⁰	$1/2(0^{-})$			$h_b(2P)$??(1+-)
$\begin{array}{c cccc} & (100) & $			A(2020)	7/2+ *						12 ^p	1/2 '	ጥጥጥ					D(2000) D*(2640)±	1/2(?) 1/2(?)			• χ _{b2} (2P)	$0^+(2^++)$
A(2100) A(2110) A(2325) A(2350			<i>Л</i> (2050)	3/2 *													D(2750)	1/2(??)			• T(35)	$0^{-}(1^{})$
A(2110) A(2125) 155 baryons 206 mesons X(1060) [±] 1 ⁺ (1) A(2325) A(2350) 155 baryons 206 mesons X(1060) [±] 1 ⁺ (1)			A(2100)				•								•		•				• γ(4S)	$0^{-}(1^{-})$
			<i>Л</i> (2110)́										~	00				_			X(10610)	[±] 1 ⁺ (1 ⁺) ′
			<i>Л</i> (2325)	155	na	rVA	าทจ						- 7	116	m	29	nn	2			X(10610)	$^{\prime} 1^{+}(1^{+})$
			<u>л(2350)</u>	100	NU	· · y ·															• 7(10860)	$0^{-}(1^{-})$
			<u>Л(2585)</u>			-	1														 <i>γ</i>(11020) 	0-(1)

All ~ 360 hadrons emerge from single QCD Lagrangian.

Observed hadrons (2020)

PDG 2020 edition

http://pdg.lbl.gov/

p	1/2+	****	<i>∆</i> (1232)	3/2+ *	***	Σ^+	1/2+ **	** =0	1/2+	****	=++		***		LIGHT UN	IFLAVORED = B = 0		STRA $(S = \pm 1, C)$	NGE = B = 0	CHARMED, S	STRANGE	c c cor	tinued $P(P^{C})$
n	1/2+	****	<i>∆</i> (1600)	3/2+ *	***	Σ^0	1/2+ **	** =-	1/2+	****		* /o±	ىلەر بەر بەر		$f(f^{C})$	<u> </u>	$f^{c}(f^{c})$	(- /-	I(I ^P)	((Ĵ ^P)	 ψ(3770) 	0-(1)
N(1440)	1/2	****	$\Delta(1620)$	1/2 *	***	Σ ⁻ Σ(120E)	1/2 ⁺ **	** =(153)) 3/2⊤ N	*	/\š	1/2 -	***	• π [±]	$1^{-}(0^{-})$	 π2(1670) 	$1^{-}(2^{-+})$	• K [±]	1/2(0-)	• D ₅	$0(0^{-})$	• $\psi_2(3823)$	$0^{-}(2^{-})$
N(1520) N(1535)	1/2	****	$\Delta(1700)$ $\Delta(1750)$	3/2 · 1/2 ⁺ *		$\Sigma(1580)$	3/2 *	=(169	9 1)	***	A ₆ (5920) ⁰	$3/2^{-1/2}$	***	• π° • η	$0^+(0^{-+})$	 φ(1680) φ₃(1690) 	$1^{+}(3^{-})$	• K ⁰	$1/2(0^{-})$ $1/2(0^{-})$	 D⁺⁺_S D[*]_S(2317)[±] 	0(?)	• ψ ₃ (3042) χ _m (3860)	$0^{+}(0^{+}+)$
N(1650)	1/2-	****	$\Delta(1900)$	1/2 *	**	$\Sigma(1620)$	1/2 *	=(105 =(182))) 3/2 ⁻	***	$\Lambda_b(6146)^{0}$	3/2+	***	• f ₀ (500)	0 ⁺ (0 ⁺ +)	 ρ(1700) 	1+(1)	• K ⁰ L	1/2(0-)	• $D_{S1}(2460)^{\pm}$	0(1 ⁺)	• $\chi_{c1}(3872)$	0+(1++)
N(1675)	5/2	****	$\Delta(1905)$	5/2+ *	***	$\Sigma(1660)$	1/2+ **	* <u>=</u> (195) -/-	***	Ab(6152)0	5/2+	***	 ρ(770) μ(792) 	$1^+(1^{})$	• $a_2(1700)$	$1^{-}(2^{++})$	• K ₀ (700)	1/2(0+)	 • D_{S1}(2536)[±] 	$0(1^+)$	• $Z_c(3900)$ • $Y(3915)$	$1^{+}(1^{+})$
N(1680)	5/2+	****	<i>∆</i> (1910)	1/2+ *	***	Σ(1670)	3/2- **	** <u>=</u> (203	$\dot{0} \geq \frac{5}{2}$? ***	Σ _b	$1/2^{+}$	***	 ω(162) η'(958) 	$0^{+}(0^{-}+)$	$\eta(1760)$	$0^{+}(0^{-+})$	• K*(892) • K1(1270)	$\frac{1}{2(1^{+})}$	 D[*]₅₂(25/3) D[*]₂(2700)[±] 	$0(2^+)$ $0(1^-)$	• χ _{c2} (3930)	$0^{+}(2^{+}+)$
N(1700)	3/2	***	<i>∆</i> (1920)	3/2+ *	**	Σ(1750)	1/2" **	* <i>Ξ</i> (212)) –	*	Σ_b^*	3/2+	***	• f ₀ (980)	0+(0++)	 π(1800) 	1-(0-+)	• K1(1400)	1/2(1+)	$D_{S1}^{*}(2860)^{\pm}$	$0(1^{-})$	X(3940)	??(???)
N(1710)	1/2+	****	$\Delta(1930)$	5/2 *	**	Σ(1775)	5/2 **	** <i>Ξ</i> (225))	**	$\Sigma_b(6097)^-$	+	***	• a₀(980) • ⊲(1020)	$1^{-}(0^{++})$ $0^{-}(1^{})$	$f_2(1810)$ $\chi(1835)$	$\frac{0^+(2^{++})}{2^?(0^{-+})}$	 K*(1410) K*(1420) 	$1/2(1^{-})$	$D_{53}^{*}(2860)^{\pm}$	0(3-)	• X(4020) [±] • ± (4040)	$1^{+}(?^{-})$ $0^{-}(1^{-})$
N(1720)	3/2	**** **	$\Delta(1940)$	3/2 *	* ***	$\Sigma(1/80)$	3/2**	Ξ(237))	**	$\sum_{b}(6097)^{-1}$	1 (0+	***	 <i>h</i>₁(1170) 	$0^{-}(1^{+})$	 φ₃(1850) 	0-(3)	• K ₀ (1430) • K ₅ (1430)	$1/2(0^{+})$ $1/2(2^{+})$	$D_{sJ}(3040)^{\pm}$	0(?:)	X(4050) [±]	$1^{-}(?^{+})$
N(1800) N(1875)	3/2-	***	$\Delta(1950)$ $\Delta(2000)$	5/2+ *	*	$\Sigma(1000)$	1/2 **	=(250	9	÷	$= \check{b}, = b$	- 1/2+	***	 b₁(1235) (10(0)) 	$1^+(1^{+-})$	 η₂(1870) 	$0^+(2^{-+})$	ĸ(1460)	1/2(0-)	BOTT	OM	X(4055) [±]	$1^{+}(?^{(-)})$
N(1873)	1/2+ 3	***	$\Delta(2000)$ $\Delta(2150)$	1/2 *		$\Sigma(1900)$ $\Sigma(1910)$	3/2 **	* 0-	3/2+	****	= b(2922)	$\frac{1}{2}$	***	• <u>a1(1260)</u> • <u>f5(1270)</u>	1(1+) $0^+(2++)$	• $\pi_2(1880)$ a(1900)	$1^{-}(2^{-})$ $1^{+}(1^{-})$	$K_2(1580)$	$1/2(2^{-})$	(D	1/2(0-)	• $\chi_{c1}(4100)^{-1}$	$1^{(?^{(1)})}$ $0^{+}(1^{++})$
N(1895)	1/2	****	$\Delta(2200)$	7/2- *	**	$\Sigma(1915)$	5/2+ **	** <u>Ω(201</u>	2)- ?-	***	$=_{b}(5955)^{-1}$	$-3/2^+$	***	 f₁(1285) 	0+(1++)	$f_2(1910)$	0+(2++)	$K_1(1650)$ $K_1(1650)$	$1/2(1^+)$ $1/2(1^+)$	• B ⁰	1/2(0-)	• ψ(4160)	$0^{-}(1^{-})$
N(1900)	3/2+ -	****	<i>∆</i> (2300)́	9/2+ *	*	Σ(1940)	3/2+ *	Ω(225) [_]	***	$\Xi_{b}(6227)$	0,2	***	 η(1295) - (1200) 	$0^+(0^{-+})$	$a_0(1950)$	$1^{-}(0^{++})$	• K*(1680)	1/2(1-)	• B [±] /B ⁰ ADM	MIXTURE	X(4160)	$\frac{?'(?'')}{1+(1+-)}$
N(1990)	7/2+	**	<i>∆</i> (2350)	5/2 *		Σ(2010)	3/2 *	Ω(238))-	**	Ω_b^-	1/2+	***	• a (1300)	$1^{-1}(0^{+})$ $1^{-}(2^{+})$	• $n_2(1950)$ • $a_4(1970)$	$\frac{0}{1^{-}(4^{++})}$	• $K_2(1770)$ • $K_2(1780)$	$1/2(2^{-})$ $1/2(3^{-})$	• B+/B°/B°/ ADMIXTUR	<i>b</i> -baryon E	• ψ(4230)	$0^{-}(1^{-})$
N(2000)	5/2+	**	<i>∆</i> (2390)	7/2+ *		Σ(2030)	7/2+ **	** Ω(247))-	**				 f₀(1370) 	0+(0++)	ρ ₃ (1990)	1+(3)	• K ₂ (1820)	1/2(3)	V _{cb} and V _{ub}	CKM Ma-	$R_{c0}(4240)$	$1^{+}(0^{})$
N(2040)	3/2	*	$\Delta(2400)$	9/2 *	*	$\Sigma(2070)$	5/2 ⁺ *	A +	1/2+	****	$P_{c}(4312)^{+}$	+ L	*	• $\pi_1(1400)$ • $v(1405)$	$1^{-}(1^{-+})$	$\pi_2(2005)$	$1^{-}(2^{-+})$ $0^{+}(2^{++})$	K(1830)	1/2(0-)	• B*	1/2(1-)	X(4250) [±] ±±(4260)	$1^{-}(?^{i+})$ $0^{-}(1^{-})$
N(2060)	5/2 ·	***	$\Delta(2420)$	12/2 *	*	Σ(2080) Σ(2100)	3/2' *	A (250	5)+ 1/2-	***	$P_{c}(4380)^{\neg}$	F F	*	 h₁(1405) h₁(1415) 	0-(1+-)	$f_0(2020)$	$0^{+}(0^{++})$	$K_0^*(1950)$ $K^*(1990)$	$1/2(0^+)$ $1/2(2^+)$	 B₁(5721)⁺ B₂(5721)⁰ 	$1/2(1^+)$ $1/2(1^+)$	• $\chi_{c1}(4274)$	$0^{+}(1^{+})$
N(2100)	3/2-	***	$\Delta(2750)$ $\Delta(2950)$	15/2+*	*	$\Sigma(2100)$ $\Sigma(2160)$	1/2 *	Ac(26)	$5)^{+} 3/2^{-}$	***	$P_{c}(4440)^{+}$	+	*	a1(1420)	$1^{-}(1^{++})$	• f ₄ (2050)	0+(4++)	• K ₄ (2045)	1/2(2)	$B_{l}^{*}(5732)$?(??)	X(4350)	$0^{+}(?^{?+})$
N(2190)	7/2	****	<u>(</u> 2300)	10/2		$\Sigma(2230)$	3/2+ *	$\Lambda_{c}(276)$	5) ⁺	*	1 2(4451)			• $t_1(1420)$ • $\omega(1420)$	$0^{+}(1^{+})^{+}(1^{-})^{-}(1^{-})^{+}$	$\pi_2(2100)$ f ₆ (2100)	$1^{-}(2^{-+})$ $0^{+}(0^{++})$	$K_2(2250)$	1/2(2-)	• B ₂ (5747) ⁺	1/2(2+)	• ψ(4360) ψ(4390)	0(1) $0^{-}(1^{-})$
N(2220)	9/2+ =	****	Λ	1/2+ *	***	Σ(2250)	· **	* Ac(286	0)+ 3/2+	***				f ₂ (1430)	0+(2++)	f2(2150)	0+(2++)	K ₃ (2320) K*(2380)	1/2(3 ⁺) 1/2(5 ⁻)	• B ₂ (5747) ⁰ B ₂ (5840) ⁺	$1/2(2^+)$ $1/2(2^?)$	 ψ(4415) 	0-(1)
N(2250)	9/2-	****	Λ	1/2- *	*	Σ(2455)	**	$\Lambda_{c}(288)$	0) ⁺ 5/2 ⁺	***				• a ₀ (1450)	$1^{-}(0^{++})$	ρ(2150)	$1^+(1^{})$	$K_{4}(2500)$	1/2(3)	B ₁ (5840) ⁰	1/2(?) 1/2(??)	• Z _c (4430)	$1^{+}(1^{+})$
N(2300)	1/2+	**	A(1405)	1/2 *	***	Σ(2620)	**	$\Lambda_c(294)$	0)+ 3/2-	***				• $\rho(1450)$ • $\eta(1475)$	$0^{+}(0^{-}+)$	• φ(2170) f ₀ (2200)	0(1) $0^+(0^{++})$	K(3100)	? [?] (? ^{??})	• B _J (5970) ⁺	$1/2(?^{?})$	x _{c0} (4500) • ψ(4660)	$0^{-}(0^{-})^{-}(1^{-})$
N(2570)	5/2	**	A(1520)	3/2 *	***	Σ(3000) Σ(3170)	*	$\Sigma_c(245)$	5) 1/2 ⁺	****				• f ₀ (1500)	0+(0++)	f _J (2220)	0+(2++	CHAR	MED	• B _J (5970) ^o	1/2(?`)	χ _{c0} (4700)	0+(0++)
N(2600)	11/2	**	A(1670)	1/2 *	***	2(3170)	*	$\Sigma_{C}(254)$	0) 3/2' 0)	***				$f_1(1510)$ $f'_1(1525)$	$0^+(1^{++})$ $0^+(2^{++})$	(2225)	$or 4^{++})$	(C = 1	±1)	BOTTOM, S	TRANGE	t	Б
11(2100)	13/2		A(1690)	3/2 *	***			=+	1/2+	***				f ₂ (1565)	$0^{+}(2^{++})$	ρ ₃ (2250)	1+(3)	• D± • D ⁰	$1/2(0^{-})$ $1/2(0^{-})$	• B ⁰	0(0 ⁻)	(+ possibly n	on-qq states)
			л(1710)	1/2+ *				=0	$1/2^+$	****				ρ(1570)	1+(1)	• f ₂ (2300)	$0^+(2^{++})$	 D*(2007)⁰ 	1/2(1-)	• B [*] _s	0(1_)	• $\eta_b(1S)$	$0^{+}(0^{-+})$
			A(1800)	1/2- *	**			Ξ'^+	1/2+	***				$h_1(1595)$ • $\pi_1(1600)$	$1^{-}(1^{+})$	f ₄ (2300) f ₆ (2330)	$0^{+}(0^{+}^{+})$	 D*(2010)[±] D*(2200)⁰ 	$1/2(1^{-})$ $1/2(0^{+})$	X(5568) [±]	?(??)	• $\chi_{b0}(1P)$	$0^{+}(0^{+}+)$
			A(1810)	1/2+ *	**			=0	1/2+	***				 a1(1600) a1(1640) 	$1^{-}(1^{++})$	 f₂(2340) 	0+(2++)	$D_0(2300)^{\pm}$ $D_0^*(2300)^{\pm}$	$1/2(0^+)$ $1/2(0^+)$	 B_{s1}(5830)⁰ B[*]₂(5840)⁰ 	$0(1^+)$ $0(2^+)$	• $\chi_{b1}(1P)$	$0^{+}(1^{+})$
			A(1820)	5/2+ *	***			$\Xi_{c}(264)$	5) 3/2 ⁺	***				$f_2(1640)$	$0^+(2^{++})$	0_(00E0)	$1^{+}(5^{})$	• D1(2420)0	1/2(1+)	$B_{sJ}^{*}(5850)$?(??)	• $h_b(1P)$	$0^{-}(1^{+})$ $0^{+}(2^{+})$
			/(1830)	5/2 *	***			$\Xi_c(279)$	0) 1/2-	***				 η₂(1645) ω(1650) 	0-(1-		(8)	$D_1(2420)^{\pm}$	$1/2(?^{f})$ $1/2(1^{\pm})$	BOTTOM, C	HARMED	$\eta_b(2S)$	$0^{+}(0^{-}+)$
			A(2000)	1/2 *			-	$\Xi_{c}(281)$	5) 3/2 ⁻	***				 ω₃(1670) 	0-(3			• D ₂ (2450) ⁰	$1/2(1^{+})$ $1/2(2^{+})$	(B = C =	= ±1)	 <i>γ</i>(25) <i>γ</i>(4.5) 	$0^{-}(1^{-})$
			A(2050)	3/2 *				$=_{c}(29)$	0)	***								• D ₂ [*] (2460) [±]	1/2(2+)	• B ⁺ _C	0(0 ⁻)	• T ₂ (1D) • Y ₁₀ (2P)	$0^{-}(2^{-})$ $0^{+}(0^{+})$
			/(2070)	3/2+ *				C(29)	0) 5)	***						<u> </u>		D(2550) ⁰	$1/2(?^{f})$	B _c (25) [⊥]	0(0)	 <i>χ</i>_{b1}(2P) 	$0^{+}(1^{+}+)$
			/(2080)	5/2- *				E_(308	0)	***								D'j(2600) D*(2640) [±]	$1/2(?^{?})$ $1/2(?^{?})$	$C\overline{C}$ (+ possibly nor	⊢aā states)	$h_b(2P)$	$0^{-}(1^{+})$
			A(2085)	7/2+ *	*			$\Xi_{c}(312)$	3)	*								D(2740)0	1/2(??)	• nc(15)	0+(0-+)	• $\chi_{b2}(2P)$ • $T(3S)$	$0^{+}(2^{+})^{+})$ $0^{-}(1^{-})^{-})$
			A(2100)	7/2- *	***			$\Omega_c^{\hat{0}}$	1/2+	***								D(2000)	1/2(3 ⁻)	 J/ψ(1S) 	0-(1)	• χ _{b1} (3P)	$0^{+(1++)}$
			/(2110) /(222E)	5/2' *	τŦ			0.07	010 2/0+	***						I		D(3000)°	1/2(:')	• $\chi_{c0}(1P)$	$0^{+}(0^{++})$	• $\chi_{b2}(3P)$ • $\Upsilon(AS)$	$0^{+}(2^{++})$ $0^{-}(1^{})$
			/1(2325) A(2350)							***					~~					• $h_c(1P)$	$0^{-}(1^{+})$	• Z _b (10610)	$1^{+}(1^{+})$
			A(2585)	16	2	'n	ar	/Or)C	***				2	7 1 Q	m	AC	n	C	• χ _{C2} (1P)	$0^{+}(2^{+}+)$	• Z _b (10650)	$1^{+}(1^{+})$
			. /				u j		J	***									J	• $\eta_c(25)$ • $\psi(25)$	$0^{-}(0^{1})$ $0^{-}(1^{1})$	• T(10753)	$0^{-(1^{-})}$
					1		-	142(314	0)~	***											- (-)	 <i>γ</i>(11020) 	0-(1)
<u> </u>									,		1											<u> </u>	

New states in 2 years (6 strange baryons)

Unstable states via strong interaction

Stable/unstable hadrons

http://pdg.lbl.gov/

р	1/2+ ****	⊿(1232)	3/2+	****	Σ^+	$1/2^{+}$	****	=0	$1/2^{+}$	****	=++		***
n	1/2+ ****	$\Delta(1600)$	3/2+	****	Σ^0	$1/2^{+}$	****	Ξ-	1/2+	****	a		
N(1440)	1/2+ ****	<i>∆</i> (1620)	$1/2^{-}$	****	Σ^{-}	$1/2^{+}$	****	Ξ(1530)	3/2+	****	Λ_{b}^{0} 1	$1/2^{+}$	***
N(1520)	3/2- ****	△(1700)	3/2-	****	Σ(1385)	3/2+	****	$\Xi(1620)$		*	Λ _b (5912) ⁰ 1	1/2-	***
N(1535)	1/2- ****	$\Delta(1750)$	$1/2^{+}$	*	Σ(1580)	3/2-	*	$\Xi(1690)$		***	Λ _b (5920) ⁰ 3	3/2-	***
N(1650)	1/2- ****	$\Delta(1900)$	$1/2^{-}$	***	$\Sigma(1620)$	$1/2^{-}$	*	$\Xi(1820)$	3/2-	***	Ab(6146) ⁰ 3	3/2+	***
N(1675)	5/2- ****	⊿(1905)	$5/2^{+}$	****	$\Sigma(1660)$	$1/2^{+}$	***	Ξ(1950)	_	***	Ab(6152)0 5	5/2+	***
N(1680)	5/2 ⁺ ****	⊿(1910)	$1/2^{+}$	****	Σ(1670)	3/2-	****	Ξ(2030)	$\geq \frac{5}{2}$?	***	Σ_b 1	1/2+	***
N(1700)	3/2" ***	⊿(1920)	3/2+	***	Σ(1750)	$1/2^{-}$	***	Ξ(2120)		*	Σ_b^* 3	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-	**	Σ(1780)	3/2+	*	Ξ(2370)		**	$\Sigma_b(6097)^-$		***
N(1860)	5/2+ **	$\Delta(1950)$	7/2+	****	Σ(1880)	$1/2^{+}$	**	Ξ(2500)		*	Ξ_{b}^{0}, Ξ_{b}^{-} 1	1/2+	***
N(1875)	3/2" ***	$\Delta(2000)$	5/2+	**	Σ(1900)	$1/2^{-}$	**				$\Xi'_{b}(5935)^{-1}$	L/2+	***
N(1880)	1/2+ ***	$\Delta(2150)$	$1/2^{-}$	*	Σ(1910)	3/2-	***	Ω^{-}	3/2+	****	$\Xi_b(5945)^0$ 3	3/2+	***
N(1895)	1/2- ****	∆(2200)	7/2-	***	Σ(1915)	$5/2^{+}$	****	Ω(2012)-	?-	***	$\Xi_b(5955)^-$ 3	3/2+	***
N(1900)	3/2+ ****	$\Delta(2300)$	9/2+	**	Σ(1940)	3/2+	*	$\Omega(2250)^{-}$		***	$\Xi_b(6227)$		***
N(1990)	7/2+ **	$\Delta(2350)$	5/2-	*	Σ(2010)	3/2-	*	<u>Ω(2380)</u> -		**	Ω_{b}^{-} 1	1/2+	***
N(2000)	5/2+ **	$\Delta(2390)$	7/2+	*	Σ(2030)	7/2+	****	$\Omega(2470)^{-}$		**			
N(2040)	3/2+ *	$\Delta(2400)$	9/2-	**	Σ(2070)	5/2+	*				$P_{c}(4312)^{+}$		*
N(2060)	5/2 ***	⊿(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+	**	Σ(2160)	1/2-	*	$\Lambda_{c}(2625)^{+}$	3/2-	***	$P_{c}(4457)^{+}$		*
N(2190)	7/2 ****				Σ(2230)	3/2+	*	$\Lambda_{c}(2765)^{+}$		*			
N(2220)	9/2+ ****	Λ	1/2+	****	Σ(2250)		***	$\Lambda_{c}(2860)^{+}$	3/2+	***			
N(2250)	9/2 ****	Λ	1/2-	本本 aludulala	Σ(2455)		**	$\Lambda_{c}(2880)^{+}$	5/2+	***			
N(2300)	1/2+ **	/(1405)	1/2-	****	$\Sigma(2620)$		**	$\Lambda_{c}(2940)^{+}$	3/2-	***			
N(2570)	5/2- **	/(1520)	3/2	****	Σ(3000)		*	$\Sigma_{c}(2455)$	1/2+	****			
N(2600)	11/2-***	/(1600)	1/2 -	****	$\Sigma(3170)$		*	$\Sigma_{c}(2520)$	3/2**	***			
N(2700)	13/2 ⁺⁺ **	/(16/0)	1/2	****				$\Sigma_{c}(2800)$	1 /o-t-	***			
		/(1690)	3/2	****				=	1/2	***			
		/(1/10)	1/2 -	****				-c	1/2+	****			
		/(1800)	1/2	***				$\Xi_{c}^{\prime+}$	1/2+	***			
		/(1810)	1/2 ' E/2+	skolok				="0"	$1/2^+$	***			
		/(1820)	5/21	skolok				$\Xi_{c}(2645)$	3/2+	***			
		/(1830)	3/2	skolok				$\Xi_{c}(2790)$	$1/2^{-}$	***			
		A(2000)	3/21	*				$\Xi_{c}(2815)$	3/2-	***			
		A(2000)	3/2-	*				E _c (2930)		**			
		A(2050)	3/2	*				c(2970)		***			
		A(2070)	5/21	*				c(3055)		***			
		A(2000)	7/2+	**				$=_{c}(3080)$		***			
		A(2100)	7/2-	****				$=_{c}(3123)$		*			
		$\Lambda(2100)$	5/2+	***				Ω_c^0	1/2+	***			
		A(2225)	3/2'					0(0770)0	2/2+	***			
		A(2325)								***			
		A(2585)	10	52	h	P	1/	nn	C	***			
		/ (2000)		JC			V		3	***			

								32C(3120)~		***			

	LIGHT UNF	-LAVORED		STRAN	IGE	CHARMED, S	STRANGE	CC continued		
	$P(f^{C})$	= B = 0)	$f^{c}(f^{C})$	$(S = \pm 1, C =$	=B=0) $I(f^2)$	(C = S =	(<i>f</i>)	• vb(3770)	$P(J^{-})$	
• π^{\pm}	1-(0-)	 π₂(1670) 	1-(2-+)	• K [±]	1/2(0-)	• D_{s}^{\pm}	0(0 ⁻)	 ψ(3110) ψ₂(3823) 	$0^{-}(2^{-})$	
• π^0	$1^{-}(0^{-+})$	 φ(1680) 	0-(1)	• K ⁰	$1/2(0^{-})$	• D_{S}^{*\pm}	0(? [?])	 ψ₃(3842) 	0-(3)	
• η ε (Εοο)	$0^+(0^{-+})$	 ρ₃(1690) (1700) 	$1^+(3^-)$	• K ⁰ _S	1/2(0-)	• $D_{s0}^*(2317)^{\pm}$	0(0+)	$\chi_{c0}(3860)$	$0^+(0^{++})$	
• 70(500)	$1^{+}(1^{-})$	• $\rho(1700)$	$1^{-}(2^{+}+)$	• K ^o _L	1/2(0)	• $D_{s1}(2460)^{\pm}$	$0(1^+)$	• X (3900)	1+(1+-)	
• ω(782)	$0^{-}(1^{-})$	• fo(1710)	$0^{+}(0^{+})$	• K*(892)	$\frac{1}{2}(0^{-1})$	$D_{51}(2536)^{-1}$	$0(1^{+})$ $0(2^{+})$	• X(3915)	$0^{+}(0/2^{+}+)$	
 η'(958) 	$0^{+}(0^{-}+)$	η(1760)	$0^{+}(0^{-}+)$	• $K_1(1270)$	$1/2(1^+)$	$D_{s2}(2373)^{\pm}$	$0(2^{-})$	• χ _{c2} (3930)	$0^{+}(2^{++})$	
• f ₀ (980)	0+(0++)	 π(1800) 	$1^{-}(0^{-+})$	• K1(1400)	1/2(1+)	$D_{s1}^{*}(2860)^{\pm}$	$0(1^{-})$	X(3940)	?!(?!!)	
• a ₀ (980)	$1^{-}(0^{++})$	$f_2(1810)$	$0^+(2^{++})$	• K*(1410)	1/2(1-)	D*3(2860)±	0(3-)	• X(4020) [±]	$1^+(?^{!-})$	
• $\phi(1020)$	$0^{-}(1^{+})$	X(1835)	(0^{-+})	• K ₀ (1430)	1/2(0+)	$D_{sJ}(3040)^{\pm}$	0(? [?])	• ψ(4040) ×(4050)±	0(1) $1^{-}(2^{2+})$	
• h(1235)	$1^{+}(1^{+})$	• φ ₃ (1000)	0(3)	• K ₂ (1430)	1/2(2 ⁺)	BOTT	ЭM	$\chi(4050)^{\pm}$	$1^{+}(7^{?}-)$	
• a1(1260)	$1^{-}(1^{++})$	 π₂(1010) π₂(1880) 	$1^{-}(2^{-+})$	K(1460) K-(1580)	$\frac{1}{2}(0)$ $\frac{1}{2}(2^{-})$	(B = ±	=1)	$X(4100)^{\pm}$	1-(???)	
• f ₂ (1270)	$0^{+}(2^{+}+)$	ρ(1900)	1+(1)	K(1630)	$1/2(2^{\circ})$ $1/2(?^{\circ})$	• B [±]	$1/2(0^{-})$	• χ _{c1} (4140)	$0^{+(1^{++})}$	
 f₁(1285) 	$0^+(1^{++})$	$f_2(1910)$	0+(2++)	$K_1(1650)$	$1/2(1^+)$	• B ⁰	1/2(0-)	 ψ(4160) 	$0^{-}(1^{-})$	
 η(1295) 	$0^+(0^{-+})$	$a_0(1950)$	$1^{-}(0^{++})$	• K*(1680)	$1/2(1^{-})$	 B[±]/B⁰ ADN 	IIXTURE	X(4160)	?:(?::)	
$\bullet \pi(1300)$	$1^{-}(0^{-+})$ $1^{-}(2^{++})$	• $t_2(1950)$	$0^+(2^++)$ $1^-(a^++)$	• K ₂ (1770)	1/2(2-)		b-baryon	$Z_{c}(4200)$	1'(1') $0^{-}(1^{-})$	
• a2(1320) • fe(1370)	$1^{(2+1)}$	• a4(1970)	$1 (4 \cdot \cdot)$ 1 + (3)	• $K_3(1780)$	1/2(3-)	V_{cb} and V_{ub}	CKM Ma-	€ φ(4230) R-o(4240)	$1^{+}(0^{-})$	
 π1(1400) 	$1^{-}(1^{-+})$	$\pi_2(2005)$	$1^{-}(2^{-}+)$	• K ₂ (1820)	$1/2(2^{-})$ $1/2(0^{-})$	trix Elements	1/0(1-)	X(4250) [±]	1-(??+)	
 η(1405) 	0+(0-+)	• f2(2010)	$0^{+}(2^{+}+)$	K*(1950)	$\frac{1}{2}(0^{+})$	• D • B: (5721)+	$\frac{1}{2}(1)$ $\frac{1}{2}(1+)$	$\psi(4260)$	$0^{-(1^{-1})}$	
 h₁(1415) 	0-(1+-)	f ₀ (2020)	0+(0++)	$K_{5}(1980)$	$1/2(2^+)$	• B ₁ (5721) ⁰	$1/2(1^+)$	• χ _{c1} (4274)	$0^+(1^{++})$	
$a_1(1420)$	$1^{-}(1^{++})$	• f ₄ (2050)	$0^+(4^{++})$	 K₄(2045) 	1/2(4+)	B*(5732)	?(??)	X(4350)	$0^+(?^{+})$	
$\bullet t_1(1420)$	0'(1'')	$\pi_2(2100)$	$1^{-}(2^{-+})$	$K_2(2250)$	$1/2(2^{-})$	• B [*] ₂ (5747) ⁺	1/2(2+)	 ψ(4360) ψ(4200) 	0(1)	
• ω(1420) fs(1430)	0(1) $0^+(2^{++})$	f ₀ (2100) f ₀ (2150)	$0^+(2^{++})$	K ₃ (2320)	1/2(3 ⁺)	 ■ B[*]₂(5747)⁰ 	1/2(2+)	 ψ(4350) ψ(4415) 	$0^{-}(1^{-})$	
• a (1450)	$1^{-}(0^{++})$	o(2150)	1+(1)	$K_{5}^{*}(2380)$	1/2(5-)	B _J (5840) ⁺	1/2(?!)	• Z _c (4430)	$1^{+}(1^{+}-)$	
 ρ(1450) 	1+(1)	 φ(2170) 	$0^{-(1)}$	K4(2500)	1/2(4)	B _J (5840) ⁹	1/2(?*)	χ _{c0} (4500)	$0^{+}(0^{+}+)$	
 η(1475) 	0+(0-+)	f ₀ (2200)	0+(0++)	N(3100)	i.(i)	• B ₂ (5970) ⁰	$\frac{1}{2}(?)$ $\frac{1}{2}(?)$	 ψ(4660) 	0-(1)	
• f ₀ (1500)	$0^+(0^{++})$	f_(2220)	0+(2++	CHARM	/ED	• 0,(3510)	1/2(.)	χ _{c0} (4700)	0+(0++)	
$f_1(1510)$	0'(1') 0+(2++)	(222E)	$or 4^{++})$	(C = ±	=1)	BOTTOM, S	TRANGE	b	b	
$f_2(1525)$ $f_6(1565)$	$0^{+}(2^{++})$	n(2223)	$1^{+}(3^{-})$	• D [±]	$1/2(0^{-})$	(B = ±1, 5	0(0-)	(+ possibly n	on-q q states)	
ρ(1570)	$1^{+}(1^{-})$	• f_(2300)	$0^+(2^{++})$	• D*(2007) ⁰	$\frac{1/2(0^{-})}{1/2(1^{-})}$	• B ^o _S	$0(0^{-})$	 η_b(1S) 	0+(0 - +)	
h1(1595)	$0^{-}(1^{+})$	f ₄ (2300)	$0^{+}(4^{+}+)$	 D[*](2010)[±] 	$1/2(1^{-})$	$(5568)^{\pm}$	7(7?)	• T(15)	0-(1)	
 π₁(1600) 	$1^{-}(1^{-+})$	f ₀ (2330)	0+(0++)	 D₀[*](2300)⁰ 	1/2(0+)	• Be1(5830)0	$0(1^+)$	• $\chi_{b0}(1P)$	$0^+(0^{++})$	
• <i>a</i> ₁ (1640)	$1^{-}(1^{++})$	• f ₂ (2340)	0+(2++)	$D_0^*(2300)^{\pm}$	1/2(0+)	 B[*]₅₂(5840)⁰ 	0(2+)	• $\chi_{b1}(1P)$	$0^+(1^+)$	
$t_2(1640)$	$0^+(2^{++})$	(And And	$1^+(5^{})$	 D₁(2420)⁰ 	$1/2(1^+)$	$B_{sJ}^{*}(5850)$?(??)	• II _b (1P)	0(1 + 1) 0+(2 + +)	
• 1/2(1045) • ((1650)	0-(1-		10)	$D_1(2420)^{\pm}$	1/2(?!)	BOTTOM C	HARMED	$\eta_{b}(2S)$	$0^{+}(0^{-}+)$	
• ω ₃ (1670)	0-(3			D1(2430) ⁰	$\frac{1}{2(1^+)}$	(B = C =	: ±1)	• T(25)	$0^{-(1^{-})}$	
5()	· ·			$D_2(2400)^{\pm}$	$\frac{1}{2(2^+)}$	• B_c^+	$0(0^{-})$	• $\gamma_2(1D)$	0-(2)	
				D(2550) ⁰	$\frac{1}{2(7?)}$	$B_c(2S)^{\pm}$	0(0-)	• $\chi_{b0}(2P)$	$0^+(0^{++})$	
				$D_{1}^{*}(2600)$	$1/2(?^{?})$	Ē		• $\chi_{b1}(2P)$	$0^+(1^+)$	
				D*(2640) [±]	$1/2(?^{?})$	(+ possibly non	$-q\overline{q}$ states)	116(2F)	$0^{+}(2^{++})$	
		1000		D(2740) ⁰	1/2(?')	• nc(15)	$(+ - 0)^+$	• T(35)	$0^{-}(1^{-})$	
				D ₃ (2750)	1/2(3)	 J/ψ(1S) 	0-(1)́	• χ _{b1} (3P)	$0^{+(1^{++)}}$	
				D(3000) ⁰	1/2(?`)	• χ _{c0} (1P)	$0^{+}(0^{+}+)$	• χ _{b2} (3P)	0+(2++)	
						• $\chi_{c1}(1P)$	$0^+(1^{++})$	• T(4S)	$0^{-}(1^{-})$	
^	^				-	• $h_c(1P)$	$0^{+}(2^{++})$	• $Z_b(10610)$ • $Z_c(10650)$	$1^+(1^+)$ $1^+(1^+)$	
	UM		es	On	S	$\chi_{\mathcal{Q}}(1P)$ $n_{\mathcal{Q}}(2S)$	$n^{+}(0^{-}+)$	$\gamma(10753)$	7?(1)	
					$\mathbf{}$	• \u03cb(25)	$0^{-}(1^{-})$	• T(10860)	0-(1)	
						, ()	()	 <i>γ</i>(11020) 	0-(1)	

Most of hadrons are unstable (above two-hadron threshold)

Relation to unstable nuclei

Stable nuclei (~300), unstable nuclei (~2000)



https://www.nishina.riken.jp/enjoy/kakuzu/index.html

Structure of unstable nuclei

- clustering, halo nuclei, Efimov effect, ...

Pole of resonances

Signals of a resonance



Well-defined characterization : pole of scattering amplitude

T. Hyodo, M. Niiyama, arXiv: 2010.07592 [hep-ph], to appear in PPNP



Theoretical analysis to pin down the pole position

QCD calculation

Lattice QCD (effective mass method)

G.P. Engel et al. (BGR), Phys. Rev. D87, 074504 (2013)

before $V \to \infty$

Φ

ΝΔΛΣΞΩ



1.0

0.5

ΝΔΛΣΞΩ

- ground states : OK
- excited states : noisy
- Scattering calculations are awaited.

1.5

1.0

0.5

Contents

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$S = -1: \Lambda(1405)/\Lambda(1380)$

$\Lambda(1405)$ and $\bar{K}N$ scattering

$\Lambda(1405)$ does not fit in standard picture —> exotic candidate

N. Isgur and G. Karl, Phys. Rev. D18, 4187 (1978)



energy

 $\Lambda(1405)$

 $\pi\Sigma$ threshold

$S = -1: \Lambda(1405)/\Lambda(1380)$

Strategy for *kN* interaction

Above the $\bar{K}N$ threshold : direct constraints

- *K*⁻*p* total cross sections (old data)
- *KN* threshold branching ratios (old data)
- *K*⁻*p* scattering length (new data : SIDDHARTA)

Below the $\bar{K}N$ threshold: indirect constraints

- $\pi\Sigma$ mass spectra (new data : LEPS, CLAS, HADES, ...)



$S = -1 : \Lambda(14\underline{05})/\Lambda(1380)$

Construction of the realistic amplitude

Chiral SU(3) coupled-channels $(\bar{K}N, \pi\Sigma, \pi\Lambda, \eta\Lambda, \eta\Sigma, K\Xi)$ approach

Y. Ikeda, T. Hyodo, W. Weise, PLB 706, 63 (2011); NPA 881 98 (2012)



$S=-1:\Lambda(1405)/\Lambda(1380)$

Best-fit results

		$_{\mathrm{TW}}$	TWB	NLO	Experiment	
st	$\Delta E \ [eV]$	373	377	306	$283 \pm 36 \pm 6$	[10]
Ő	$\Gamma \ [eV]$	495	514	591	$541\pm89\pm22$	[10]
	γ	2.36	2.36	2.37	2.36 ± 0.04	[11]
a	R_n	0.20	0.19	0.19	0.189 ± 0.015	[11]
X	R_c	0.66	0.66	0.66	0.664 ± 0.011	[11]
	$\chi^2/{ m d.o.f}$	1.12	1.15	0.96		

SIDDHARTA

Branching ratios



Accurate description of all existing data ($\chi^2/d.o.f \sim 1$)

14

$S = -1 : \Lambda(1405) / \Lambda(1380)$

Comparison with SIDDHARTA

	тw	TWB	NLO
χ² /d.o.f.	1.12	1.15	0.957



TW and TWB are reasonable, while best-fit requires NLO.

$S = -1: \Lambda(1405)/\Lambda(1380)$

Subthreshold extrapolation

Uncertainty of $\bar{K}N \rightarrow \bar{K}N(I=0)$ amplitude below threshold



Y. Kamiya, K. Miyahara, S. Ohnishi, Y. Ikeda, T. Hyodo, E. Oset, W. Weise, NPA 954, 41 (2016)

- c.f. without SIDDHARTA

R. Nissler, Doctoral Thesis (2007)





$S = -1: \underline{\Lambda(1405)}/\underline{\Lambda(1380)}$

Extrapolation to complex energy: two poles

Two poles : superposition of two eigenstates

J.A. Oller, U.G. Meißner, PLB 500, 263 (2001);
D. Jido, J.A. Oller, E. Oset, A. Ramos, U.G. Meißner, NPA 723, 205 (2003);
U.G. Meißner, Symmetry 12, 981 (2020); M. Mai, arXiv: 2010.00056 [nucl-th];
T. Hyodo, M. Niiyama, arXiv: 2010.07592 [hep-ph], to appear in PPNP



T. Hyodo, D. Jido, Prog. Part. Nucl. Phys. 67, 55 (2012)

NLO analysis confirms the two-pole structure.

PDG has changed

2020 update of PDG

P.A. Zyla, et al., PTEP 2020, 083C01 (2020); http://pdg.lbl.gov/



T. Hyodo, M. Niiyama, arXiv: 2010.07592 [hep-ph], to appear in PPNP

- "Λ(1405)" is no longer at 1405 MeV but ~ 1420 MeV.
- Lower pole: two-star resonance $\Lambda(1380)$

$S = -1 : \Lambda(1405) / \underline{\Lambda(1380)}$

New data : *K*⁻*p* **correlation function**

K⁻*p* total cross sections

<u>Y. Ikeda, T. Hyodo, W. Weise, PLB 706, 63 (2011)</u>

- Old bubble chamber data

K⁻p correlation function

ALICE collaboration, PRL 124, 092301 (2020)





- Excellent precision ($\bar{K}^0 n$ cusp)
- Low-energy data below $\bar{K}^0 n$
- -> important constraint on $\Lambda(1405)$ theories



Coulomb Coulomb+Strong (Kyoto Model) $0.7 < S_T < 1$

$S = -1 : \Lambda(1405)/\Lambda(1380)$

Prediction from chiral SU(3) dynamics

the see

Theoretical calculation of C(q)

- wave function $\Psi_{\mathbf{q}}^{(-)}(\mathbf{r})$: coupled-channel $\bar{K}N$ - $\pi\Sigma$ - $\pi\Lambda$ potential K. Miyahara. T. Hyodo, W. Weise, PRC98, 025201 (2018)
- source function $S(\mathbf{r})$: determined by K^+p data



<u>Y. Kamiya, T. Hyodo, K. Morita, A. Ohnishi, W. Weise. PRL124, 132501 (2020)</u> Correlation function is well reproduced.

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S = -2, -3 baryon spectrum

- **Baryon spectrum with** S = -2, -3
 - not well explored
 - (difficulty in fixed target experiments)
 - Flavor SU(3) symmetry?
 - $N_{\Xi} \sim N_N + N_{\Delta}$
 - $N_{\Omega} \sim N_{\Delta}$
 - J^P determined only for a few states



-> New data (heavy hadron decays at Belle, LHCb, BES,...) 22

New data for Ξ resonances

$\Xi_c \rightarrow \pi \pi \Xi$ decay at Belle

M. Sumihama, et al. (Belle), PRL 122, 072501 (2019)

- clear peaks of Ξ(1620) and Ξ(1690)
- Breit-Wigner fit

 $M_{\Xi(1620)} = 1610 \pm 6.0^{+6.1}_{-4.2} \text{ MeV}$ $\Gamma_{\Xi(1620)} = 59.9 \pm 4.8^{+2.8}_{-7.1} \text{ MeV}$

- not seen in the sideband (non- Ξ_c) events



Effect of thresholds? $\bar{K}\Lambda \sim 1612 \text{ MeV}, \bar{K}\Sigma \sim 1689 \text{ MeV}$

Theoretical analysis

Theoretical study of $\Xi_c \rightarrow \pi \pi \Xi$ **decay (before experiment)**

K. Miyahara, T. Hyodo, M. Oka, J. Nieves, E. Oset. PRC95, 035212 (2017)

- spectrum near $\bar{K}\Sigma$ threshold



- even without resonance, peak like structure appears

Update of meson-baryon amplitude with Belle data

New Ω resonance

- $\bar{K}\Xi$ spectra in $\Upsilon(nS)$ decays at Belle
 - J. Yelton, et al. (Belle), PRL 121, 052003 (2018)
 - clear peak of $\Omega(2012)$
 - Breit-Wigner fit

 $M_{\Omega(2012)} = 2012.4 \pm 0.7 \pm 0.6 \text{ MeV}$ $\Gamma_{\Omega(2012)} = 6.4^{+2.5}_{-2.0} \pm 1.6 \text{ MeV}$

- *K*Ξ(1530) **molecule?** M.P. Valderrama, PRD 98, 054009 (2018), ...
- not seen in $\Omega(2012) \to \overline{K}\Xi(1530) \to \overline{K}\pi\Xi$ S. Jia, *et al.* (Belle), PRD 100, 032006 (2019)
- upper limit is compatible with \overline{K} Ξ (1530) molecule J.X. Lu, *et al.*, EPJC 80, 361 (2020), ...
- **Discussion is ongoing...**



Summary

Summary

Strange baryons : complicated but interesting! T. Hyodo, M. Niiyama, arXiv: 2010.07592 [hep-ph], to appear in PPNP; P.A. Zyla, et al. (Particle Data Group), PTEP 2020, 083C01 (2020) Pole structure of the $\Lambda(1405)$ region is now well constrained by the experimental data. " $\Lambda(1405)$ " —> $\Lambda(1405)$ and $\Lambda(1380)$ Y. Ikeda, T. Hyodo, W. Weise, PLB 706, 63 (2011); NPA 881, 98 (2012); Y. Kamiya, T. Hyodo, K. Morita, A. Ohnishi, W. Weise. PRL124, 132501 (2020) Spectroscopy of S = -2, -3 sectors are stimulated by the new data of heavy hadron

decays. Theoretical investigation is needed.

K. Miyahara, T. Hyodo, M. Oka, J. Nieves, E. Oset. PRC95, 035212 (2017)