Strong decays of doubly charmed baryons and higer charmonium states in $^3P_0$ model

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Outline

- hadron spectroscopy
- $^3p_0$ model
  - doubly charmed baryons
  - charmonium states
- summary and outlook

Hadron spectroscopy: we know 6 quarks & 6 leptons

FERMIONS

matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin =1/2

Flavor	Mass GeV/c^2	Electric charge
ν_L lightest neutrino*	$(0-0.13)\times10^{-9}$	0
e electron	0.000511	–1
ν_M middle neutrino*	$(0.009-0.13)\times10^{-9}$	0
μ muon	0.106	–1
ν_H heaviest neutrino*	$(0.04-0.14)\times10^{-9}$	0
τ tau	1.777	–1

Quarks spin =1/2

Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.002	2/3
d down	0.005	–1/3
c charm	1.3	2/3
s strange	0.1	–1/3
t top	173	2/3
b bottom	4.2	–1/3

We know four types of interactions

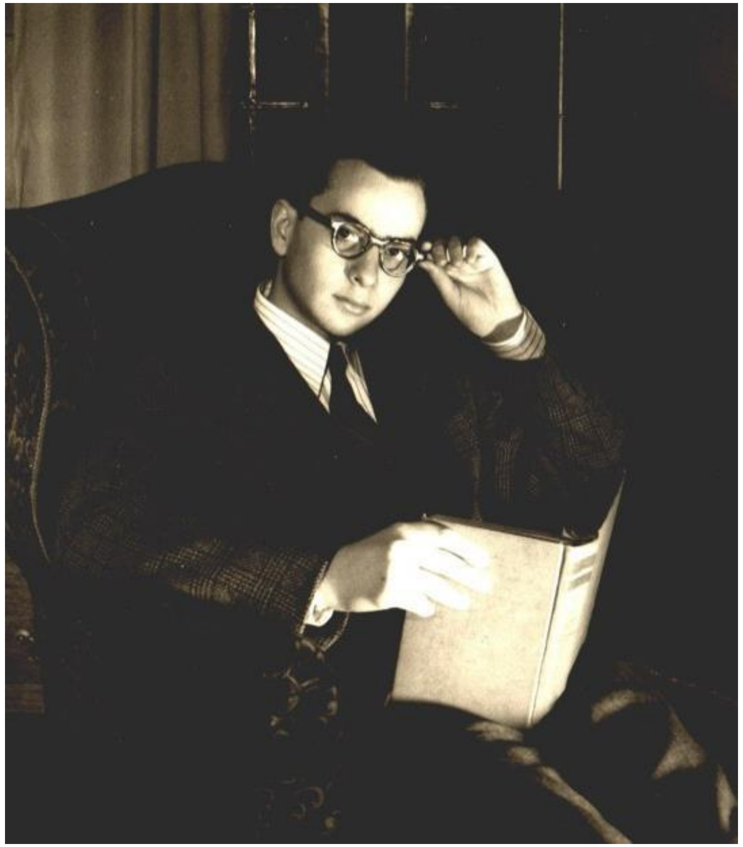
Properties of the Interactions

The strengths of the interactions (forces) are shown relative to the strength of the electromagnetic force for two u quarks separated by the specified distances.

Property	Gravitational Interaction	Weak Interaction (Electroweak)	Electromagnetic Interaction	Strong Interaction
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge
Particles experiencing:	All	Quarks, Leptons	Electrically Charged	Quarks, Gluons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons
Strength at 10^{-18} m	10^{-41}	0.8	1	25
Strength at 3×10^{-17} m	10^{-41}	10^{-4}	1	60

- Gravity is responsible for the structure of the Universe
- Electromagnetic interaction → the molecules and atoms
- Weak interaction → the stars shine
- Strong interaction → the structure of the nuclei, nucleons, hadronic matters from the building blocks ---quarks! but HOW?

We know quark pair makes mesons and three quarks makes baryons



M. Gell-Mann

A simpler and more elegant scheme can be constructed if we allow non-integral values for the charges. We can dispense entirely with the basic baryon b if we assign to the triplet t the following properties: spin $\frac{1}{2}$, $z = -\frac{1}{3}$, and baryon number $\frac{1}{3}$. We then refer to the members $u^{\frac{2}{3}}$, $d^{-\frac{1}{3}}$, and $s^{-\frac{1}{3}}$ of the triplet as "quarks" [6] q and the members of the anti-triplet as anti-quarks $\bar{q}$. Baryons can now be constructed from quarks by using the combinations $(q\,q\,q)$, $(q\,q\,q\,q\,\bar{q})$, etc., while mesons are made out of $(q\,\bar{q})$, $(q\,q\,\bar{q}\,\bar{q})$, etc. It is assuming that the lowest baryon configuration $(q\,q\,q)$ gives just the representations **1**, **8**, and **10** that have been observed, while the lowest meson configuration $(q\,\bar{q})$ similarly gives just **1** and **8**.

Published in Physics Letters 8, 214 (1964);
Similar idea by G. Zweig, CERN-TH-401 (1964).

What did we observe?

Meson Summary Table

See also the table of suggested $q\bar{q}$ 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 UNFLAVORED ($S = C = B = 0$)

	$I^G(J^{PC})$
• $\pi^\pm$	$1^-(0^-)$
• π^0	$1^-(0^{-+})$
• η	$0^+(0^{-+})$
• $f_0(500)$	$0^+(0^{++})$
• $\rho(770)$	$1^+(1^{--})$
• $\omega(782)$	$0^-(1^{--})$
• $\eta'(958)$	$0^+(0^{-+})$
• $f_0(980)$	$0^+(0^{++})$
• $a_0(980)$	$1^-(0^{++})$
• $\phi(1020)$	$0^-(1^{--})$
• $h_1(1170)$	$0^-(1^{+-})$
• $b_1(1235)$	$1^+(1^{+-})$
• $a_1(1260)$	$1^-(1^{++})$
• $f_2(1270)$	$0^+(2^{++})$
• $f_1(1285)$	$0^+(1^{++})$
• $\eta(1295)$	$0^+(0^{-+})$
• $\pi(1300)$	$1^-(0^{-+})$
• $a_2(1320)$	$1^-(2^{++})$
• $f_0(1370)$	$0^+(0^{++})$
$h_1(1380)$	$?^-(1^{+-})$
• $\pi_1(1400)$	$1^-(1^{-+})$
• $\eta(1405)$	$0^+(0^{-+})$
$a_1(1420)$	$1^-(1^{++})$
• $f_1(1420)$	$0^+(1^{++})$
• $\omega(1420)$	$0^-(1^{--})$
$f_2(1430)$	$0^+(2^{++})$
• $a_0(1450)$	$1^-(0^{++})$
• $\rho(1450)$	$1^+(1^{--})$
• $\eta(1475)$	$0^+(0^{-+})$
• $f_0(1500)$	$0^+(0^{++})$
$f_1(1510)$	$0^+(1^{++})$
• $f'_2(1525)$	$0^+(2^{++})$
$f_2(1565)$	$0^+(2^{++})$
$\rho(1570)$	$1^+(1^{--})$
$h_1(1595)$	$0^-(1^{+-})$
• $\pi_1(1600)$	$1^-(1^{-+})$
$a_1(1640)$	$1^-(1^{++})$
$f_2(1640)$	$0^+(2^{++})$
• $\eta_2(1645)$	$0^+(2^{-+})$
• $\omega(1650)$	$0^-(1^{--})$
• $\omega_3(1670)$	$0^-(3^{--})$
• $\pi_2(1670)$	$1^-(2^{-+})$
• $\phi(1680)$	$0^-(1^{--})$
• $\rho_3(1690)$	$1^+(3^{--})$
• $\rho(1700)$	$1^+(1^{--})$
$a_2(1700)$	$1^-(2^{++})$
• $f_0(1710)$	$0^+(0^{++})$
$\eta(1760)$	$0^+(0^{-+})$
• $\pi(1800)$	$1^-(0^{-+})$
$f_2(1810)$	$0^+(2^{++})$
$X(1835)$	$?^?(0^{-+})$
$X(1840)$	$?^?(?^{??})$
• $\phi_3(1850)$	$0^-(3^{--})$
$\eta_2(1870)$	$0^+(2^{-+})$
• $\pi_2(1880)$	$1^-(2^{-+})$
$\rho(1900)$	$1^+(1^{--})$
$f_2(1910)$	$0^+(2^{++})$
$a_0(1950)$	$1^-(0^{++})$
• $f_2(1950)$	$0^+(2^{++})$
$\rho_3(1990)$	$1^+(3^{--})$
• $f_2(2010)$	$0^+(2^{++})$
$f_0(2020)$	$0^+(0^{++})$
• $a_4(2040)$	$1^-(4^{++})$
• $f_4(2050)$	$0^+(4^{++})$
$\pi_2(2100)$	$1^-(2^{-+})$
$f_0(2100)$	$0^+(0^{++})$
$f_2(2150)$	$0^+(2^{++})$
$\rho(2150)$	$1^+(1^{--})$
• $\phi(2170)$	$0^-(1^{--})$
$f_0(2200)$	$0^+(0^{++})$
$f_J(2220)$	$0^+(2^{++}$ or $4^{++})$
$\eta(2225)$	$0^+(0^{-+})$
$\rho_3(2250)$	$1^+(3^{--})$
• $f_2(2300)$	$0^+(2^{++})$
$f_4(2300)$	$0^+(4^{++})$
$f_0(2330)$	$0^+(0^{++})$
• $f_2(2340)$	$0^+(2^{++})$
$\rho_5(2350)$	$1^+(5^{--})$
$a_6(2450)$	$1^-(6^{++})$
$f_6(2510)$	$0^+(6^{++})$

OTHER LIGHT

Further States

STRANGE ($S = \pm1$, $C = B = 0$)

	$I(J^P)$
• $K^\pm$	$1/2(0^-)$
• K^0	$1/2(0^-)$
• K^0_S	$1/2(0^-)$
• K^0_L	$1/2(0^-)$
• $K^*_0(700)$	$1/2(0^+)$
• $K^*(892)$	$1/2(1^-)$
• $K_1(1270)$	$1/2(1^+)$
• $K_1(1400)$	$1/2(1^+)$
• $K^*(1410)$	$1/2(1^-)$
• $K^*_0(1430)$	$1/2(0^+)$
• $K^*_2(1430)$	$1/2(2^+)$
$K(1460)$	$1/2(0^-)$
$K_2(1580)$	$1/2(2^-)$
$K(1630)$	$1/2(?^?)$
$K_1(1650)$	$1/2(1^+)$
• $K^*(1680)$	$1/2(1^-)$
• $K_2(1770)$	$1/2(2^-)$
• $K^*_3(1780)$	$1/2(3^-)$
• $K_2(1820)$	$1/2(2^-)$
$K(1830)$	$1/2(0^-)$
$K^*_0(1950)$	$1/2(0^+)$
$K^*_2(1980)$	$1/2(2^+)$
• $K^*_4(2045)$	$1/2(4^+)$
$K_2(2250)$	$1/2(2^-)$
$K_3(2320)$	$1/2(3^+)$
$K^*_5(2380)$	$1/2(5^-)$
$K_4(2500)$	$1/2(4^-)$
$K(3100)$	$?^?(?^{??})$

CHARMED ($C = \pm1$)

	$I(J^P)$
• $D^\pm$	$1/2(0^-)$
• D^0	$1/2(0^-)$
• $D^*(2007)^0$	$1/2(1^-)$
• $D^*(2010)^\pm$	$1/2(1^-)$
• $D^*_0(2400)^0$	$1/2(0^+)$
$D^*_0(2400)^\pm$	$1/2(0^+)$
• $D_1(2420)^0$	$1/2(1^+)$
$D_1(2420)^\pm$	$1/2(?^?)$
$D_1(2430)^0$	$1/2(1^+)$
• $D^*_2(2460)^0$	$1/2(2^+)$
• $D^*_2(2460)^\pm$	$1/2(2^+)$
$D(2550)^0$	$1/2(?^?)$
$D^*_J(2600)$	$1/2(?^?)$
$D^*(2640)^\pm$	$1/2(?^?)$
$D(2740)^0$	$1/2(?^?)$
$D^*_3(2750)$	$1/2(3^-)$
$D(3000)^0$	$1/2(?^?)$

CHARMED, STRANGE ($C = S = \pm1$)

	$I(J^P)$
• $D^\pm_s$	$0(0^-)$
• $D^{*\pm}_s$	$0(?^?)$
• $D^*_{s0}(2317)^\pm$	$0(0^+)$
• $D_{s1}(2460)^\pm$	$0(1^+)$
• $D_{s1}(2536)^\pm$	$0(1^+)$
• $D^*_{s2}(2573)$	$0(2^+)$
• $D^*_{s1}(2700)^\pm$	$0(1^-)$
$D^*_{s1}(2860)^\pm$	$0(1^-)$
$D^*_{s3}(2860)^\pm$	$0(3^-)$
$D_{sJ}(3040)^\pm$	$0(?^?)$

BOTTOM ($B = \pm1$)

	$I(J^P)$
• $B^\pm$	$1/2(0^-)$
• 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^*	$1/2(1^-)$
• $B_1(5721)^+$	$1/2(1^+)$
• $B_1(5721)^0$	$1/2(1^+)$
$B^*_J(5732)$	$?(?^?)$
• $B^*_2(5747)^+$	$1/2(2^+)$
• $B^*_2(5747)^0$	$1/2(2^+)$
$B_J(5840)^+$	$1/2(?^?)$
$B_J(5840)^0$	$1/2(?^?)$
• $B_J(5970)^+$	$1/2(?^?)$
• $B_J(5970)^0$	$1/2(?^?)$

BOTTOM, STRANGE ($B = \pm1$, $S = \mp1$)

	$I(J^P)$
• B^0_s	$0(0^-)$
• B^*_s	$0(1^-)$
$X(5568)^\pm$	$?(?^?)$
• $B_{s1}(5830)^0$	$0(1^+)$
• $B^*_{s2}(5840)^0$	$0(2^+)$
$B^*_{sJ}(5850)$	$?(?^?)$

BOTTOM, CHARMED ($B = C = \pm1$)

	$I(J^P)$
• B^+_c	$0(0^-)$
$B_c(2S)^\pm$	$0(0^-)$

$c\bar{c}$

	$I^G(J^{PC})$
• $\eta_c(1S)$	$0^+(0^{-+})$
• $J/\psi(1S)$	$0^-(1^{--})$
• $\chi_{c0}(1P)$	$0^+(0^{++})$
• $\chi_{c1}(1P)$	$0^+(1^{++})$
• $h_c(1P)$	$?^?(1^{+-})$
• $\chi_{c2}(1P)$	$0^+(2^{++})$
• $\eta_c(2S)$	$0^+(0^{-+})$
• $\psi(2S)$	$0^-(1^{--})$
• $\psi(3770)$	$0^-(1^{--})$
• $\psi_2(3823)$	$0^-(2^{--})$
$\chi_{c0}(3860)$	$0^+(0^{++})$
• $\chi_{c1}(3872)$	$0^+(1^{++})$
• $Z_c(3900)$	$1^+(1^{+-})$
• $X(3915)$	$0^+(0/2^{++})$
• $\chi_{c2}(3930)$	$0^+(2^{++})$
$X(3940)$	$?^?(?^{??})$
• $X(4020)$	$1^+(?^{?-})$
• $\psi(4040)$	$0^-(1^{--})$
$X(4050)^\pm$	$1^-(?^{?+})$
$X(4055)^\pm$	$1^+(?^{?-})$
• $\chi_{c1}(4140)$	$0^+(1^{++})$
• $\psi(4160)$	$0^-(1^{--})$
$X(4160)$	$?^?(?^{??})$
$Z_c(4200)$	$1^+(1^{+-})$
$\psi(4230)$	$0^-(1^{--})$
$R_{c0}(4240)$	$1^+(0^{--})$
$X(4250)^\pm$	$1^-(?^{?+})$
• $\psi(4260)$	$0^-(1^{--})$
• $\chi_{c1}(4274)$	$0^+(1^{++})$
$X(4350)$	$0^+(?^{?+})$
• $\psi(4360)$	$0^-(1^{--})$
$\psi(4390)$	$0^-(1^{--})$
• $\psi(4415)$	$0^-(1^{--})$
• $Z_c(4430)$	$1^+(1^{+-})$
$\chi_{c0}(4500)$	$0^+(0^{++})$
• $\psi(4660)$	$0^-(1^{--})$
$\chi_{c0}(4700)$	$0^+(0^{++})$

$b\bar{b}$

	$I^G(J^{PC})$
• $\eta_b(1S)$	$0^+(0^{-+})$
• $\Upsilon(1S)$	$0^-(1^{--})$
• $\chi_{b0}(1P)$	$0^+(0^{++})$
• $\chi_{b1}(1P)$	$0^+(1^{++})$
• $h_b(1P)$	$?^?(1^{+-})$
• $\chi_{b2}(1P)$	$0^+(2^{++})$
$\eta_b(2S)$	$0^+(0^{-+})$
• $\Upsilon(2S)$	$0^-(1^{--})$
• $\Upsilon_2(1D)$	$0^-(2^{--})$
• $\chi_{b0}(2P)$	$0^+(0^{++})$
• $\chi_{b1}(2P)$	$0^+(1^{++})$
$h_b(2P)$	$?^?(1^{+-})$
• $\chi_{b2}(2P)$	$0^+(2^{++})$
• $\Upsilon(3S)$	$0^-(1^{--})$
• $\chi_{b1}(3P)$	$0^+(1^{++})$
• $\Upsilon(4S)$	$0^-(1^{--})$
• $Z_b(10610)$	$1^+(1^{+-})$
$Z_b(10650)$	$1^+(1^{+-})$
• $\Upsilon(10860)$	$0^-(1^{--})$
• $\Upsilon(11020)$	$0^-(1^{--})$

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.

p	$1/2^+$	****
n	$1/2^+$	****
$N(1440)$	$1/2^+$	****
$N(1520)$	$3/2^-$	****
$N(1535)$	$1/2^-$	****
$N(1650)$	$1/2^-$	****
$N(1675)$	$5/2^-$	****
$N(1680)$	$5/2^+$	****
$N(1700)$	$3/2^-$	***
$N(1710)$	$1/2^+$	****
$N(1720)$	$3/2^+$	****
$N(1860)$	$5/2^+$	**
$N(1875)$	$3/2^-$	***
$N(1880)$	$1/2^+$	***
$N(1895)$	$1/2^-$	****
$N(1900)$	$3/2^+$	****
$N(1990)$	$7/2^+$	**
$N(2000)$	$5/2^+$	**
$N(2040)$	$3/2^+$	*
$N(2060)$	$5/2^-$	***
$N(2100)$	$1/2^+$	***
$N(2120)$	$3/2^-$	***
$N(2190)$	$7/2^-$	****
$N(2220)$	$9/2^+$	****
$N(2250)$	$9/2^-$	****
$N(2300)$	$1/2^+$	**
$N(2570)$	$5/2^-$	**
$N(2600)$	$11/2^-$	***
$N(2700)$	$13/2^+$	**

$\Delta(1232)$	$3/2^+$	****
$\Delta(1600)$	$3/2^+$	****
$\Delta(1620)$	$1/2^-$	****
$\Delta(1700)$	$3/2^-$	****
$\Delta(1750)$	$1/2^+$	*
$\Delta(1900)$	$1/2^-$	***
$\Delta(1905)$	$5/2^+$	****
$\Delta(1910)$	$1/2^+$	****
$\Delta(1920)$	$3/2^+$	***
$\Delta(1930)$	$5/2^-$	***
$\Delta(1940)$	$3/2^-$	**
$\Delta(1950)$	$7/2^+$	****
$\Delta(2000)$	$5/2^+$	**
$\Delta(2150)$	$1/2^-$	*
$\Delta(2200)$	$7/2^-$	***
$\Delta(2300)$	$9/2^+$	**
$\Delta(2350)$	$5/2^-$	*
$\Delta(2390)$	$7/2^+$	*
$\Delta(2400)$	$9/2^-$	**
$\Delta(2420)$	$11/2^+$	****
$\Delta(2750)$	$13/2^-$	**
$\Delta(2950)$	$15/2^+$	**
Λ	$1/2^+$	****
$\Lambda(1405)$	$1/2^-$	****
$\Lambda(1520)$	$3/2^-$	****
$\Lambda(1600)$	$1/2^+$	***
$\Lambda(1670)$	$1/2^-$	****
$\Lambda(1690)$	$3/2^-$	****
$\Lambda(1710)$	$1/2^+$	*
$\Lambda(1800)$	$1/2^-$	***
$\Lambda(1810)$	$1/2^+$	***
$\Lambda(1820)$	$5/2^+$	****
$\Lambda(1830)$	$5/2^-$	****
$\Lambda(1890)$	$3/2^+$	****
$\Lambda(2000)$		*
$\Lambda(2020)$	$7/2^+$	*
$\Lambda(2050)$	$3/2^-$	*
$\Lambda(2100)$	$7/2^-$	****
$\Lambda(2110)$	$5/2^+$	***
$\Lambda(2325)$	$3/2^-$	*
$\Lambda(2350)$	$9/2^+$	***
$\Lambda(2585)$		**

Σ^+	$1/2^+$	****
Σ^0	$1/2^+$	****
Σ^-	$1/2^+$	****
$\Sigma(1385)$	$3/2^+$	****
$\Sigma(1480)$		*
$\Sigma(1560)$		**
$\Sigma(1580)$	$3/2^-$	*
$\Sigma(1620)$	$1/2^-$	*
$\Sigma(1660)$	$1/2^+$	***
$\Sigma(1670)$	$3/2^-$	****
$\Sigma(1690)$		**
$\Sigma(1730)$	$3/2^+$	*
$\Sigma(1750)$	$1/2^-$	***
$\Sigma(1770)$	$1/2^+$	*
$\Sigma(1775)$	$5/2^-$	****
$\Sigma(1840)$	$3/2^+$	*
$\Sigma(1880)$	$1/2^+$	**
$\Sigma(1900)$	$1/2^-$	*
$\Sigma(1915)$	$5/2^+$	****
$\Sigma(1940)$	$3/2^+$	*
$\Sigma(1940)$	$3/2^-$	***
$\Sigma(2000)$	$1/2^-$	*
$\Sigma(2030)$	$7/2^+$	****
$\Sigma(2070)$	$5/2^+$	*
$\Sigma(2080)$	$3/2^+$	**
$\Sigma(2100)$	$7/2^-$	*
$\Sigma(2250)$		***
$\Sigma(2455)$		**
$\Sigma(2620)$		**
$\Sigma(3000)$		*
$\Sigma(3170)$		*

Ξ^0	$1/2^+$	****
Ξ^-	$1/2^+$	****
$\Xi(1530)$	$3/2^+$	****
$\Xi(1620)$		*
$\Xi(1690)$		***
$\Xi(1820)$	$3/2^-$	***
$\Xi(1950)$		***
$\Xi(2030)$	$\geq \frac{5}{2}^?$	***
$\Xi(2120)$		*
$\Xi(2250)$		**
$\Xi(2370)$		**
$\Xi(2500)$		*
Ω^-	$3/2^+$	****
$\Omega(2250)^-$		***
$\Omega(2380)^-$		**
$\Omega(2470)^-$		**

Λ^+_c	$1/2^+$	****
$\Lambda_c(2595)^+$	$1/2^-$	***
$\Lambda_c(2625)^+$	$3/2^-$	***
$\Lambda_c(2765)^+$		*
$\Lambda_c(2860)^+$	$3/2^+$	***
$\Lambda_c(2880)^+$	$5/2^+$	***
$\Lambda_c(2940)^+$	$3/2^-$	***
$\Sigma_c(2455)$	$1/2^+$	****
$\Sigma_c(2520)$	$3/2^+$	***
$\Sigma_c(2800)$		***
Ξ^+_c	$1/2^+$	***
Ξ^0_c	$1/2^+$	***
Ξ'^+_c	$1/2^+$	***
Ξ'^0_c	$1/2^+$	***
$\Xi_c(2645)$	$3/2^+$	***
$\Xi_c(2790)$	$1/2^-$	***
$\Xi_c(2815)$	$3/2^-$	***
$\Xi_c(2930)$		*
$\Xi_c(2970)$		***
$\Xi_c(3055)$		***
$\Xi_c(3080)$		***
$\Xi_c(3123)$		*
Ω^0_c	$1/2^+$	***
$\Omega_c(2770)^0$	$3/2^+$	***
$\Omega_c(3000)^0$		***
$\Omega_c(3050)^0$		***
$\Omega_c(3065)^0$		***
$\Omega_c(3090)^0$		***
$\Omega_c(3120)^0$		***
Ξ^+_{cc}		*
Ξ^{++}_{cc}		***
Λ^0_b	$1/2^+$	***
$\Lambda_b(5912)^0$	$1/2^-$	***
$\Lambda_b(5920)^0$	$3/2^-$	***
Σ_b	$1/2^+$	***
Σ^*_b	$3/2^+$	***
Ξ^0_b, Ξ^-_b	$1/2^+$	***
$\Xi'_b(5935)^-$	$1/2^+$	***
$\Xi_b(5945)^0$	$3/2^+$	***
$\Xi_b(5955)^-$	$3/2^+$	***
Ω^-_b	$1/2^+$	***
$P_c(4380)^+$		*
$P_c(4450)^+$		*

**** 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.

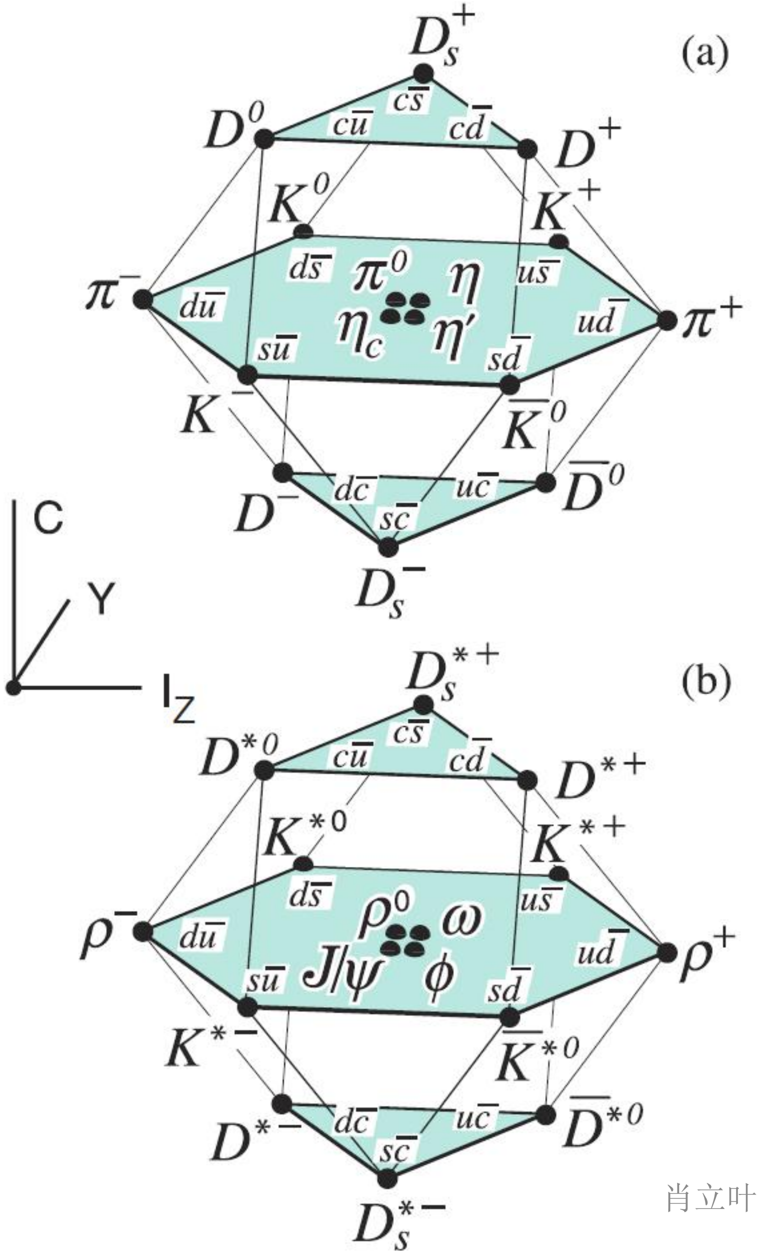
* Evidence of existence is poor.

From PDG 2018

We can put (all of) them in a simple picture!

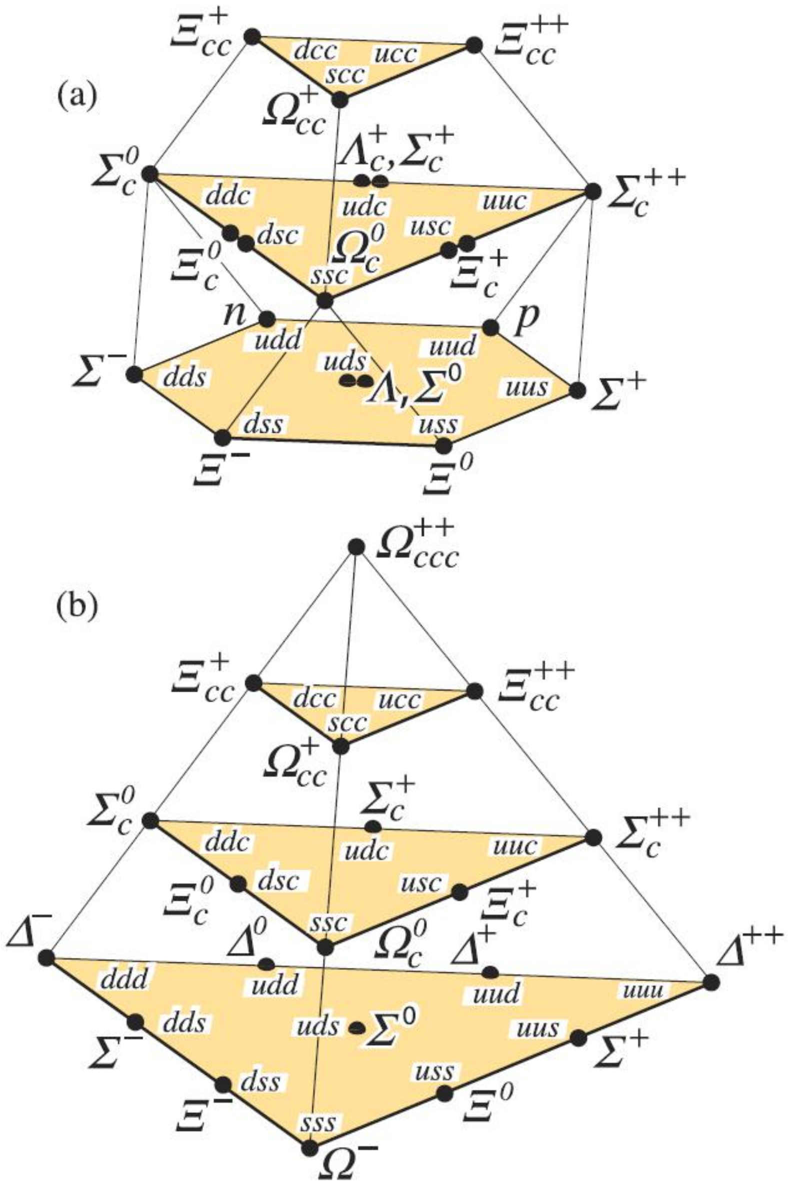
J=0

J=1



J=1/2

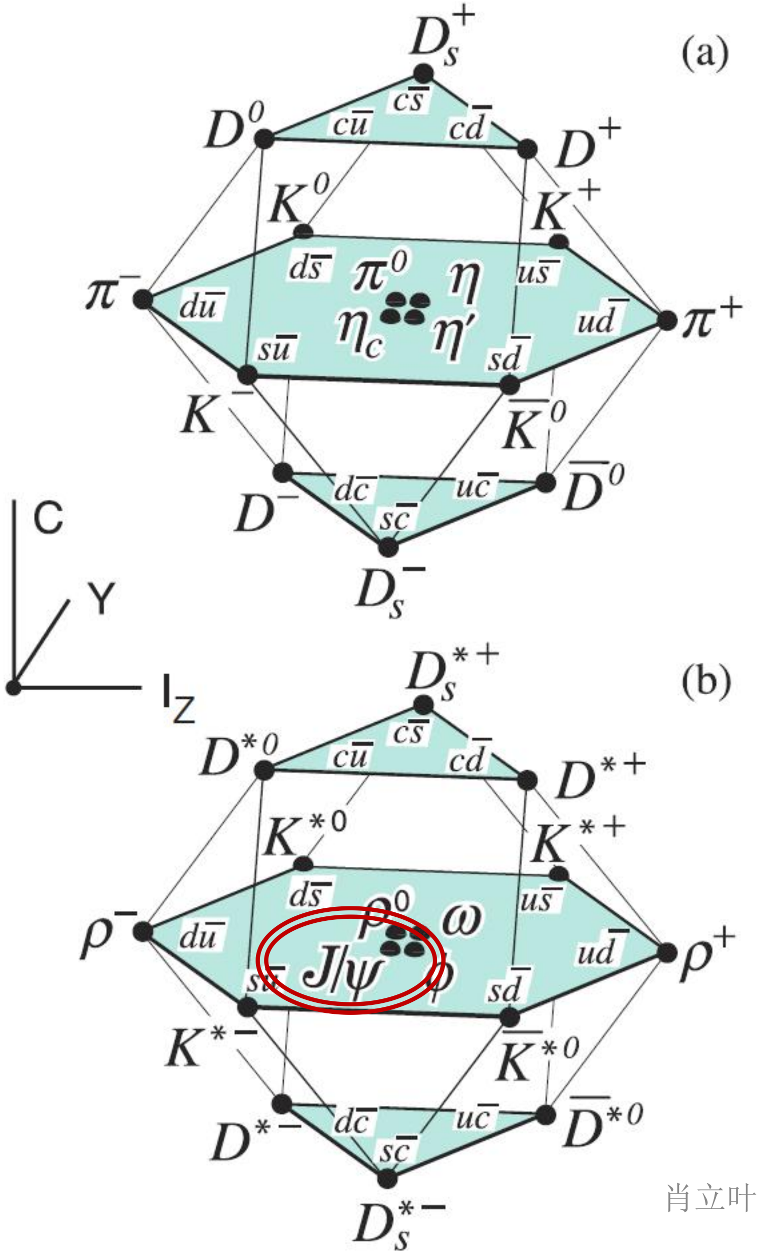
J=3/2



We can put (all of) them in a simple picture!

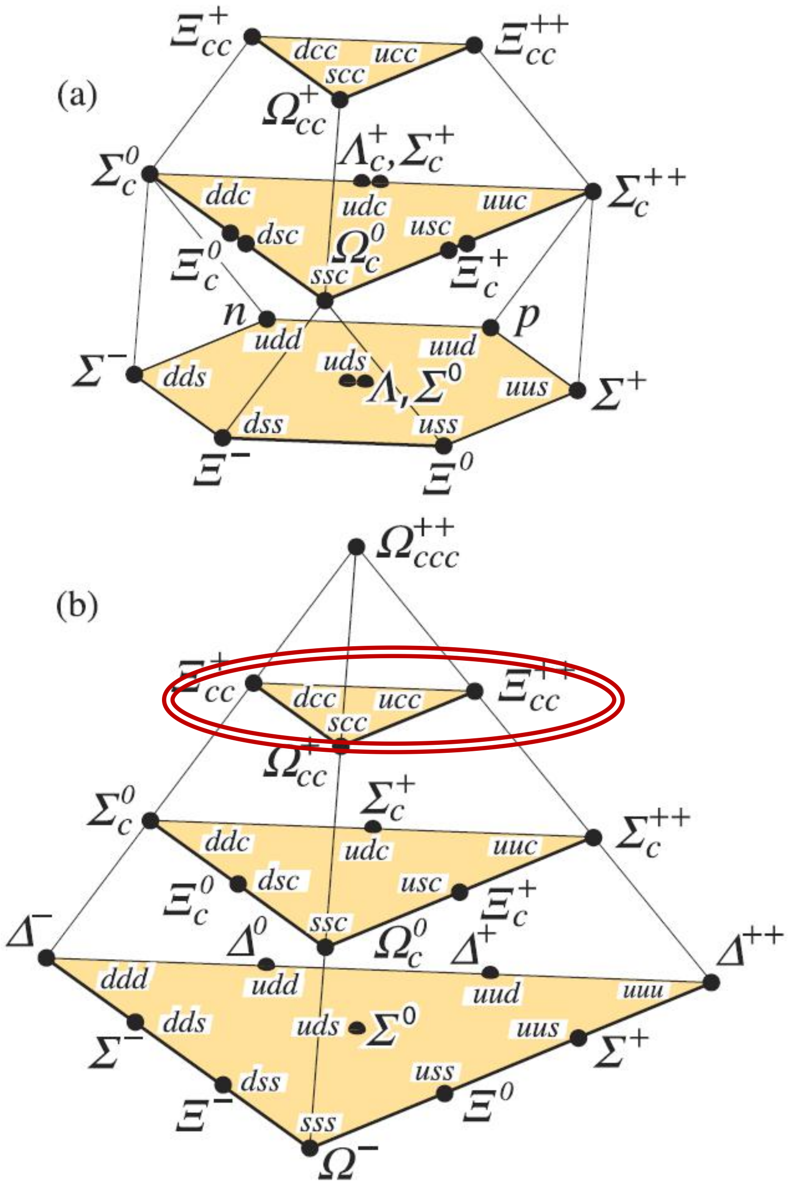
J=0

J=1

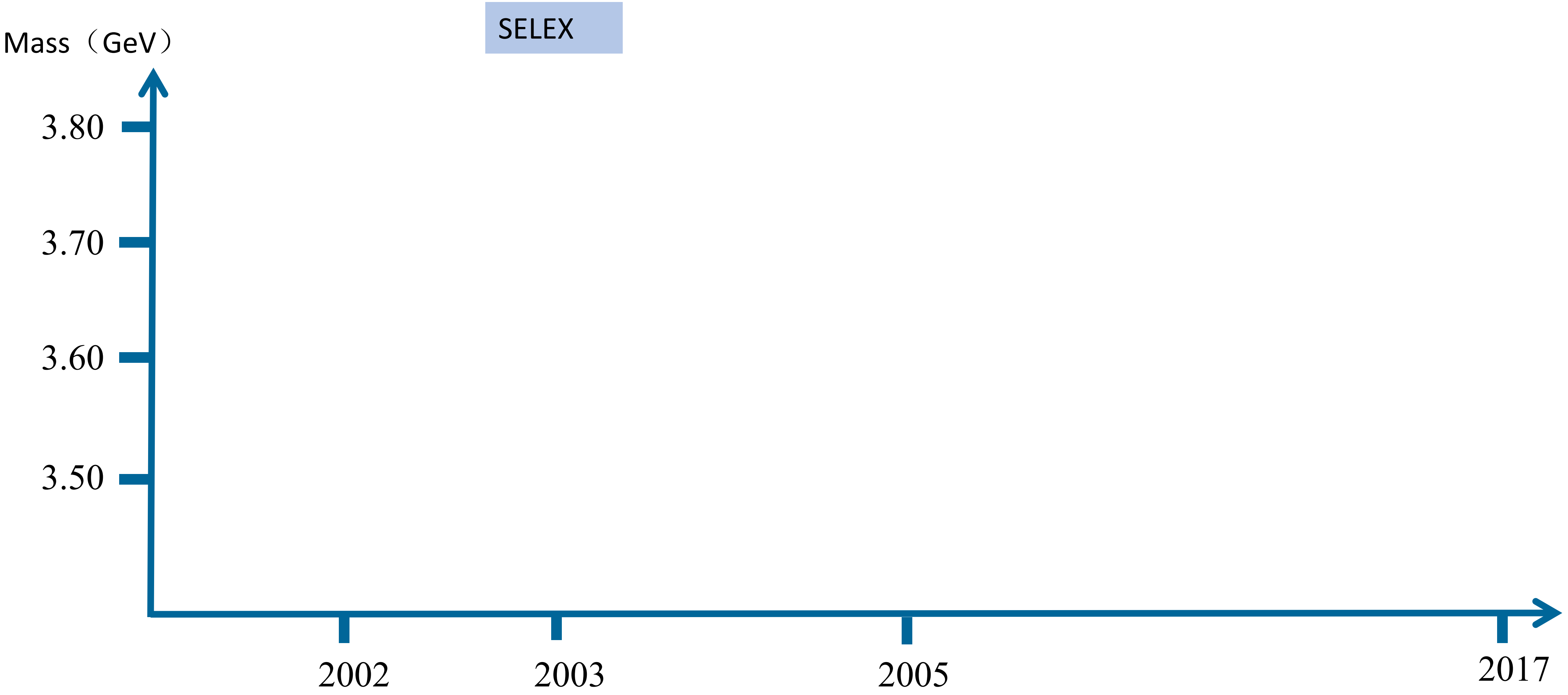


J=1/2

J=3/2

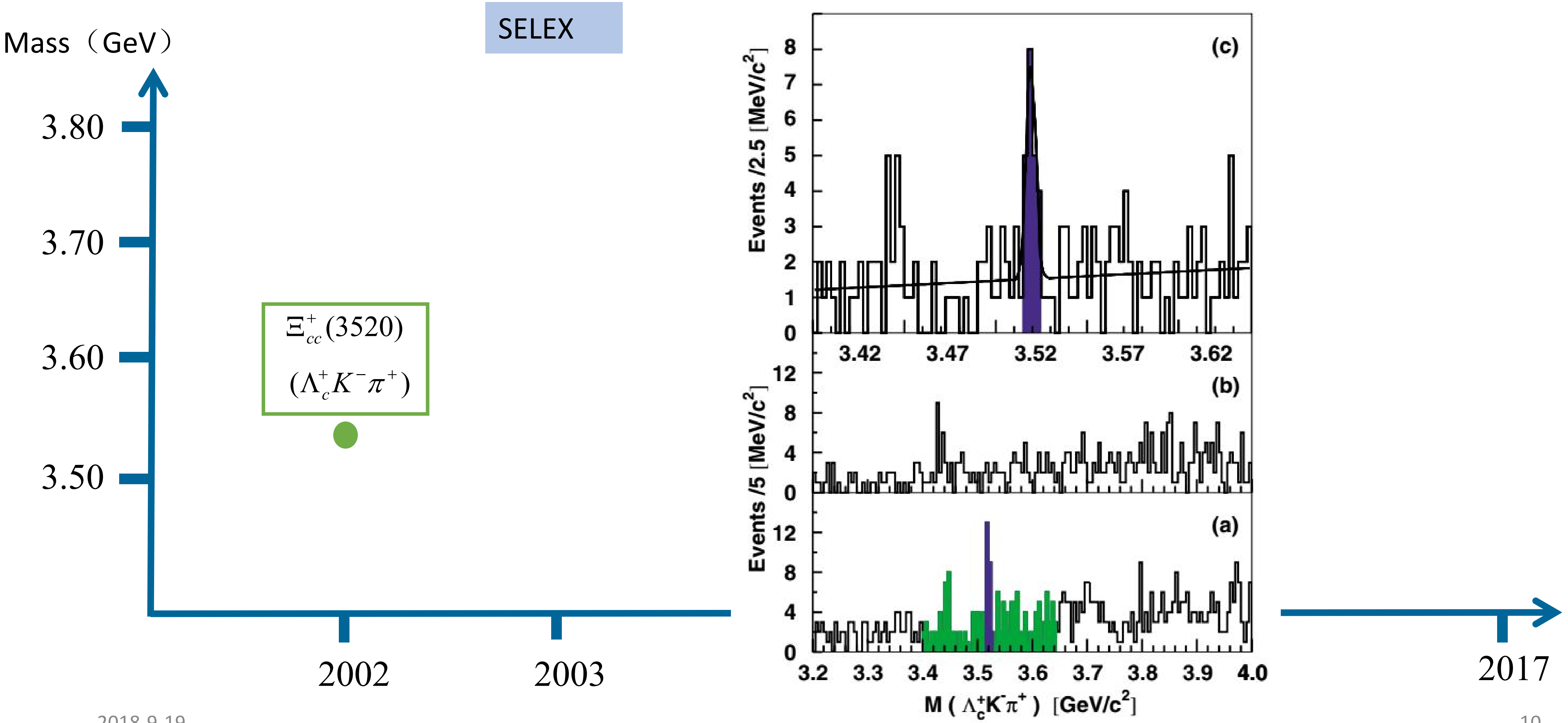


Doubley charmed baryons:



Doubley charmed baryons:

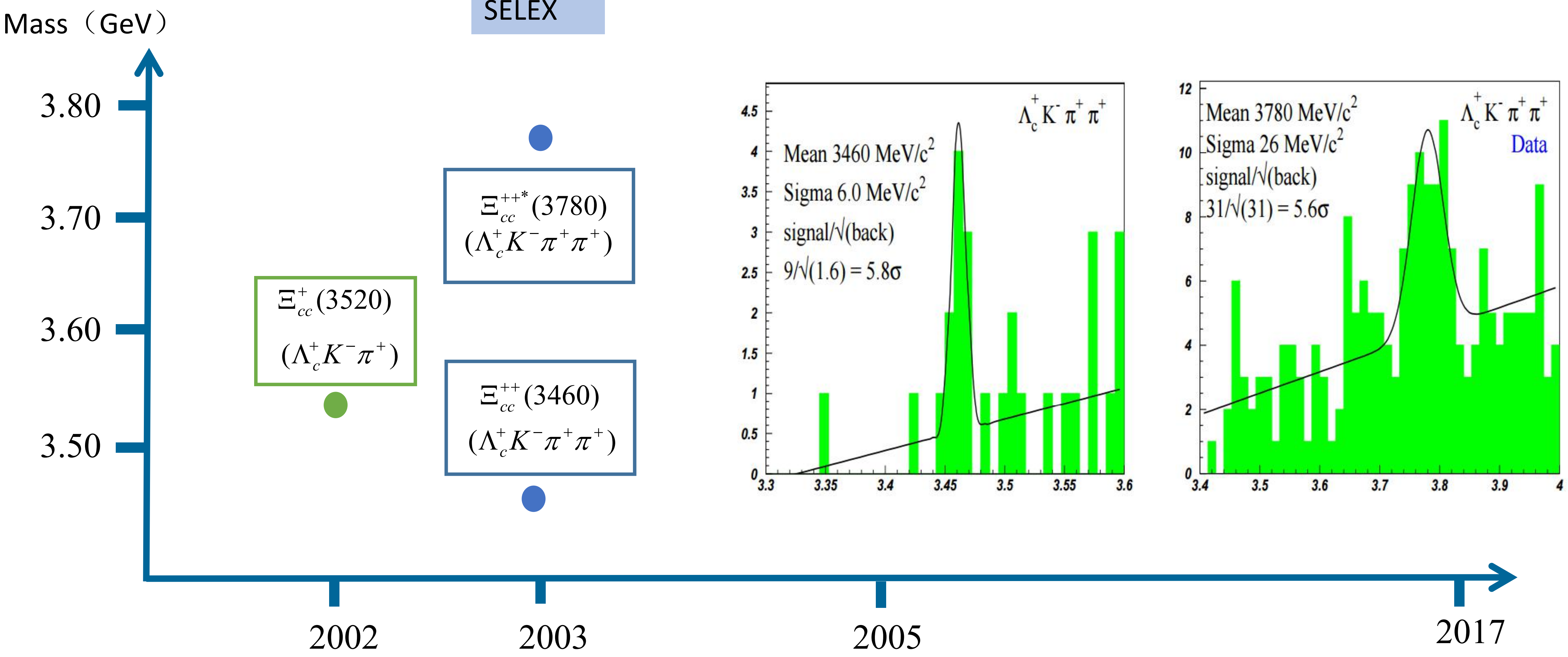
SELEX Collaboration PRL89,112001 (2002).



Doubley charmed baryons:

SELEX Collaboration PRL89,112001 (2002).

SELEX Collaboration CJP53,B201 (2003).

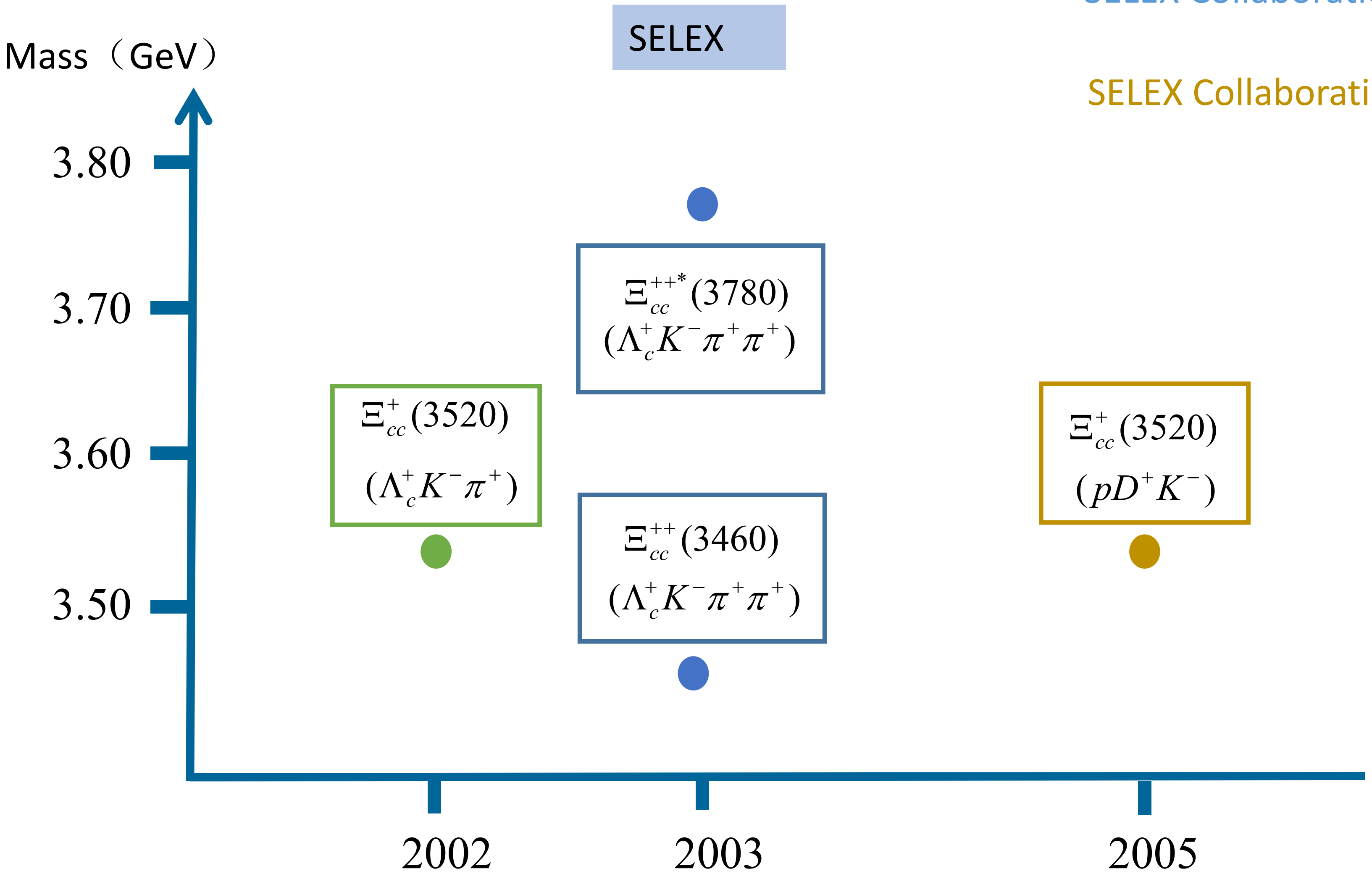


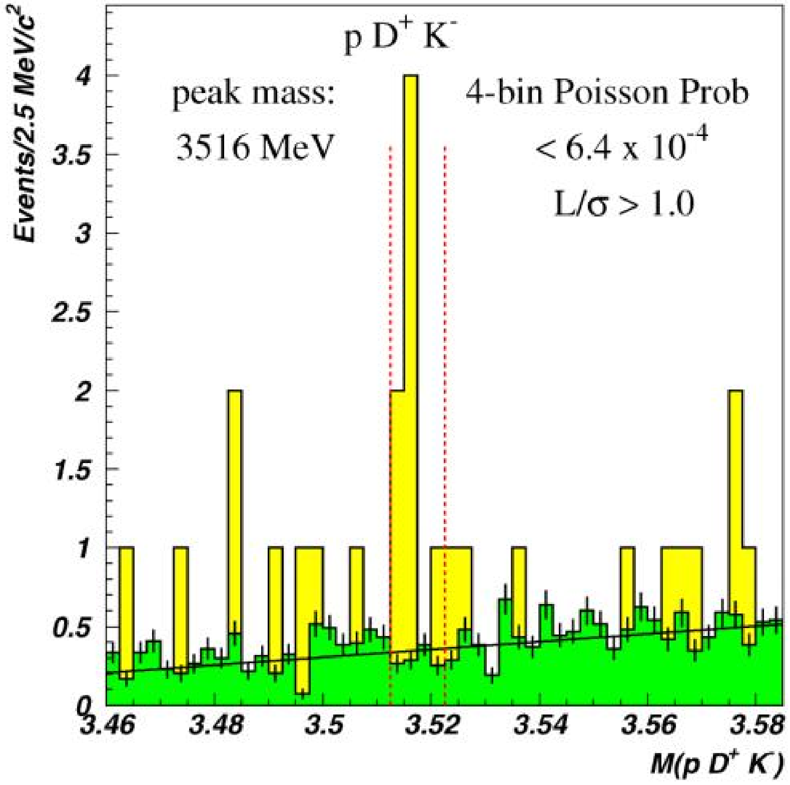
Doubley charmed baryons:

SELEX Collaboration PRL89,112001 (2002).

SELEX Collaboration CJP53,B201 (2003).

SELEX Collaboration PLB628,18(2005).

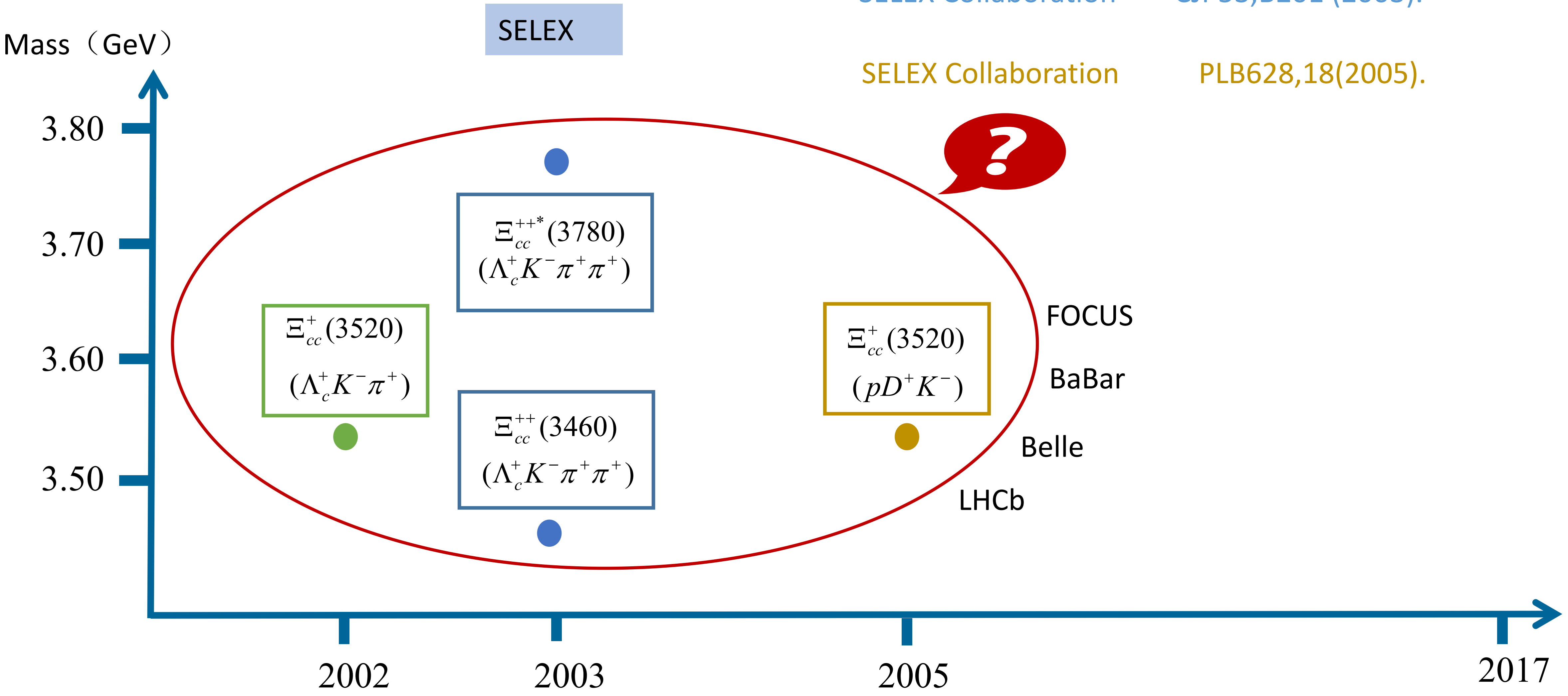




Doubley charmed baryons:

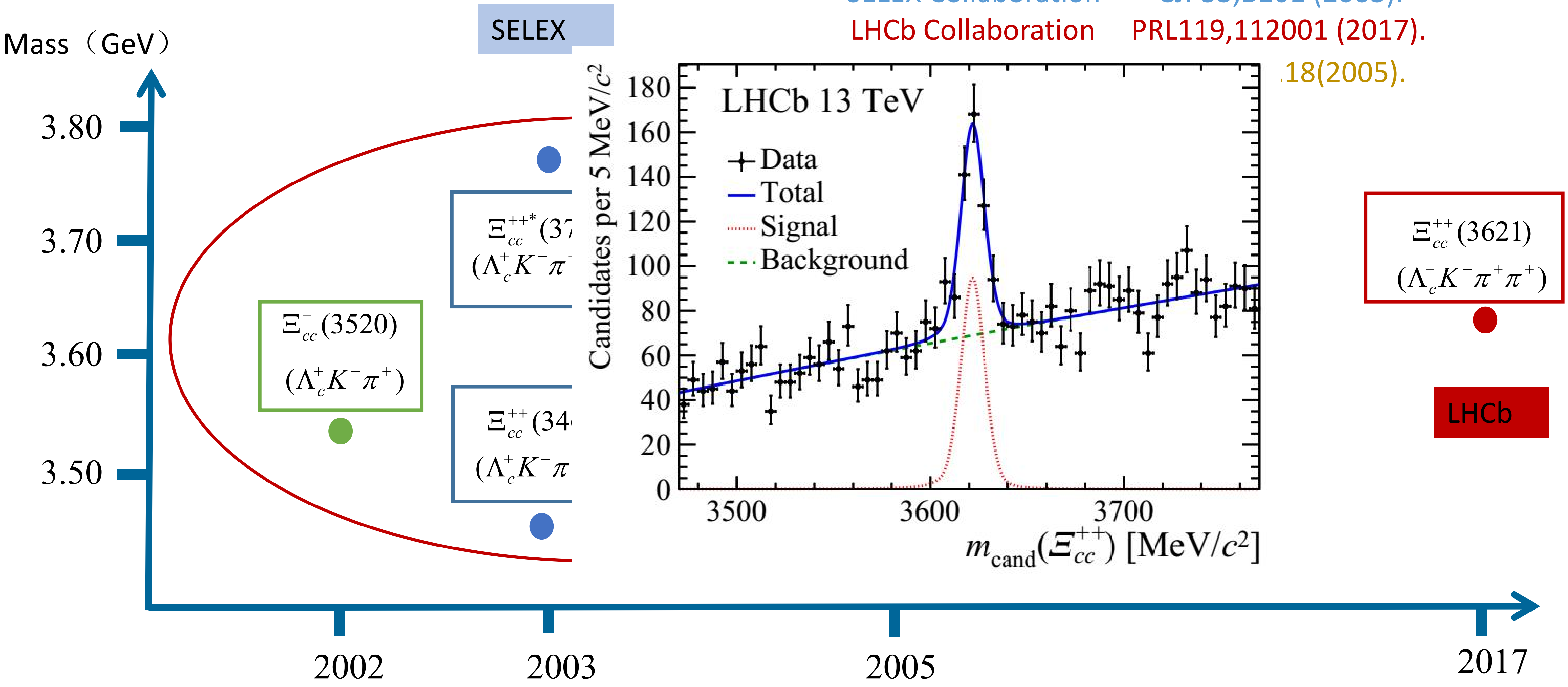
SELEX Collaboration PRL89,112001 (2002).
SELEX Collaboration CJP53,B201 (2003).

SELEX Collaboration PLB628,18(2005).



Doubley charmed baryons:

SELEX Collaboration PRL89,112001 (2002).
SELEX Collaboration CJP53,B201 (2003).
LHCb Collaboration PRL119,112001 (2017).
.18(2005).



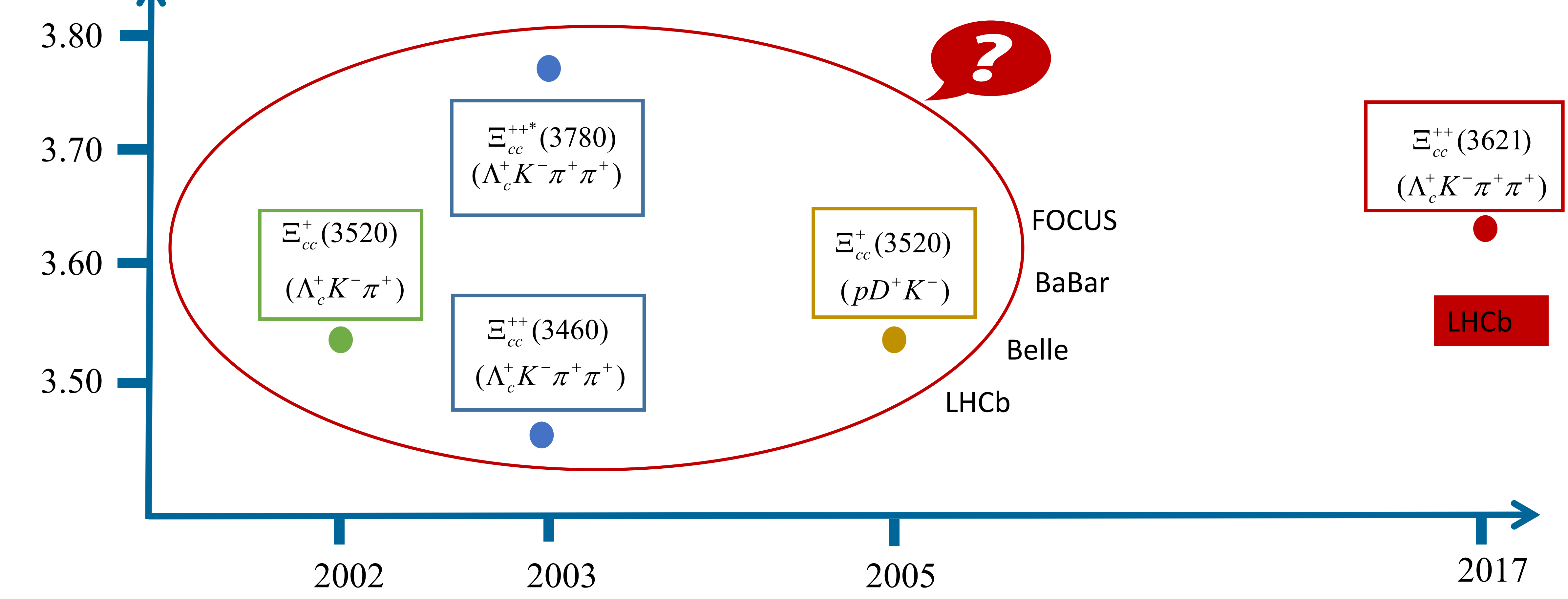
Doubley charmed baryons:

SELEX Collaboration PRL89,112001 (2002).

SELEX Collaboration CJP53,B201 (2003).

LHCb Collaboration PRL119,112001 (2017).

SELEX Collaboration PLB628,18(2005).



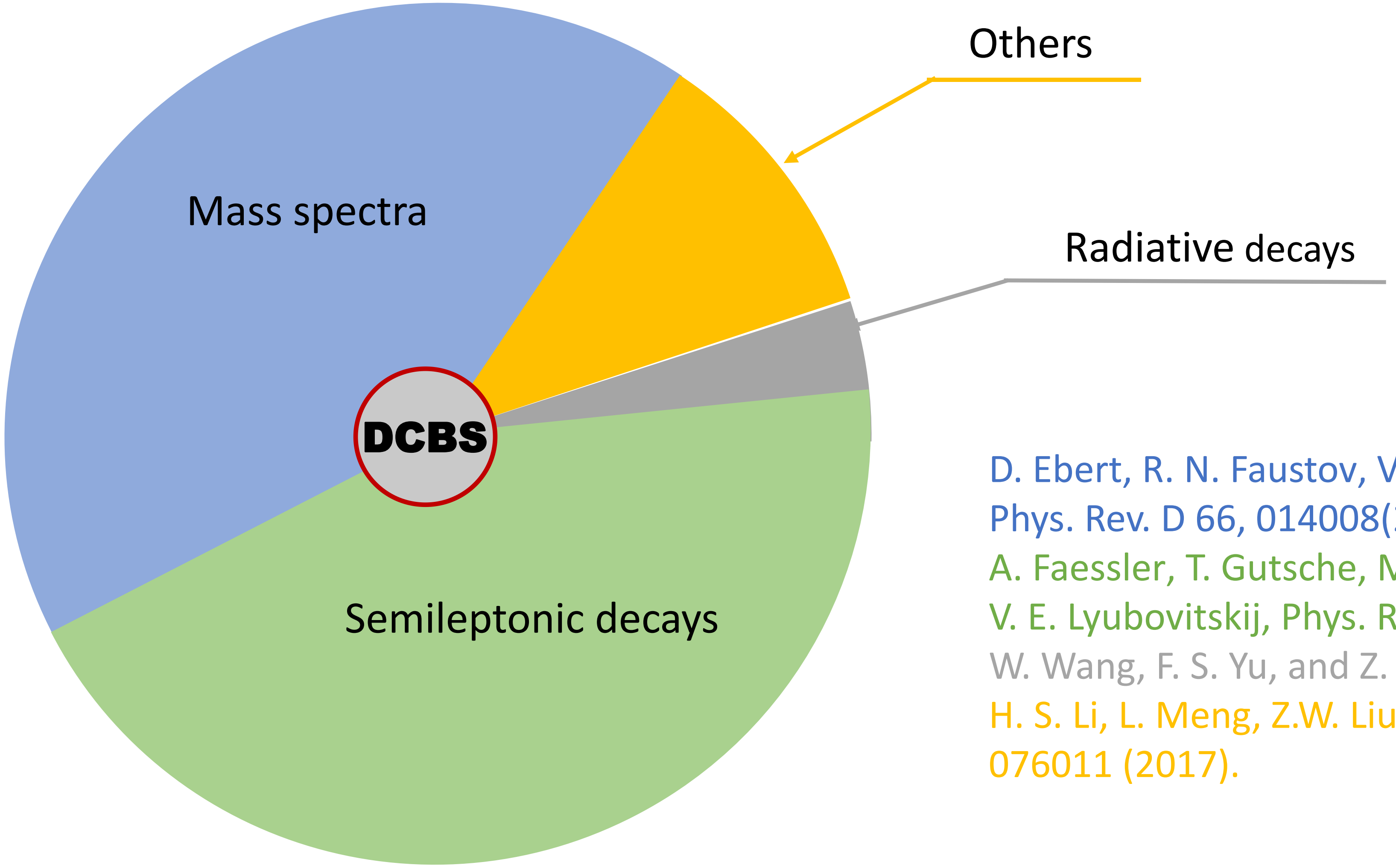
Doubley charmed baryons:

HEP 找到 **1** 笔记录

1. **First observation of the doubly charmed baryon Xi+(cc)**
   SELEX Collaboration (M. Mattson (Carnegie Mellon U.) *et al.*). Aug 2002. 5 pp.
   Published in **Phys.Rev.Lett. 89 (2002) 112001**
   FERMILAB-PUB-02-183-E
   DOI: 10.1103/PhysRevLett.89.112001
   e-Print: **hep-ex/0208014** | **PDF**
   References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
   ADS Abstract Service; Fermilab Library Server (fulltext available)
   详细记录 - Cited by 344 records 250+

1. **Observation of the doubly charmed baryon Ξ_{cc}^{++}**
   LHCb Collaboration (Roel Aaij (CERN) *et al.*). Jul 5, 2017. 10 pp.
   Published in **Phys.Rev.Lett. 119 (2017) no.11, 112001**
   LHCB-PAPER-2017-018, CERN-EP-2017-156
   DOI: 10.1103/PhysRevLett.119.112001
   e-Print: **arXiv:1707.01621 [hep-ex]** | **PDF**
   References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
   CERN Document Server; ADS Abstract Service; Link to conference slides; Interactions.org article; Link to Fulltext
   详细记录 - Cited by 123 records 100+

Doubley charmed baryons:



D. Ebert, R. N. Faustov, V. O. Galkin, and A. P. Martynenko, Phys. Rev. D 66, 014008(2002).

A. Faessler, T. Gutsche, M. A. Ivanov, J. G. Korner, and V. E. Lyubovitskij, Phys. Rev. D 80, 034025 (2009).

W. Wang, F. S. Yu, and Z. X. Zhao, arXiv:1707.02834.

H. S. Li, L. Meng, Z.W. Liu, and S. L. Zhu, Phys. Rev. D 96, 076011 (2017).

2018-9-19

Doubley charmed baryons:

20、 PRD66,014008 (2002). 46、 PRD77,074008 (2008).

TABLE I: Masses and possible two body strong decay channels of the $1P$ and $2D$ doubly charmed baryons (denoted by $|N^{2S+1}L_\sigma J^P\rangle$), where $|N^{2S+1}L_\sigma J^P\rangle=\sum_{L_z+S_z=J_z}\langle LL_z,SS_z|JJ_z\rangle^N\Psi^\sigma_{LL_z}\chi_{S_z}\phi$ [46]. The masses (MeV) are taken from the relativistic quark model [20].

State		Ξ_{cc}		Ω_{cc}	
$N^{2S+1}L_\sigma J^P$	Wave function	Mass [20]	Strong decay channel	Mass [20]	Strong decay channel
$\|0^2S\frac{1}{2}^+\rangle$	${}^0\Psi^S_{00}\chi^\lambda_{S_z}\phi$	3620	$\cdots$	3778	$\cdots$
$\|0^4S\frac{3}{2}^+\rangle$	${}^0\Psi^S_{00}\chi^s_{S_z}\phi$	3727	$\cdots$	3872	$\cdots$
$\|1^2P_\rho\frac{1}{2}^-\rangle$	${}^1\Psi^\rho_{1L_z}\chi^\rho_{S_z}\phi$	3838	$\cdots$	4002	$\cdots$
$\|1^2P_\rho\frac{3}{2}^-\rangle$		3959	$\cdots$	4102	$\cdots$
$\|1^2P_\lambda\frac{1}{2}^-\rangle$	${}^1\Psi^\lambda_{1L_z}\chi^\lambda_{S_z}\phi$	4136	$\Xi^{(*)}_{cc}\pi$	4271	$\Xi^{(*)}_{cc}K$
$\|1^2P_\lambda\frac{3}{2}^-\rangle$		4196	$\Xi^{(*)}_{cc}\pi$	4325	$\Xi^{(*)}_{cc}K$
$\|1^4P_\lambda\frac{1}{2}^-\rangle$	${}^1\Psi^\lambda_{1L_z}\chi^s_{S_z}\phi$	4053	$\Xi^{(*)}_{cc}\pi$	4208	$\Xi_{cc}K$
$\|1^4P_\lambda\frac{3}{2}^-\rangle$		4101	$\Xi^{(*)}_{cc}\pi$	4252	$\Xi^{(*)}_{cc}K$
$\|1^4P_\lambda\frac{5}{2}^-\rangle$		4155	$\Xi^{(*)}_{cc}\pi$	4303	$\Xi^{(*)}_{cc}K$
$\|2^2D_{\rho\rho}\frac{3}{2}^+\rangle$	${}^2\Psi^{\rho\rho}_{2L_z}\chi^\lambda_{S_z}\phi$		Λ_cD		Ξ_cD
$\|2^2D_{\rho\rho}\frac{5}{2}^+\rangle$			Λ_cD, $\Sigma^{(*)}_cD$		Ξ_cD, $\Xi'^{(*)}_cD$
$\|2^4D_{\rho\rho}\frac{1}{2}^+\rangle$	${}^2\Psi^{\rho\rho}_{2L_z}\chi^s_{S_z}\phi$		Λ_cD		Ξ_cD
$\|2^4D_{\rho\rho}\frac{3}{2}^+\rangle$			Λ_cD, Σ_cD		Ξ_cD, Ξ'_cD
$\|2^4D_{\rho\rho}\frac{5}{2}^+\rangle$			Λ_cD, $\Sigma^{(*)}_cD$		Ξ_cD, Ξ'^*_cD
$\|2^4D_{\rho\rho}\frac{7}{2}^+\rangle$			Λ_cD, $\Sigma^{(*)}_cD$, Ξ_cD_s, Ξ'_cD_s		Ξ_cD, $\Xi'^{(*)}_cD$, $\Omega^{(*)}_cD_s$
$\|2^2D_{\lambda\lambda}\frac{3}{2}^+\rangle$	${}^2\Psi^{\lambda\lambda}_{2L_z}\chi^\lambda_{S_z}\phi$		$\Xi^{(*)}_{cc}\pi$, $\Omega^{(*)}_{cc}K$, Λ_cD, $\Sigma^{(*)}_cD$, Ξ_cD_s, $\Xi'^{(*)}_cD_s$		$\Xi^{(*)}_{cc}K$, $\Omega^{(*)}_{cc}\eta$, Ξ_cD $\Xi'^{(*)}_cD$, $\Omega^{(*)}_cD_s$, $\Omega^{(*)}_{cc}\eta'$
$\|2^2D_{\lambda\lambda}\frac{5}{2}^+\rangle$			$\Xi^{(*)}_{cc}\pi$, $\Omega^{(*)}_{cc}K$, Λ_cD, $\Sigma^{(*)}_cD$, Ξ_cD_s, $\Xi'^{(*)}_cD_s$		$\Xi^{(*)}_{cc}K$, $\Omega^{(*)}_{cc}\eta$, Ξ_cD, $\Xi'^{(*)}_cD$, $\Omega^{(*)}_cD_s$, $\Omega^{(*)}_{cc}\eta'$
$\|2^4D_{\lambda\lambda}\frac{1}{2}^+\rangle$	${}^2\Psi^{\lambda\lambda}_{2L_z}\chi^s_{S_z}\phi$		$\Xi^{(*)}_{cc}\pi$, $\Omega^{(*)}_{cc}K$, Λ_cD, $\Sigma^{(*)}_cD$, Ξ_cD_s, Ξ'_cD_s		$\Xi^{(*)}_{cc}K$, $\Omega^{(*)}_{cc}\eta$, Ξ_cD, $\Xi'^{(*)}_cD$, Ω_cD_s
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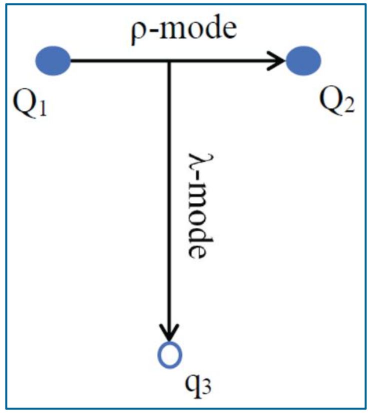
$\|2^4D_{\lambda\lambda}\frac{5}{2}^+\rangle$			$\Xi^{(*)}_{cc}\pi$, $\Omega^{(*)}_{cc}K$, Λ_cD, $\Sigma^{(*)}_cD$, Ξ_cD_s, $\Xi'^{(*)}_cD_s$		$\Xi^{(*)}_{cc}K$, $\Omega^{(*)}_{cc}\eta$, $\Omega_{cc}\eta'$, Ξ_cD, $\Xi'^{(*)}_cD$, $\Omega^{(*)}_cD_s$
$\|2^4D_{\lambda\lambda}\frac{7}{2}^+\rangle$			$\Xi^{(*)}_{cc}\pi$, $\Omega^{(*)}_{cc}K$, Λ_cD, $\Sigma^{(*)}_cD$, Ξ_cD_s, $\Xi'^{(*)}_cD_s$		$\Xi^{(*)}_{cc}K$, $\Omega^{(*)}_{cc}\eta$, $\Omega^{(*)}_{cc}\eta'$, Ξ_cD, $\Xi'^{(*)}_cD$, $\Omega^{(*)}_cD_s$



Doubley charmed baryons:

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$\|2^2D_{\rho\rho}\frac{5}{2}^+\rangle$			Λ_cD, $\Sigma^{(*)}_cD$		Ξ_cD, $\Xi'^{(*)}_cD$
$\|2^4D_{\rho\rho}\frac{1}{2}^+\rangle$	${}^2\Psi^{\rho\rho}_{2L_z}\chi^s_{S_z}\phi$		Λ_cD		Ξ_cD
$\|2^4D_{\rho\rho}\frac{3}{2}^+\rangle$			Λ_cD, Σ_cD		Ξ_cD, Ξ'_cD
$\|2^4D_{\rho\rho}\frac{5}{2}^+\rangle$			Λ_cD, $\Sigma^{(*)}_cD$		Ξ_cD, Ξ'^*_cD
$\|2^4D_{\rho\rho}\frac{7}{2}^+\rangle$			Λ_cD, $\Sigma^{(*)}_cD$, Ξ_cD_s, Ξ'_cD_s		Ξ_cD, $\Xi'^{(*)}_cD$, $\Omega^{(*)}_cD_s$
$\|2^2D_{\lambda\lambda}\frac{3}{2}^+\rangle$	${}^2\Psi^{\lambda\lambda}_{2L_z}\chi^\lambda_{S_z}\phi$		$\Xi^{(*)}_{cc}\pi$, $\Omega^{(*)}_{cc}K$, Λ_cD, $\Sigma^{(*)}_cD$, Ξ_cD_s, $\Xi'^{(*)}_cD_s$		$\Xi^{(*)}_{cc}K$, $\Omega^{(*)}_{cc}\eta$, Ξ_cD $\Xi'^{(*)}_cD$, $\Omega^{(*)}_cD_s$, $\Omega^{(*)}_{cc}\eta'$
$\|2^2D_{\lambda\lambda}\frac{5}{2}^+\rangle$			$\Xi^{(*)}_{cc}\pi$, $\Omega^{(*)}_{cc}K$, Λ_cD, $\Sigma^{(*)}_cD$, Ξ_cD_s, $\Xi'^{(*)}_cD_s$		$\Xi^{(*)}_{cc}K$, $\Omega^{(*)}_{cc}\eta$, Ξ_cD, $\Xi'^{(*)}_cD$, $\Omega^{(*)}_cD_s$, $\Omega^{(*)}_{cc}\eta'$
$\|2^4D_{\lambda\lambda}\frac{1}{2}^+\rangle$	${}^2\Psi^{\lambda\lambda}_{2L_z}\chi^s_{S_z}\phi$		$\Xi^{(*)}_{cc}\pi$, $\Omega^{(*)}_{cc}K$, Λ_cD, $\Sigma^{(*)}_cD$, Ξ_cD_s, Ξ'_cD_s		$\Xi^{(*)}_{cc}K$, $\Omega^{(*)}_{cc}\eta$, Ξ_cD, $\Xi'^{(*)}_cD$, Ω_cD_s
$\|2^4D_{\lambda\lambda}\frac{3}{2}^+\rangle$			$\Xi^{(*)}_{cc}\pi$, $\Omega^{(*)}_{cc}K$, Λ_cD, $\Sigma^{(*)}_cD$, Ξ_cD_s, $\Xi'^{(*)}_cD_s$		$\Xi^{(*)}_{cc}K$, $\Omega^{(*)}_{cc}\eta$, $\Omega_{cc}\eta'$, Ξ_cD, $\Xi'^{(*)}_cD$, $\Omega^{(*)}_cD_s$
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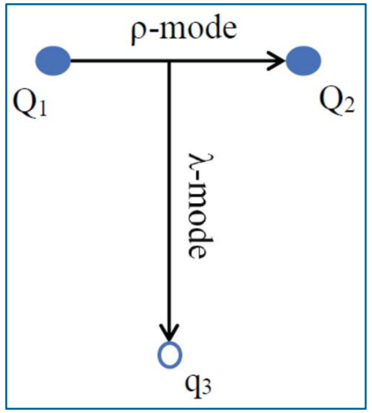
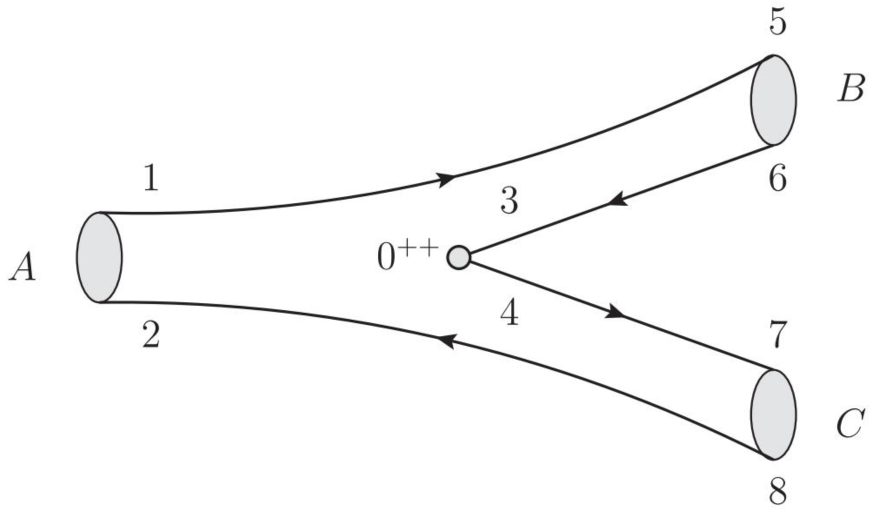
${}^3P_0$ model



$^3P_0$ model:

$$A(\text{initial meson}) \to B(\text{final meson}) + C(\text{final meson})$$



0^{++} → $l=1$, $S=1$ ⟹ $^{2S+1}L_J = {}^3P_0$

$$H_{q\bar{q}} = \gamma \sum_f 2m_f \int d^3x \bar{\psi}_f \psi_f$$

nonrelativistic limit →

$$T = -3\gamma \sum_m \langle 1m;1-m|00\rangle \int d^3p_3 d^3p_4 \delta^3(p_3+p_4) \times \omega_0^{34} \varphi_0^{34} \chi_{1,-m}^{34} Y_1^m\left(\frac{p_3-p_4}{2}\right) a_{3i}^+ b_{4j}^+$$

$$\omega_0^{34} = \frac{R_4\bar{R}_3 + G_4\bar{G}_3 + B_4\bar{B}_3}{\sqrt{3}}$$

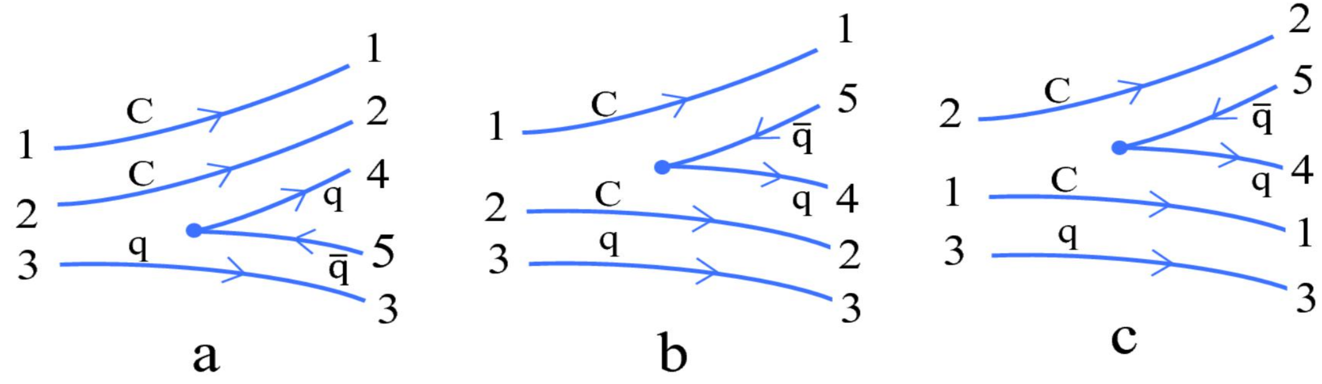
$$\varphi_0^{34} = \frac{u_4\bar{u}_3 + d_4\bar{d}_3 + s_4\bar{s}_3}{\sqrt{3}}$$

$$Y_1^m(\vec{p}) = |\vec{p}|\, y_1^m(\theta,\varphi)$$

L. Micu, Nucl. Phys. B10,521(1969).

R. D. Carlitz and M. Kislinger , Phys. Rev. D2,336(1970).

$^3P_0$ model:



$$T = -3\gamma \sum_m \langle 1m;1-m|00\rangle \int d^3p_4 d^3p_5 \delta^3(p_4+p_5) \times \omega_0^{45}\varphi_0^{45}\chi_{1,-m}^{45} \mathrm{Y}_1^m\left(\frac{p_4-p_5}{2}\right) a_{4i}^+ b_{5j}^+$$

$$\mathrm{M}^{M_{J_A}M_{J_B}M_{J_C}}(A\to B+C) = \sqrt{8E_AE_BE_C}\,\gamma \sum \langle L_AM_{L_A};S_AM_{S_A}|J_AM_{J_A}\rangle\langle L_BM_{L_B};S_BM_{S_B}|J_BM_{J_B}\rangle\langle L_CM_{L_C};S_CM_{S_C}|J_CM_{J_C}\rangle \times\langle 1m;1-m|00\rangle\langle \chi^{124}_{S_BM_{S_B}}\chi^{35}_{S_CM_{S_C}}|\chi^{123}_{S_AM_{S_A}}\chi^{45}_{1-m}\rangle\langle\varphi_B^{124}\varphi_C^{35}|\varphi_A^{123}\varphi_0^{45}\rangle I^{M_{L_A},m}_{M_{L_B},M_{L_C}}$$

$$I^{M_{L_A},m}_{M_{L_B},M_{L_C}}(p) = \int d^3\vec{p}_1 d^3\vec{p}_2 d^3\vec{p}_3 d^3\vec{p}_4 d^3\vec{p}_5 \delta^3(\vec{p}_4+\vec{p}_5)\delta^3(\vec{p}_1+\vec{p}_2+\vec{p}_3-\vec{p}_A)\delta^3(\vec{p}_3+\vec{p}_5-\vec{p}_C)\delta^3(\vec{p}_1+\vec{p}_2+\vec{p}_4-\vec{p}_B) \times\psi^*_{n_BL_BM_{L_B}}(\vec{p}_1,\vec{p}_2,\vec{p}_4)\psi^*_{n_CL_CM_{L_C}}(\vec{p}_3,\vec{p}_5)\psi_{n_AL_AM_{L_A}}(\vec{p}_1,\vec{p}_2,\vec{p}_3)\mathrm{Y}_1^m\left(\frac{\vec{p}_4-\vec{p}_5}{2}\right)$$

$^3P_0$ model:

C. Hayne and N. Isgur, Phys.Rev. D25,1944(1982).

- baryon wave function

$$\left|A(N_A{}^{2S_A+1}L_A J_A M_{J_A})(p_A)\right\rangle = \sqrt{2E_A}\varphi_A^{123}\omega_A^{123}\sum_{M_{L_A},M_{S_A}}\left\langle L_A M_{L_A};S_A M_{S_A}\middle|J_A M_{J_A}\right\rangle \times\int d^3p_1 d^3p_2 d^3p_3\delta^3(p_1+p_2+p_3-p_A) \times\psi_{N_A L_A M_{L_A}}(p_1,p_2,p_3)\chi^{123}_{S_A M_{S_A}}\left|q_1(p_1)q_2(p_2)q_3(p_3)\right\rangle$$

- meson wave function

$$\left|C(N_C{}^{2S_A+1}L_C J_A M_{J_C})(p_C)\right\rangle = \sqrt{2E_C}\varphi_C^{ab}\omega_C^{ab}\sum_{M_{L_C},M_{S_C}}\left\langle L_C M_{L_C};S_C M_{S_C}\middle|J_C M_{J_C}\right\rangle \times\int d^3p_a d^3p_b\delta^3(p_a+p_b-p_C) \times\psi_{N_C L_C M_{L_C}}(p_a,p_b)\chi^{ab}_{S_C M_{S_C}}\left|q_a(p_a)q_b(p_b)\right\rangle$$

spatial wave function —SHO→

$$\psi^0_{lm}(\vec{p})=(-i)^l\left[\frac{2^{l+2}}{\sqrt{\pi}(2l+1)!!}\right]^{\frac{1}{2}}\left(\frac{1}{\alpha}\right)^{l+\frac{3}{2}}\exp\left(-\frac{\vec{p}^2}{2\alpha^2}\right)Y_l^m(\vec{p})$$

$$\Gamma[A\to B+C]=\pi^2\frac{|P|}{M_A^2}\frac{1}{2J_A+1}\sum_{M_{J_A},M_{J_B},M_{J_C}}\left|\mathcal{M}_{M_{J_A}M_{J_B}M_{J_C}}\right|^2$$

Result: $1P_\rho$

D. Ebert PRD66,014008 (2002).

$^{2S+1}L_{\rho/\lambda}J^P$	$\Xi_{cc}^{++}\,{}^2P_\rho\,\frac{1}{2}^-$	$\Xi_{cc}^{++}\,{}^2P_\rho\,\frac{3}{2}^-$	$\Omega_{cc}\,{}^2P_\rho\,\frac{1}{2}^-$	$\Omega_{cc}\,{}^2P_\rho\,\frac{3}{2}^-$
mass（MeV）	3838	3959	4002	4102

orthogonality of SHO function ✗ → doubly charmed baryon+light flavor meson

below the threshold ✗ → singly charmed baryon+heavy-light meson

The decay widths of the $1P_\rho$ states should be fairly narrow !

Result: $1P_{\lambda}$

State	Mass	$\Gamma[\Xi_{cc}\pi]$ $^3P_0$	$\Gamma[\Xi_{cc}^{*}\pi]$ $^3P_0$	Total $^3P_0$	$\mathcal{B}$ $^3P_0$
$\vert\Xi_{cc}\ ^2P_{\lambda}\frac{1}{2}^-\rangle$	4136	21.9	18.6	40.5	1.18
$\vert\Xi_{cc}\ ^2P_{\lambda}\frac{3}{2}^-\rangle$	4196	13.7	117	131	0.18
$\vert\Xi_{cc}\ ^4P_{\lambda}\frac{1}{2}^-\rangle$	4053	200	0.60	201	333
$\vert\Xi_{cc}\ ^4P_{\lambda}\frac{3}{2}^-\rangle$	4101	4.43	127	131	0.03
$\vert\Xi_{cc}\ ^4P_{\lambda}\frac{5}{2}^-\rangle$	4155	45.9	12.6	58.5	3.64

State	Mass	$\Gamma[\Xi_{cc}K]$ $^3P_0$	$\Gamma[\Xi_{cc}^{*}K]$ $^3P_0$	Total $^3P_0$	$\mathcal{B}$ $^3P_0$
$\vert\Omega_{cc}\ ^2P_{\lambda}\frac{1}{2}^-\rangle$	4271	49.3	1.53	50.8	32.2
$\vert\Omega_{cc}\ ^2P_{\lambda}\frac{3}{2}^-\rangle$	4325	8.50	199	208	0.04
$\vert\Omega_{cc}\ ^4P_{\lambda}\frac{1}{2}^-\rangle$	4208	378	⋯	378	⋯
$\vert\Omega_{cc}\ ^4P_{\lambda}\frac{3}{2}^-\rangle$	4252	2.02	154	156	0.01
$\vert\Omega_{cc}\ ^4P_{\lambda}\frac{5}{2}^-\rangle$	4303	29.1	2.62	31.7	11.1

Result: $1P_\lambda$

State	Mass	$\Gamma[\Xi_{cc}\pi]$	$\Gamma[\Xi_{cc}^{*}\pi]$	Total	$\mathcal{B}$
		$^3P_0$	$^3P_0$	$^3P_0$	$^3P_0$
$\lvert\Xi_{cc}\ ^2P_{\lambda}\frac{1}{2}^-\rangle$	4136	21.9	18.6	40.5	1.18
$\lvert\Xi_{cc}\ ^2P_{\lambda}\frac{3}{2}^-\rangle$	4196	13.7	117	131	0.18
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		$^3P_0$	$^3P_0$	$^3P_0$	$^3P_0$
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$\lvert\Omega_{cc}\ ^4P_{\lambda}\frac{1}{2}^-\rangle$	4208	378	···	378	···
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Result: $1P_\lambda$

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State	Mass	$\Gamma[\Xi_{cc}K]$ $^3P_0$	$\Gamma[\Xi_{cc}^*K]$ $^3P_0$	Total $^3P_0$	$\mathcal{B}$ $^3P_0$
$\lvert\Omega_{cc}\ {}^2P_\lambda \frac{1}{2}^-\rangle$	4271	49.3	1.53	50.8	32.2
$\lvert\Omega_{cc}\ {}^2P_\lambda \frac{3}{2}^-\rangle$	4325	8.50	199	208	0.04
$\lvert\Omega_{cc}\ {}^4P_\lambda \frac{1}{2}^-\rangle$	4208	378	$\cdots$	378	$\cdots$
$\lvert\Omega_{cc}\ {}^4P_\lambda \frac{3}{2}^-\rangle$	4252	2.02	154	156	0.01
$\lvert\Omega_{cc}\ {}^4P_\lambda \frac{5}{2}^-\rangle$	4303	29.1	2.62	31.7	11.1

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$\lvert\Omega_{cc}\ ^2P_\lambda \frac{1}{2}^-\rangle$	4271	49.3	1.53	50.8	32.2
$\lvert\Omega_{cc}\ ^2P_\lambda \frac{3}{2}^-\rangle$	4325	8.50	199	208	0.04
$\lvert\Omega_{cc}\ ^4P_\lambda \frac{1}{2}^-\rangle$	4208	378	···	378	···
$\lvert\Omega_{cc}\ ^4P_\lambda \frac{3}{2}^-\rangle$	4252	2.02	154	156	0.01
$\lvert\Omega_{cc}\ ^4P_\lambda \frac{5}{2}^-\rangle$	4303	29.1	2.62	31.7	11.1

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$\vert\Xi_{cc}\ ^2P_\lambda \frac{3}{2}^-\rangle$	4196	13.7	117	131	0.18
$\vert\Xi_{cc}\ ^4P_\lambda \frac{1}{2}^-\rangle$	4053	200	0.60	201	333
$\vert\Xi_{cc}\ ^4P_\lambda \frac{3}{2}^-\rangle$	4101	4.43	127	131	0.03
$\vert\Xi_{cc}\ ^4P_\lambda \frac{5}{2}^-\rangle$	4155	45.9	12.6	58.5	3.64

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$\vert\Omega_{cc}\ ^2P_\lambda \frac{1}{2}^-\rangle$	4271	49.3	1.53	50.8	32.2
$\vert\Omega_{cc}\ ^2P_\lambda \frac{3}{2}^-\rangle$	4325	8.50	199	208	0.04
$\vert\Omega_{cc}\ ^4P_\lambda \frac{1}{2}^-\rangle$	4208	378	···	378	···
$\vert\Omega_{cc}\ ^4P_\lambda \frac{3}{2}^-\rangle$	4252	2.02	154	156	0.01
$\vert\Omega_{cc}\ ^4P_\lambda \frac{5}{2}^-\rangle$	4303	29.1	2.62	31.7	11.1

Result: $1P_\lambda$

State	Mass	$\Gamma[\Xi_{cc}\pi]$ $^3P_0$	$\Gamma[\Xi_{cc}^*\pi]$ $^3P_0$	Total $^3P_0$	$\mathcal{B}$ $^3P_0$
$\lvert\Xi_{cc}\ ^2P_\lambda\frac{1}{2}^-\rangle$	4136	21.9	18.6	40.5	1.18
$\lvert\Xi_{cc}\ ^2P_\lambda\frac{3}{2}^-\rangle$	4196	13.7	117	131	0.18
$\lvert\Xi_{cc}\ ^4P_\lambda\frac{1}{2}^-\rangle$	4053	200	0.60	201	333
$\lvert\Xi_{cc}\ ^4P_\lambda\frac{3}{2}^-\rangle$	4101	4.43	127	131	0.03
$\lvert\Xi_{cc}\ ^4P_\lambda\frac{5}{2}^-\rangle$	4155	45.9	12.6	58.5	3.64

State	Mass	$\Gamma[\Xi_{cc}K]$ $^3P_0$	$\Gamma[\Xi_{cc}^*K]$ $^3P_0$	Total $^3P_0$	$\mathcal{B}$ $^3P_0$
$\lvert\Omega_{cc}\ ^2P_\lambda\frac{1}{2}^-\rangle$	4271	49.3	1.53	50.8	32.2
$\lvert\Omega_{cc}\ ^2P_\lambda\frac{3}{2}^-\rangle$	4325	8.50	199	208	0.04
$\lvert\Omega_{cc}\ ^4P_\lambda\frac{1}{2}^-\rangle$	4208	378	...	378	...
$\lvert\Omega_{cc}\ ^4P_\lambda\frac{3}{2}^-\rangle$	4252	2.02	154	156	0.01
$\lvert\Omega_{cc}\ ^4P_\lambda\frac{5}{2}^-\rangle$	4303	29.1	2.62	31.7	11.1

Result: $1P_\lambda$

State	Mass	$\Gamma[\Xi_{cc}\pi]$	$\Gamma[\Xi_{cc}^*\pi]$	Total	$\mathcal{B}$
		$^3P_0$	$^3P_0$	$^3P_0$	$^3P_0$
$\lvert\Xi_{cc}\ ^2P_\lambda\frac{1}{2}^-\rangle$	4136	21.9	18.6	40.5	1.18
$\lvert\Xi_{cc}\ ^2P_\lambda\frac{3}{2}^-\rangle$	4196	13.7	117	131	0.18
$\lvert\Xi_{cc}\ ^4P_\lambda\frac{1}{2}^-\rangle$	4053	200	0.60	201	333
$\lvert\Xi_{cc}\ ^4P_\lambda\frac{3}{2}^-\rangle$	4101	4.43	127	131	0.03
$\lvert\Xi_{cc}\ ^4P_\lambda\frac{5}{2}^-\rangle$	4155	45.9	12.6	58.5	3.64

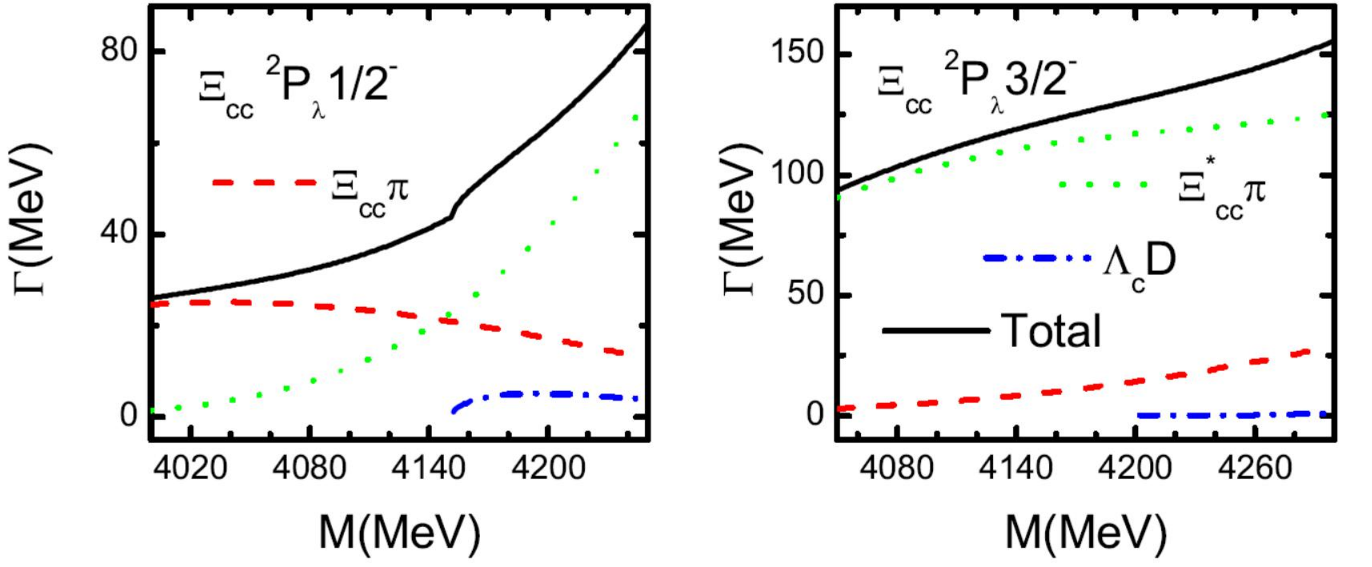
State	Mass	$\Gamma[\Xi_{cc}K]$	$\Gamma[\Xi_{cc}^*K]$	Total	$\mathcal{B}$
		$^3P_0$	$^3P_0$	$^3P_0$	$^3P_0$
$\lvert\Omega_{cc}\ ^2P_\lambda\frac{1}{2}^-\rangle$	4271	49.3	1.53	50.8	32.2
$\lvert\Omega_{cc}\ ^2P_\lambda\frac{3}{2}^-\rangle$	4325	8.50	199	208	0.04
$\lvert\Omega_{cc}\ ^4P_\lambda\frac{1}{2}^-\rangle$	4208	378	...	378	...
$\lvert\Omega_{cc}\ ^4P_\lambda\frac{3}{2}^-\rangle$	4252	2.02	154	156	0.01
$\lvert\Omega_{cc}\ ^4P_\lambda\frac{5}{2}^-\rangle$	4303	29.1	2.62	31.7	11.1

Result: $1P_\lambda$

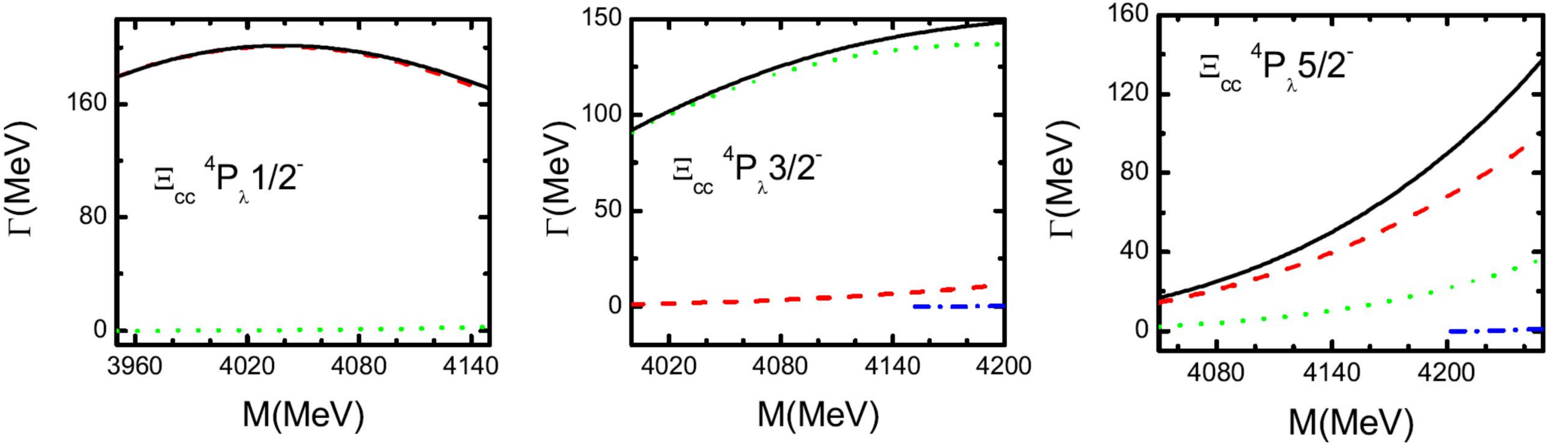
State	Mass	$\Gamma[\Xi_{cc}\pi]$		$\Gamma[\Xi^*_{cc}\pi]$		Total		$\mathcal{B}$	
		$^3P_0$	CQM	$^3P_0$	CQM	$^3P_0$	CQM	$^3P_0$	CQM
$\|\Xi_{cc}\ ^2P_\lambda \frac{1}{2}^-\rangle$	4136	21.9	15.6	18.6	33.9	40.5	49.5	1.18	0.46
$\|\Xi_{cc}\ ^2P_\lambda \frac{3}{2}^-\rangle$	4196	13.7	21.6	117	101	131	123	0.18	0.21
$\|\Xi_{cc}\ ^4P_\lambda \frac{1}{2}^-\rangle$	4053	200	133	0.60	1.22	201	134	333	110
$\|\Xi_{cc}\ ^4P_\lambda \frac{3}{2}^-\rangle$	4101	4.43	7.63	127	84.6	131	92.2	0.03	0.09
$\|\Xi_{cc}\ ^4P_\lambda \frac{5}{2}^-\rangle$	4155	45.9	75.3	12.6	22.8	58.5	98.1	3.64	3.30

State	Mass	$\Gamma[\Xi_{cc}K]$		$\Gamma[\Xi^*_{cc}K]$		Total		$\mathcal{B}$	
		$^3P_0$	CQM	$^3P_0$	CQM	$^3P_0$	CQM	$^3P_0$	CQM
$\|\Omega_{cc}\ ^2P_\lambda \frac{1}{2}^-\rangle$	4271	49.3	33.1	1.53	2.36	50.8	35.5	32.2	14.0
$\|\Omega_{cc}\ ^2P_\lambda \frac{3}{2}^-\rangle$	4325	8.50	11.4	199	174	208	185	0.04	0.06
$\|\Omega_{cc}\ ^4P_\lambda \frac{1}{2}^-\rangle$	4208	378	323	...	...	378	323	...	...
$\|\Omega_{cc}\ ^4P_\lambda \frac{3}{2}^-\rangle$	4252	2.02	3.08	154	137	156	140	0.01	0.02
$\|\Omega_{cc}\ ^4P_\lambda \frac{5}{2}^-\rangle$	4303	29.1	41.5	2.62	4.38	31.7	45.9	11.1	9.47

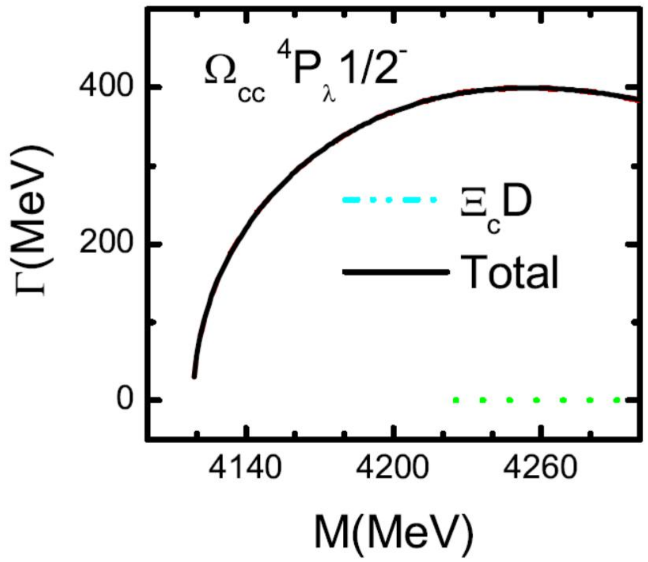
Result: $\Xi^{++}_{cc}1P_\lambda$

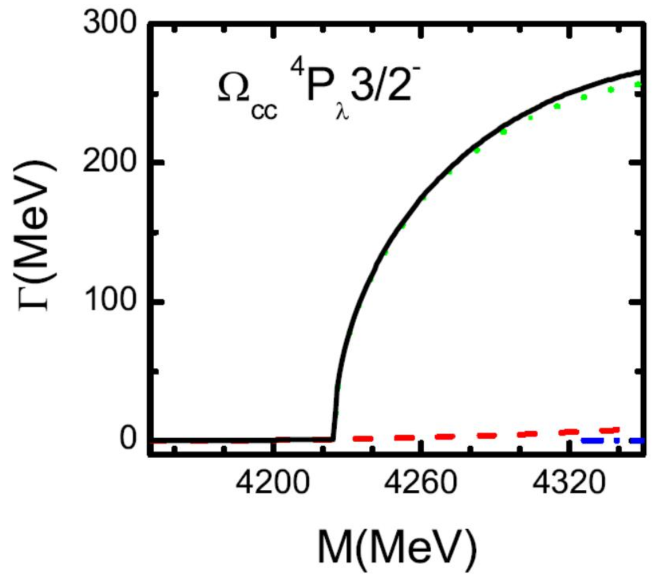


states	$^2P_\lambda \frac{1}{2}^-$	$^2P_\lambda \frac{3}{2}^-$	$^4P_\lambda \frac{1}{2}^-$	$^4P_\lambda \frac{3}{2}^-$	$^4P_\lambda \frac{5}{2}^-$
mass(MeV)	4136	4196	4053	4101	4155

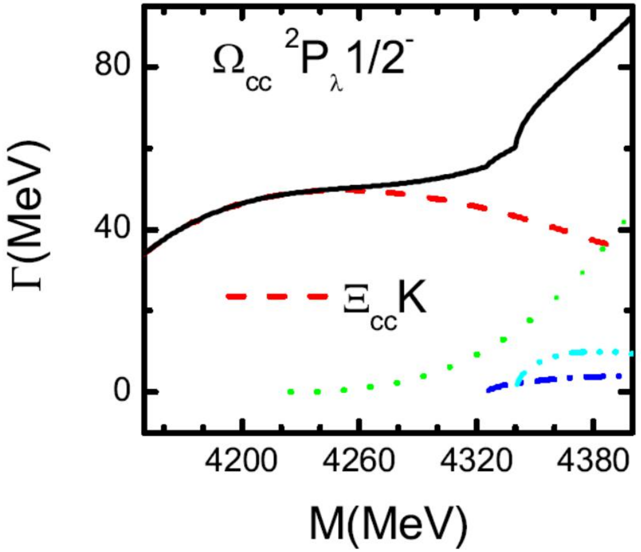


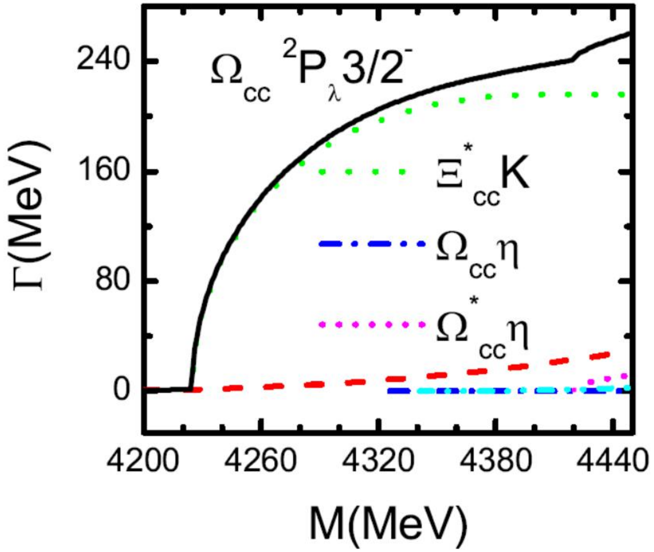
Result: $\Omega_{cc}1P_{\lambda}$

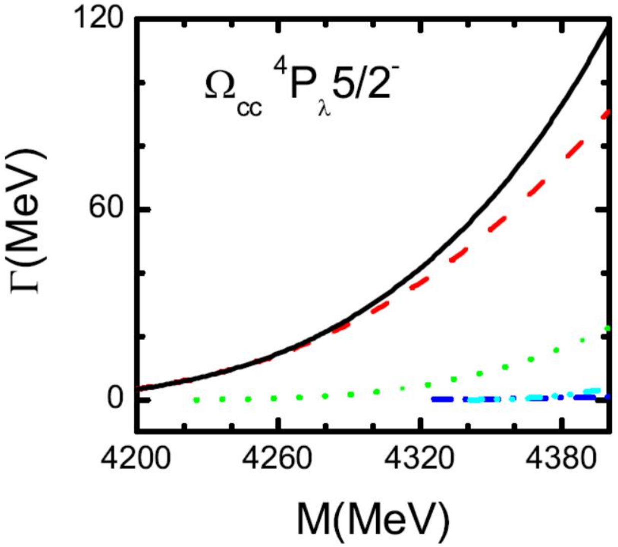




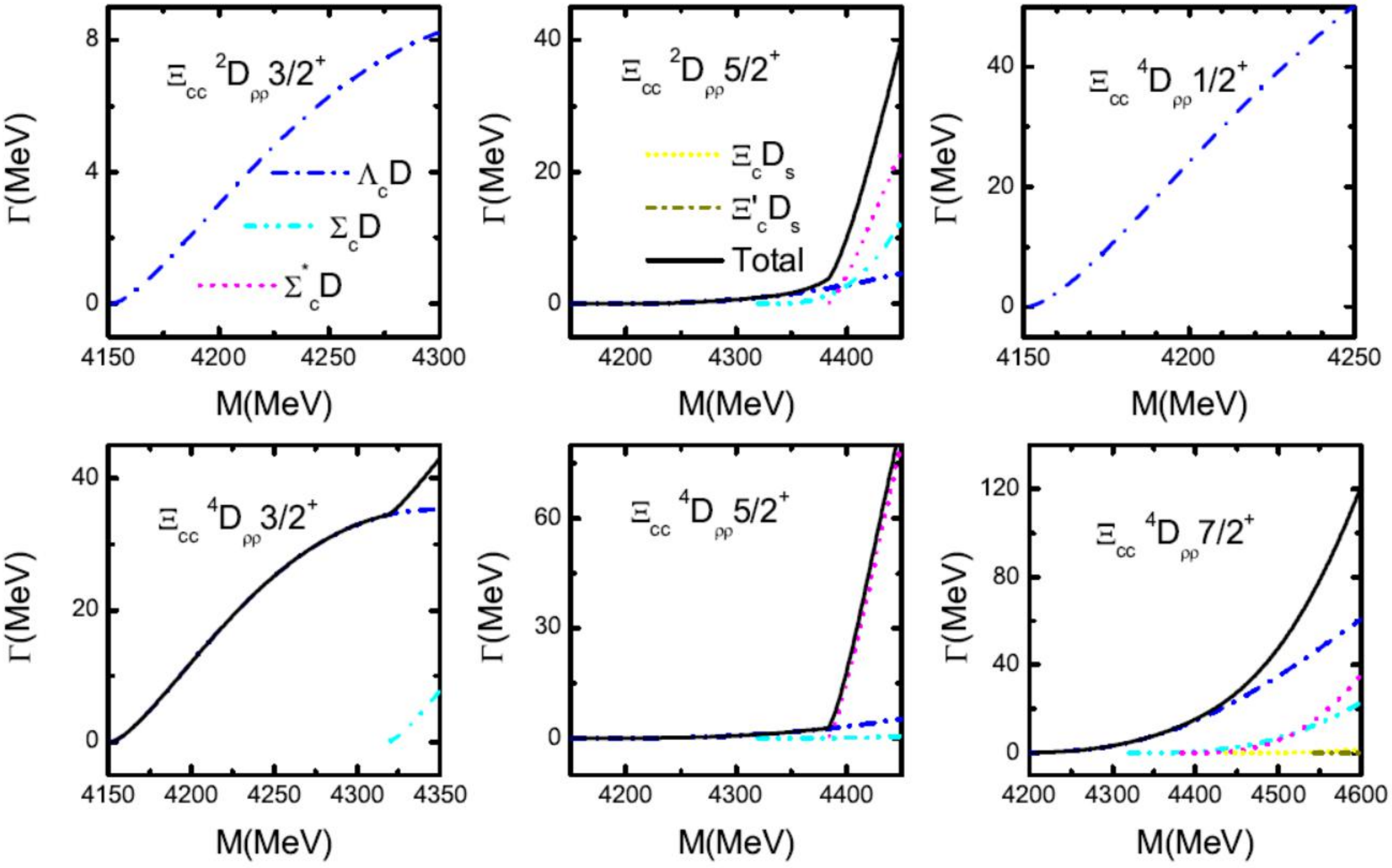
states	$^2P_{\lambda}\,\frac{1}{2}^-$	$^2P_{\lambda}\,\frac{3}{2}^-$	$^4P_{\lambda}\,\frac{1}{2}^-$	$^4P_{\lambda}\,\frac{3}{2}^-$	$^4P_{\lambda}\,\frac{5}{2}^-$
mass(MeV)	4271	4325	4208	4252	4303





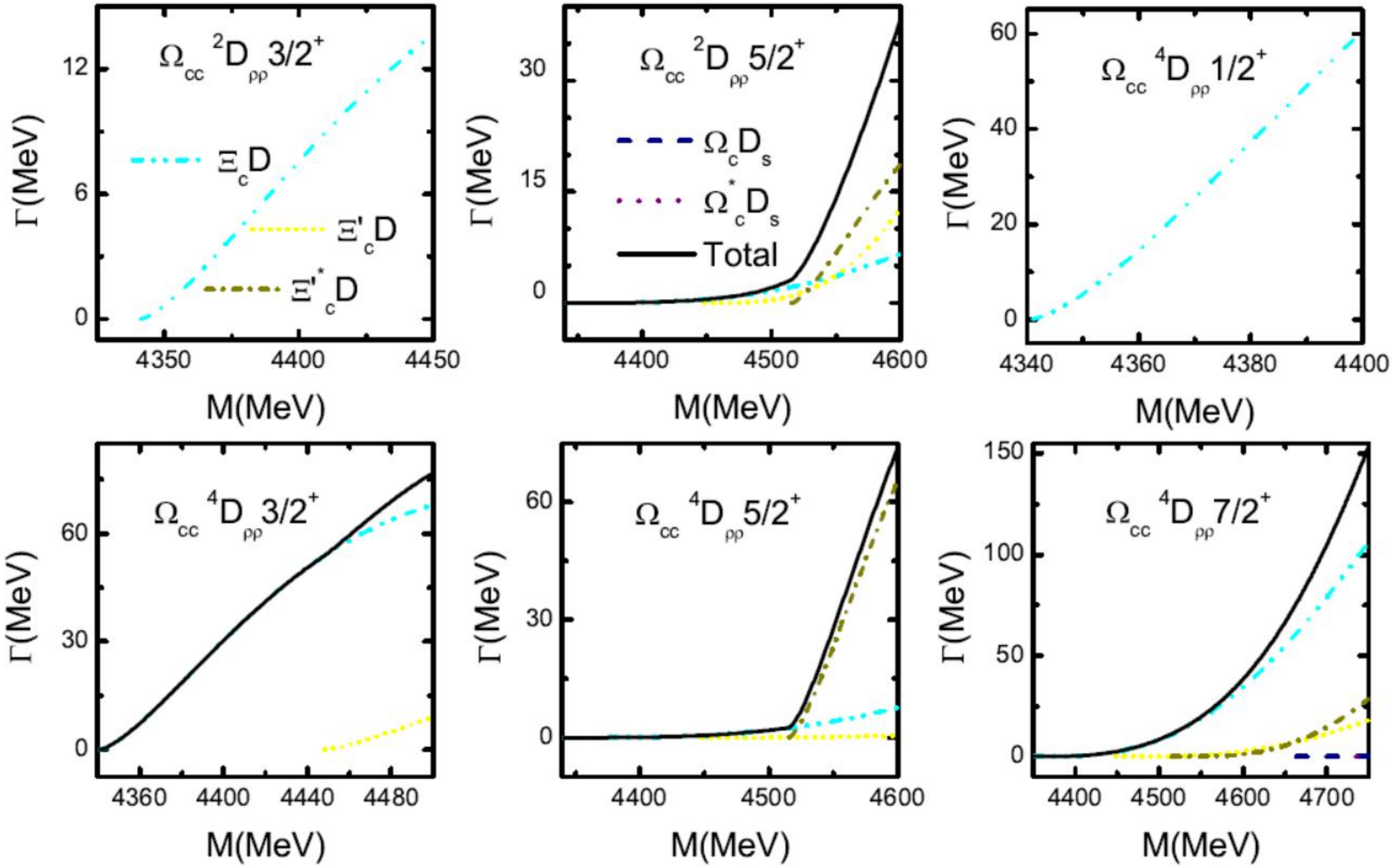


Result: $\Xi^{++}_{cc}2D_{\rho\rho}$



The main decay channels are sensitive to the masses.

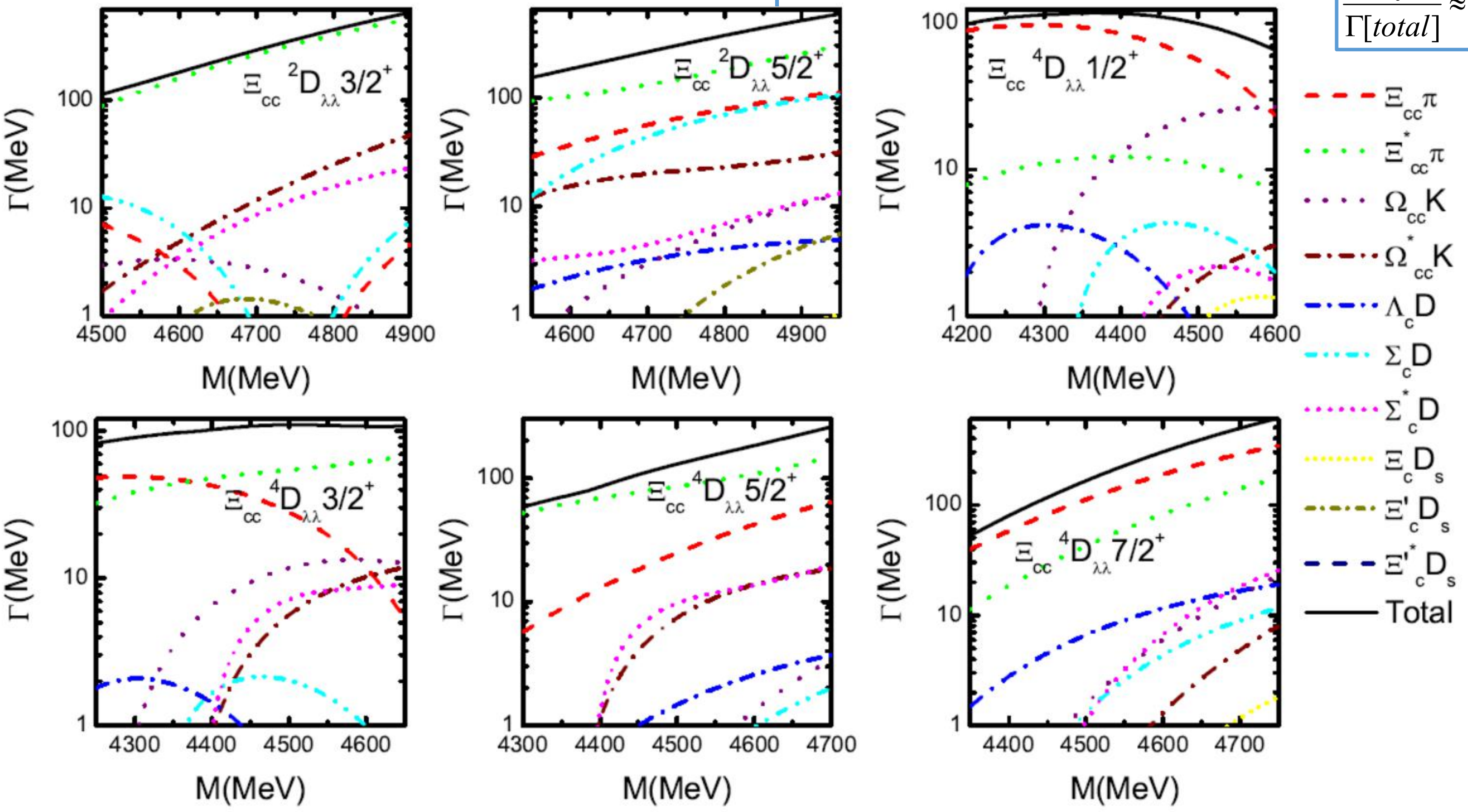
Result: $\Omega_{cc}2D_{\rho\rho}$



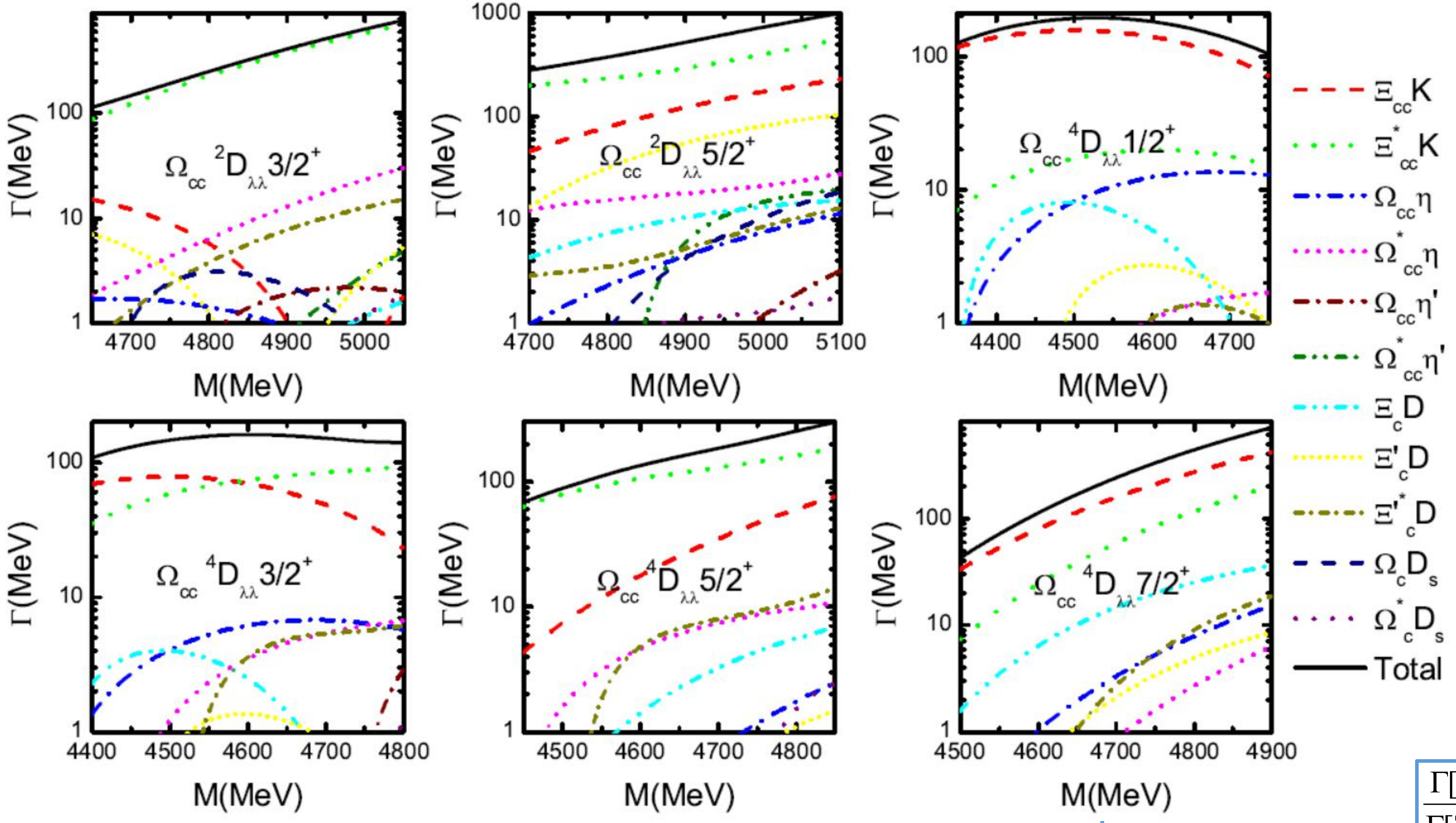
The main decay channels are sensitive to the masses.

Result: $\Xi^{++}_{cc}2D_{\lambda\lambda}$

$$\frac{\Gamma[\Sigma_c D]}{\Gamma[total]} \approx (8-18)\%$$



Result: $\Omega_{cc}2D_{\lambda\lambda}$



$$\frac{\Gamma[\Xi_c D]}{\Gamma[\Xi_{cc} K]} \approx (4.6-8.7)\%$$

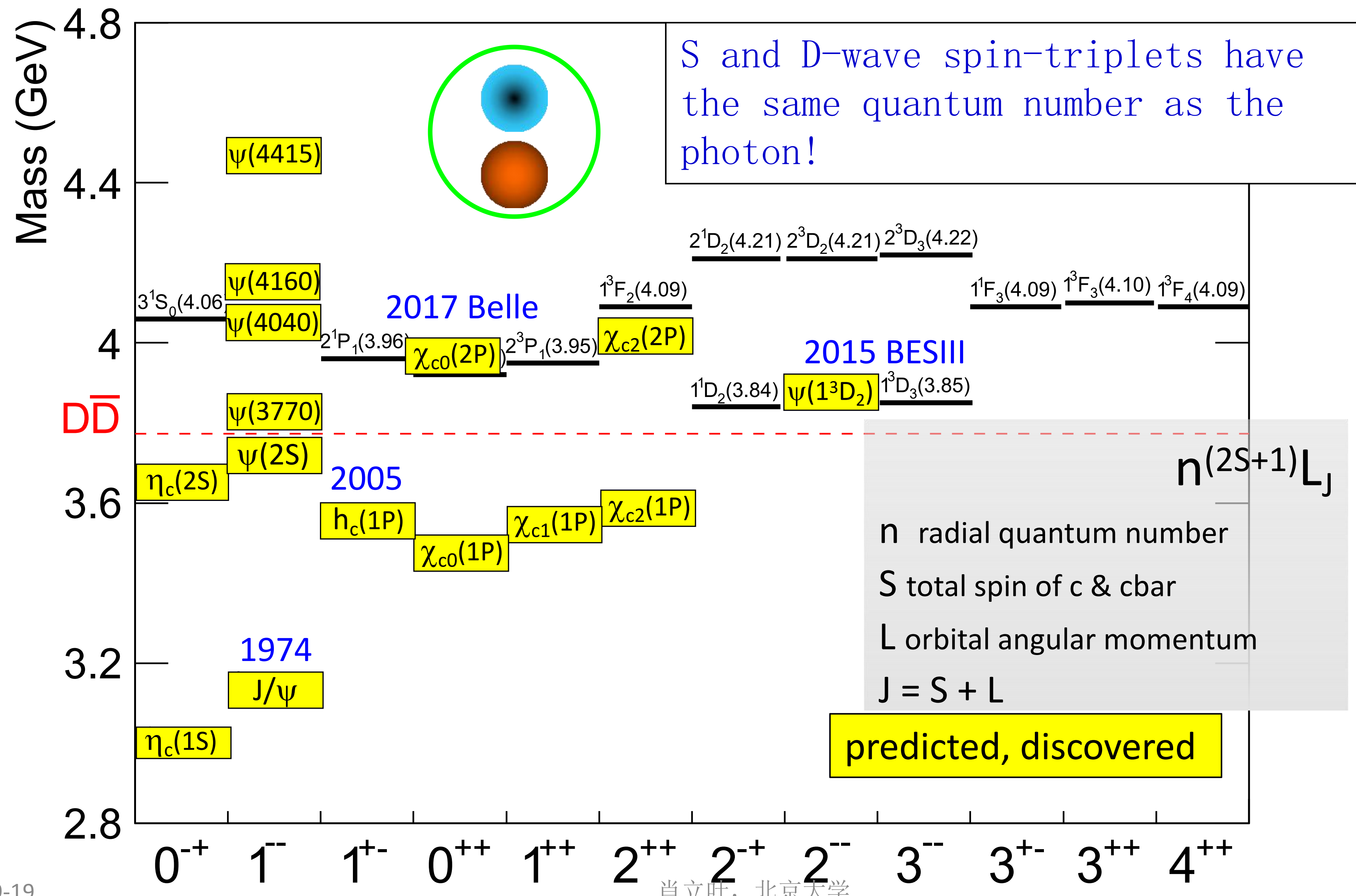
Summary: Doubley charmed baryons with $^3P_0$ model

The strong decay properties of the doubly charmed baryons: Ξ^{++}_{cc} and Ω_{cc}

- For the 1P ρ mode states: $\Gamma \backsim$ fairly narrow
- For the 1P λ mode states: $\Gamma \backsim$ 100 MeV
- For the $2D_{\rho\rho}$ states: They mainly decay via emitting a heavy-light meson
  $\Gamma \backsim$ several tens MeV
- For the $2D_{\lambda\lambda}$ states: $\Gamma >$ 100 MeV

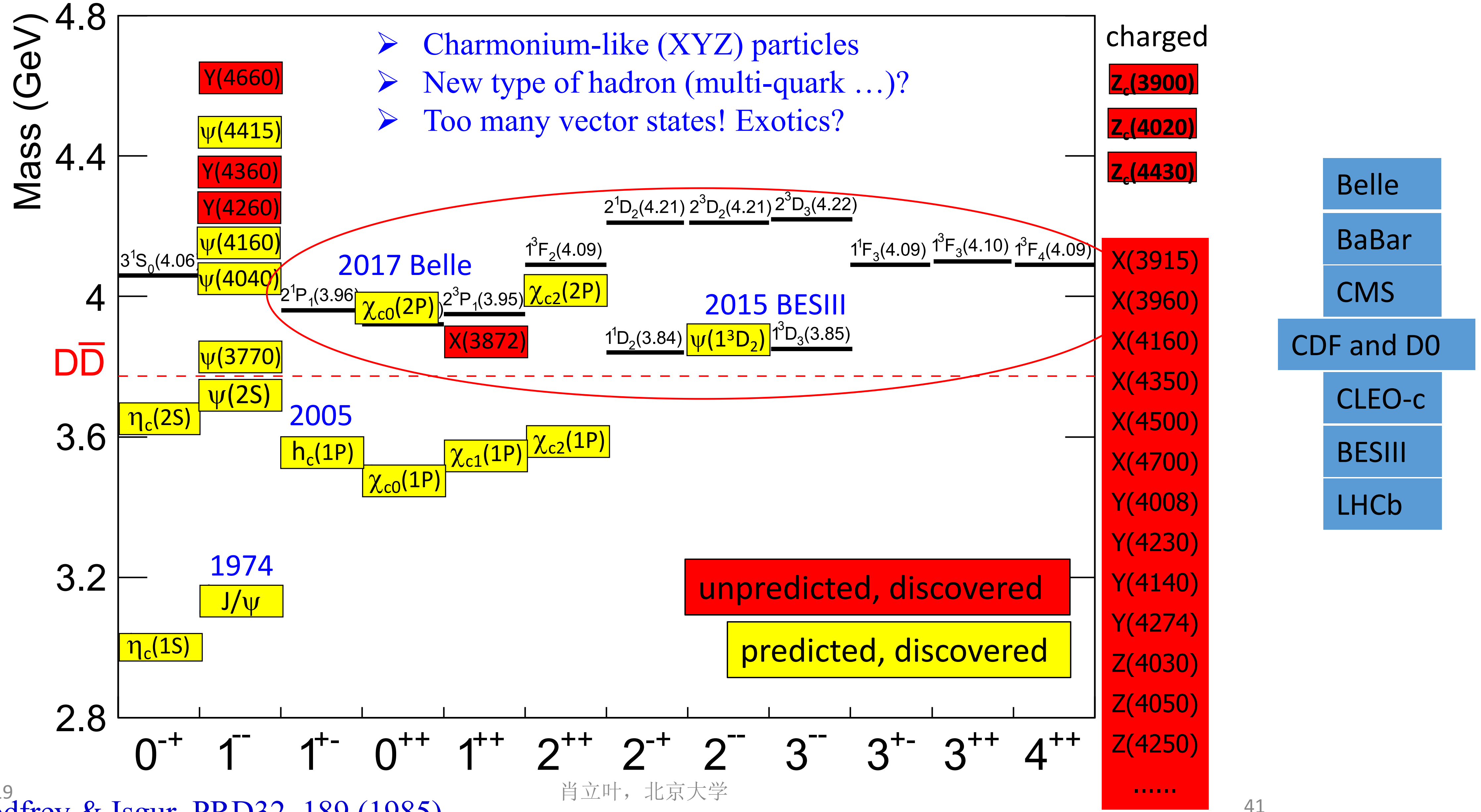
$Y(4660) \to \Lambda_c \bar{\Lambda}_c$

Charmonium spectroscopy



Godfrey & Isgur, PRD32, 189 (1985)

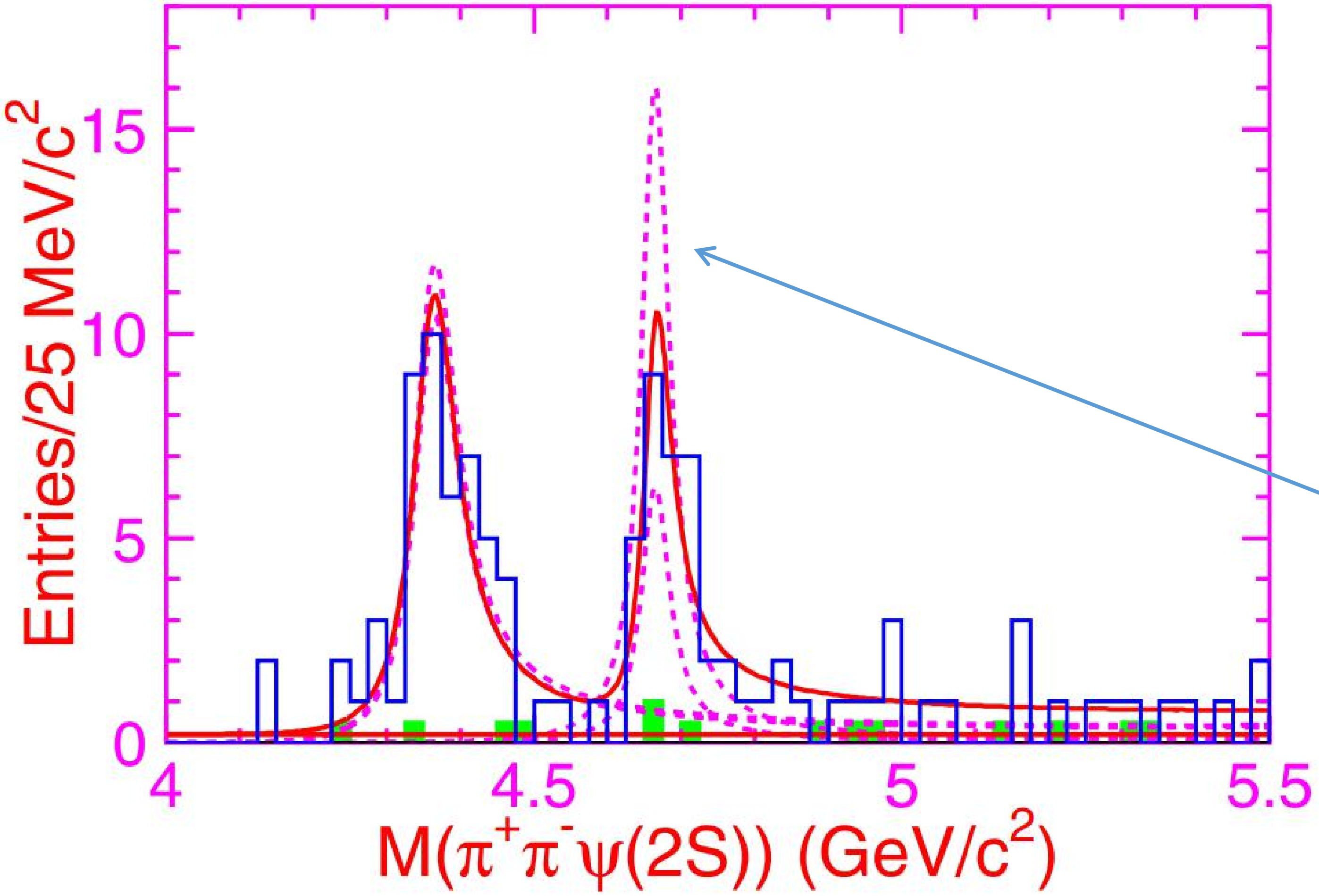
Charmonium(like) spectroscopy

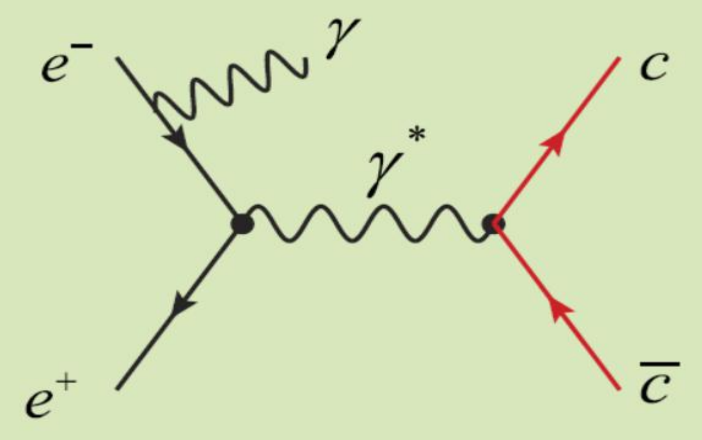


Godfrey & Isgur, PRD32, 189 (1985)

Y(4660) : first observation at Belle

PRL99 142002(2007)
673/fb data



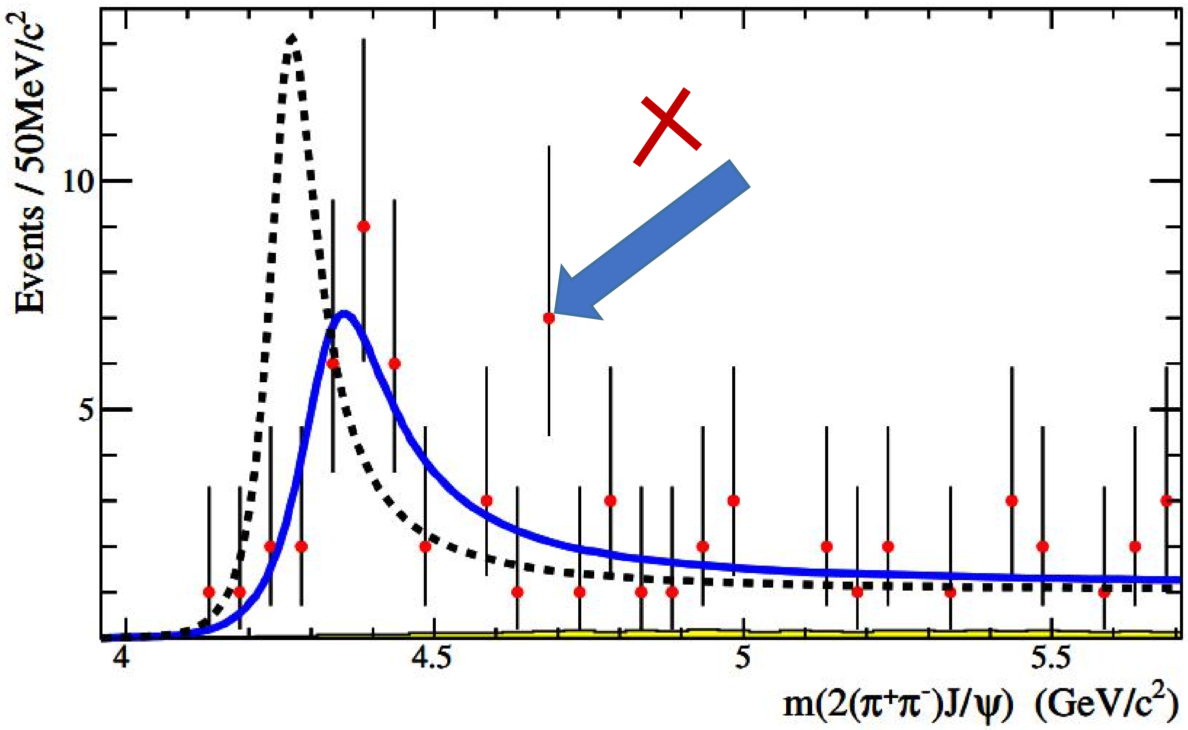


$$M(Y(4660)) = 4664 \pm 11 \pm 5 MeV$$
$$\Gamma_{tot}(Y(4660)) = 48 \pm 15 \pm 3 MeV$$

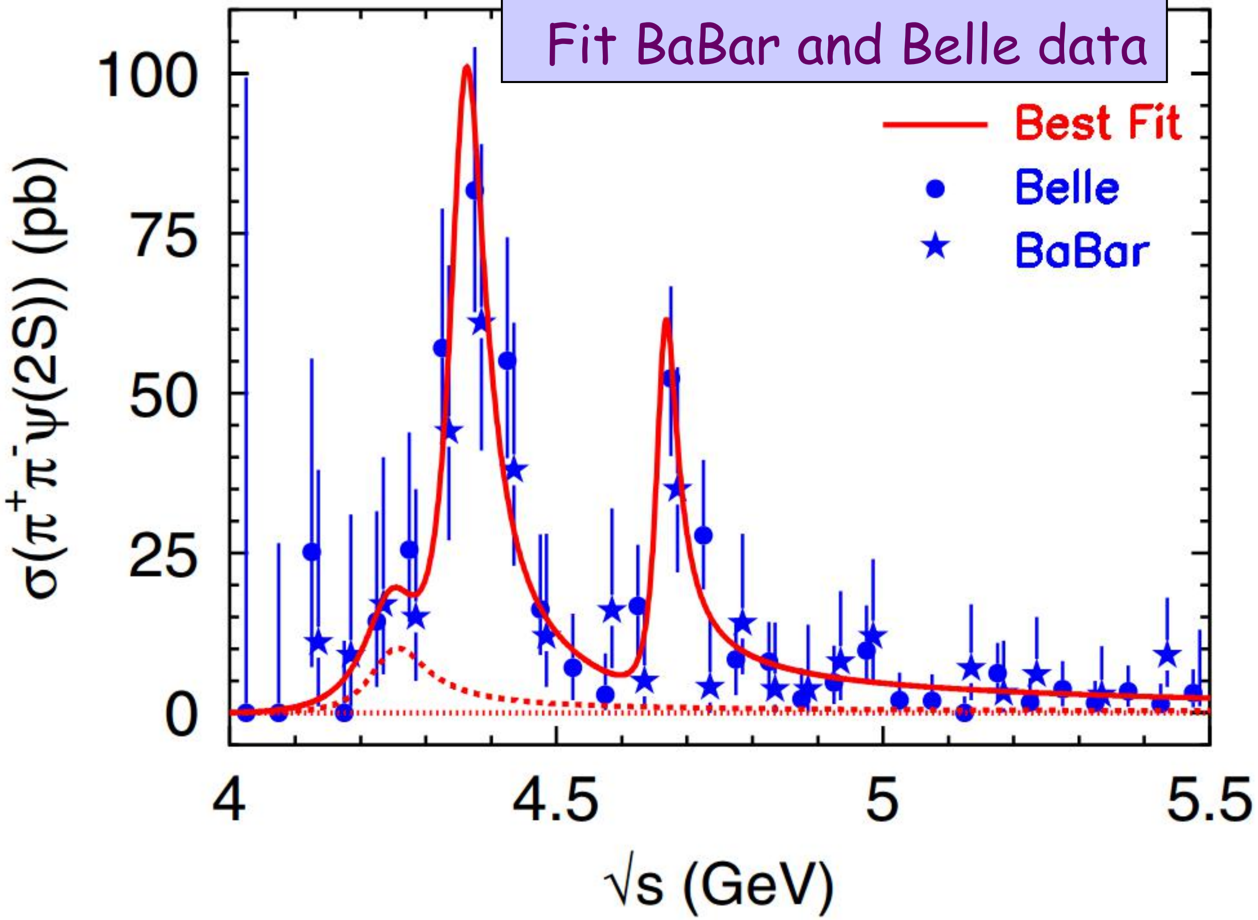
5.8σ

Y(4660) : not be confirmed by BaBar

PRL98 212001(2007)
298/fb data



PRD78 014032(2008)
Fit BaBar and Belle data

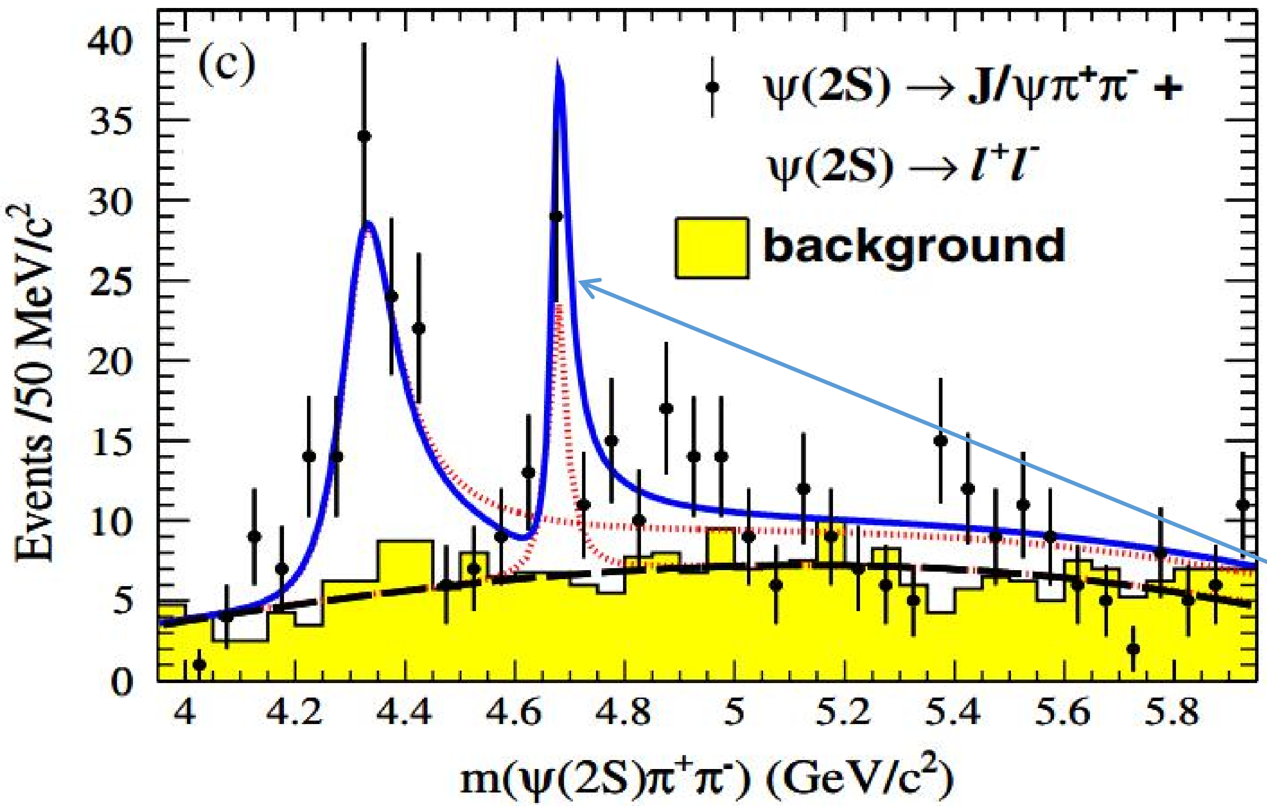


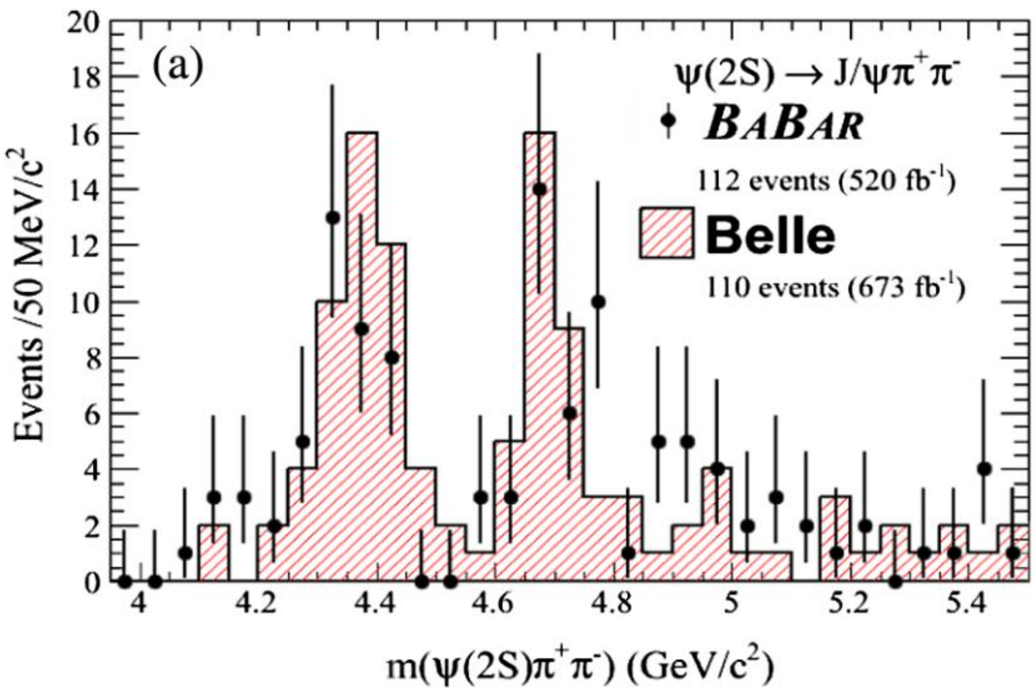
$$M(Y(4660)) = 4661^{+9}_{-8} \pm 6 MeV$$

$$\Gamma(Y(4660)) = 42^{+17}_{-12} \pm 6 MeV$$

Y(4660) : confirmation by BaBar in 2012

PRD89 111103(2014)
520/fb data



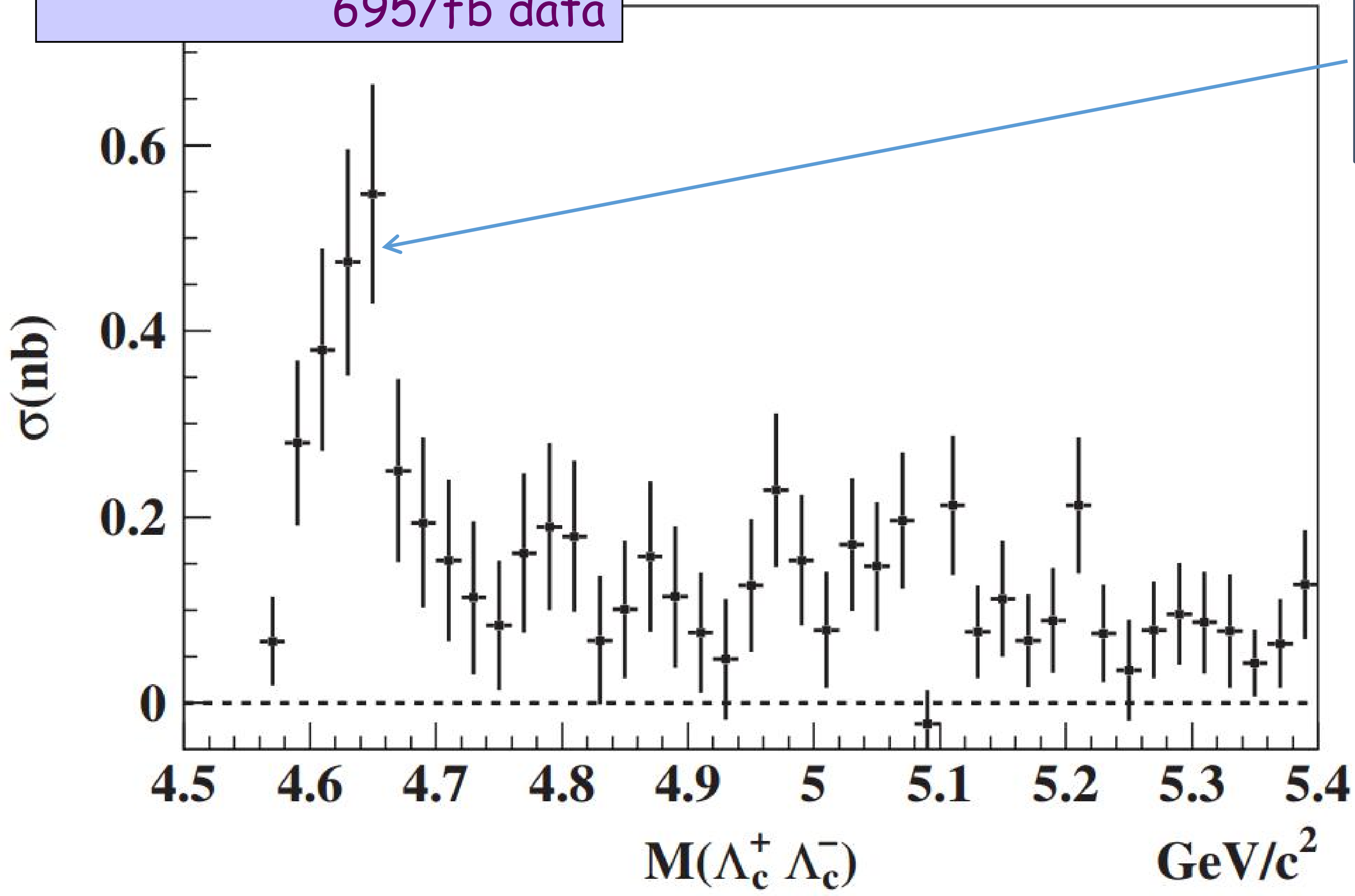


$$M(Y(4660)) = 4669 \pm 21 \pm 3 MeV$$
$$\Gamma_{tot}(Y(4660)) = 104 \pm 48 \pm 10 MeV$$

5.7σ

Y(4630) : first observation at Belle

PRL101 172001(2008)
695/fb data



$$M(Y(4630)) = 4634^{+8}_{-7}(stat)^{+5}_{-8}(syst)MeV$$

$$\Gamma_{tot}(Y(4630)) = 92^{+40}_{-24}(stat)^{+10}_{-21}(syst)MeV$$

8.2σ

consistent with Y(4660)

Y(4660) and Y(4630): interpretation in theory

Y(4660)

- As charmonium state:
  - $\psi(6S)$
  - $\psi(5D)$
  - $\psi(5S)$
  - $\psi(4D)$
  - $\psi(4S)$
  - $\psi(3D)$
- As exotic state:
  - $\psi' f_0(980)$ bound state
  - tetraquark state
  - hadro-charmonium state

Y(4630)

- As exotic state:
  - $\Lambda_c \bar{\Lambda}_c$ bound state
  - tetraquark state

Y(4660) and Y(4630)

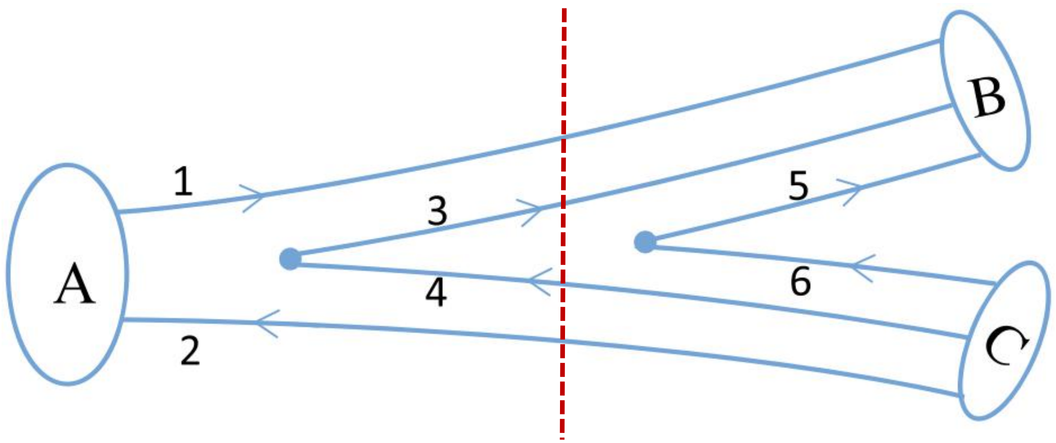
- As charmonium state:
  - tetraquark state
  - $\psi' f_0(980)$ bound state

Phys. Rept. 639, 1-121 (2016)

$^3P_0$ model: $\psi(nS/nD)\to\Lambda_c\bar{\Lambda}_c$

$A(\text{initial meson}) \to B(\text{final baryon}) + C(\text{final baryon})$

$$H_{q\bar{q}} = \gamma \sum_f 2m_f \int d^3x \bar{\psi}_f \psi_f$$



$$\delta^3(\mathbf{p}_A - \mathbf{p}_B - \mathbf{p}_C) M^{M_{J_A} M_{J_B} M_{J_B}} = \frac{\sum_k \langle BC|H_{q\bar{q}}|k\rangle\langle k|H_{q\bar{q}}|A\rangle}{E_k - E_A}.$$

hadron level: $J^P=1^{--}$

PRD89 114010(20014)

$D\bar{D}_1, D^*\bar{D}_1, D^*\bar{D}_0, D^*\bar{D}_2, J/\psi\ f_0(500)/f_0(600),$

$h_c(1P)\eta, h_c(1P)\pi, \chi_{c0}(1P)\omega(782), \chi_{c2}(1P)\omega(782)$

~ 4.0GeV

quark level: intermediate state - initial state = two quarks

$Ek - EA \approx 0.6GeV \approx 2m_q$ as a constant

$^3P_0$ model: $\psi(nS/nD)\to\Lambda_c\bar{\Lambda}_c$

$$H_{q\bar{q}}=\gamma\sum_f 2m_f\int d^3x\bar{\psi}_f\psi_f$$

$$T=\frac{9\gamma^2}{4m_\mu}\sum_{m,m'}\langle 1m;1-m|00\rangle\langle 1m';1-m'|00\rangle$$
$$\times\int d^3\mathbf{p}_3d^3\mathbf{p}_4d^3\mathbf{p}_5d^3\mathbf{p}_6\delta^3(\mathbf{p}_3+\mathbf{p}_4)\delta^3(\mathbf{p}_5+\mathbf{p}_6)$$
$$\times\varphi_0^{34}\omega_0^{34}\chi_{1,-m}^{34}\mathcal{Y}_1^m\left(\frac{\mathbf{p}_3-\mathbf{p}_4}{2}\right)a_{3i}^\dagger b_{4j}^\dagger$$
$$\times\varphi_0^{56}\omega_0^{56}\chi_{1,-m'}^{56}\mathcal{Y}_1^{m'}\left(\frac{\mathbf{p}_5-\mathbf{p}_6}{2}\right)a_{5i}^\dagger b_{6j}^\dagger,$$

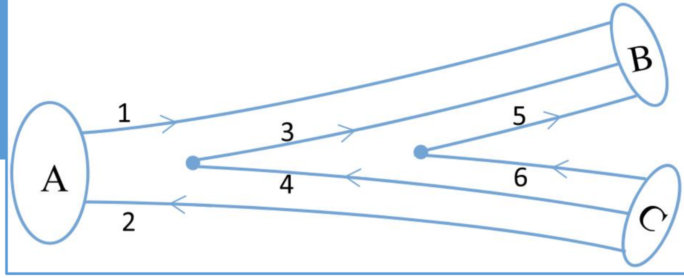
$$\delta^3(\mathbf{p}_A-\mathbf{p}_B-\mathbf{p}_C)M^{M_{J_A}M_{J_B}M_{J_B}}=\frac{\sum_k\langle BC|H_{q\bar{q}}|k\rangle\langle k|H_{q\bar{q}}|A\rangle}{E_k-E_A}.$$

nonrelativistic limit

$$\frac{\langle BC|H_{q\bar{q}}H_{q\bar{q}}|A\rangle}{2m_q}$$

$$Ek-EA\approx 0.6GeV\approx 2m_q\qquad\text{as a constant}$$

$^3P_0$ model: $\psi(nS/nD)\to\Lambda_c\bar{\Lambda}_c$



C. Hayne and N. Isgur, Phys.Rev. D25,1944(1982).

- meson wave function

$$
\begin{aligned}
|A(N_A\,{}^{2S_A+1}L_A J_A M_{J_A})(\mathbf{p}_A)\rangle &= \sqrt{2E_A}\varphi_A^{12}\omega_A^{12} \\
&\times \sum_{M_{L_A},M_{S_A}} \langle L_A M_{L_A}; S_A M_{S_A}|J_A M_{J_A}\rangle \\
&\times \int d^3\mathbf{p}_1 d^3\mathbf{p}_2 \delta^3(\mathbf{p}_1+\mathbf{p}_2-\mathbf{p}_A) \\
&\times \Psi_{N_A L_A M_{L_A}(\mathbf{p}_1,\mathbf{p}_2)} \chi^{12}_{S_A M_{S_A}} |q_1(\mathbf{p}_1) q_2(\mathbf{p}_2)\rangle,
\end{aligned}
$$

SHO wave function

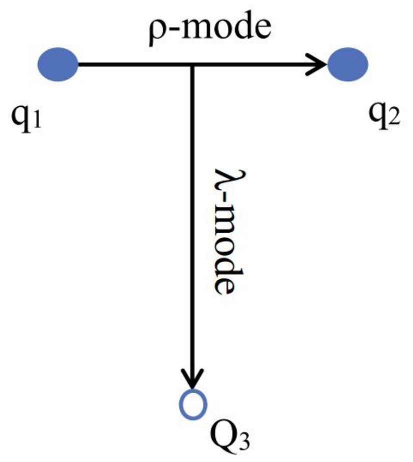
spatial wave function

$$
\psi^0_{lm}(\mathbf{p}) = (-i)^l \left[\frac{2^{l+2}}{\sqrt{\pi}(2l+1)!!}\right]^{\frac{1}{2}} \left(\frac{1}{\beta}\right)^{l+\frac{3}{2}} \times \exp\left(-\frac{\mathbf{p}_R^2}{2\beta^2}\right) \mathcal{Y}_l^m(\mathbf{p}),
$$

$$
\psi_{0,0} = 3^{\frac{3}{4}} \left(\frac{1}{\pi\alpha_\rho^2}\right)^{\frac{3}{4}} \left(\frac{1}{\pi\alpha_\lambda^2}\right)^{\frac{3}{4}} \exp\left(-\frac{\mathbf{p}_\rho^2}{2\alpha_\rho^2} - \frac{\mathbf{p}_\lambda^2}{2\alpha_\lambda^2}\right)
$$

- baryon wave function

$$
\begin{aligned}
|B(N_B\,{}^{2S_B+1}L_B J_B M_{J_B})(\mathbf{p}_B)\rangle &= \sqrt{2E_B}\varphi_B^{135}\omega_B^{135} \\
&\times \sum_{M_{L_B},M_{S_B}} \langle L_B M_{L_B}; S_B M_{S_B}|J_B M_{J_B}\rangle \\
&\times \int d^3\mathbf{p}_1 d^3\mathbf{p}_3 d^3\mathbf{p}_5 \delta^3(\mathbf{p}_1+\mathbf{p}_3+\mathbf{p}_5-\mathbf{p}_B) \\
&\times \Psi_{N_B L_B M_{L_B}(\mathbf{p}_1,\mathbf{p}_3,\mathbf{p}_5)} \chi^{135}_{S_B M_{S_B}} |q_1(\mathbf{p}_1) q_3(\mathbf{p}_3) q_5(\mathbf{p}_5)\rangle.
\end{aligned}
$$

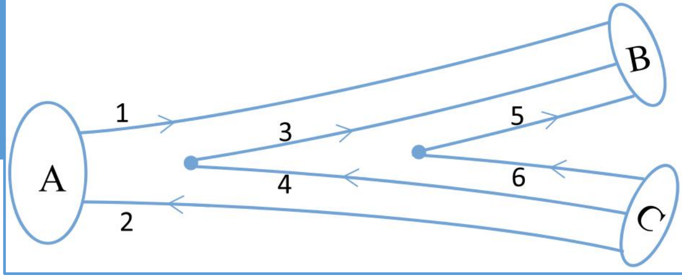


$$\rho = \frac{\mathbf{r}_1 - \mathbf{r}_2}{\sqrt{2}}$$

$$\lambda = \frac{\mathbf{r}_1 + \mathbf{r}_2 - 2\mathbf{r}_3}{\sqrt{6}}$$

$$\alpha_\lambda = \left(\frac{3m_Q}{2m_q + m_Q}\right)^{1/4} \alpha_\rho$$

$^3P_0$ model：$\psi(nS/nD)\to\Lambda_c\bar{\Lambda}_c$



$$\Gamma[A\to BC]=\pi^2\frac{|\mathbf{p}|}{M_A^2}\frac{1}{2J_A+1}\times\sum_{M_{J_A},M_{J_B},M_{J_C}}|\mathcal{M}^{M_{J_A}M_{J_B}M_{J_C}}|^2$$

$$\mathcal{M}_{4S}=\frac{1}{3\sqrt{35}}\left(15\beta\frac{\partial}{\partial\beta}+6\beta^2\frac{\partial^2}{\partial\beta^2}+2\beta^3\frac{\partial^3}{\partial\beta^3}\right)\mathcal{M}_{1S},$$

$$\mathcal{M}_{5S}=\frac{1}{18\sqrt{70}}\left(63+72\beta\frac{\partial}{\partial\beta}+96\beta^2\frac{\partial^2}{\partial\beta^2}+24\beta^3\frac{\partial^3}{\partial\beta^3}+4\beta^4\frac{\partial^4}{\partial\beta^4}\right)\mathcal{M}_{1S},$$

$$\mathcal{M}_{6S}=\frac{1}{45\sqrt{77}}\left(\frac{675}{2}\beta\frac{\partial}{\partial\beta}+240\beta^2\frac{\partial^2}{\partial\beta^2}+120\beta^3\frac{\partial^3}{\partial\beta^3}+20\beta^4\frac{\partial^4}{\partial\beta^4}+2\beta^5\frac{\partial^5}{\partial\beta^5}\right)\mathcal{M}_{1S},$$

$$\mathcal{M}_{3D}=\frac{1}{3\sqrt{14}}\left(7+2\beta\frac{\partial}{\partial\beta}+2\beta^2\frac{\partial^2}{\partial\beta^2}\right)\mathcal{M}_{1D},$$

$$\mathcal{M}_{4D}=\frac{1}{3\sqrt{231}}\left(27\beta\frac{\partial}{\partial\beta}+6\beta^2\frac{\partial^2}{\partial\beta^2}+2\beta^3\frac{\partial^3}{\partial\beta^3}\right)\mathcal{M}_{1D},$$

$$\mathcal{M}_{5D}=\frac{1}{6\sqrt{6006}}\left(231+120\beta\frac{\partial}{\partial\beta}+144\beta^2\frac{\partial^2}{\partial\beta^2}+24\beta^3\frac{\partial^3}{\partial\beta^3}+4\beta^4\frac{\partial^4}{\partial\beta^4}\right)\mathcal{M}_{1D}.$$

Result:

$M(Y(4660)) = 4643 \pm 9 MeV$

$\Gamma_{tot}(Y(4660)) = 72 \pm 11 MeV$

TABLE I: The $\Lambda_c\bar{\Lambda}_c$ partial decay widths (MeV) of the vector charmonium with a mass of $M = 4643$ MeV. $\mathcal{B}$ represents the branching ratio of the $\Lambda_c\bar{\Lambda}_c$ pair.

State	$\psi(4^3S_1)$	$\mathcal{B}$	$\psi(5^3S_1)$	$\mathcal{B}$	$\psi(6^3S_1)$	$\mathcal{B}$
$\Gamma_{\Lambda_c\bar{\Lambda}_c}$	6.57	9%	2.44	3%	0.84	1%
State	$\psi(3^3D_1)$	$\mathcal{B}$	$\psi(4^3D_1)$	$\mathcal{B}$	$\psi(5^3D_1)$	$\mathcal{B}$
$\Gamma_{\Lambda_c\bar{\Lambda}_c}$	0.33	0.4%	0.19	0.3%	0.09	0.1%

$\Gamma(\psi(4S/5S/6S) \to \Lambda_c\bar{\Lambda}_c) \backsim$ a few MeV

$\Gamma(\psi(3D/4D/5D) \to \Lambda_c\bar{\Lambda}_c) \backsim$ less than one MeV

If the enhancement Y(4630) in the $\Lambda_c\bar{\Lambda}_c$ invariant-mass distribution is the same atructure as Y(4660), the Y(4660) resoannce is most likely to be a S-wave charmonium state.

Result:

TABLE II: The possible assignments of the $Y(4660)$ with the predicted masses (MeV) from various models.

State	QM [47]	QM [48]	QM [49]	SSE/EA[50]	NR/GI [51]	SP [10]	LP/SP [52]
$\psi(4^3S_1)$	4625	4450	4389	4398/4426	4406/4450	4273	4412/4281
$\psi(5^3S_1)$	⋯	⋯	4641	4642/4672	⋯	4463	4711/4472
$\psi(6^3S_1)$	⋯	⋯	⋯	4804/4828	⋯	4608	⋯
$\psi(3^3D_1)$	⋯	4520	4426	4464/4477	⋯	4317	4478/4336
$\psi(4^3D_1)$	⋯	⋯	4641	4690/4707	⋯	⋯	⋯
$\psi(5^3D_1)$	⋯	⋯	⋯	4840/4855	⋯	⋯	⋯

10、 PRD79,094004 (2009).

47、 PRD72,094004 (2005).

48、 PRD21,203 (1980).

49、 PRD32,189 (1985).

50、 arXiv:0810.2875.

51、 Phys. Atom. Nucl.72,638 (2009).

52、 PRD72,054026 (2005).

Result:

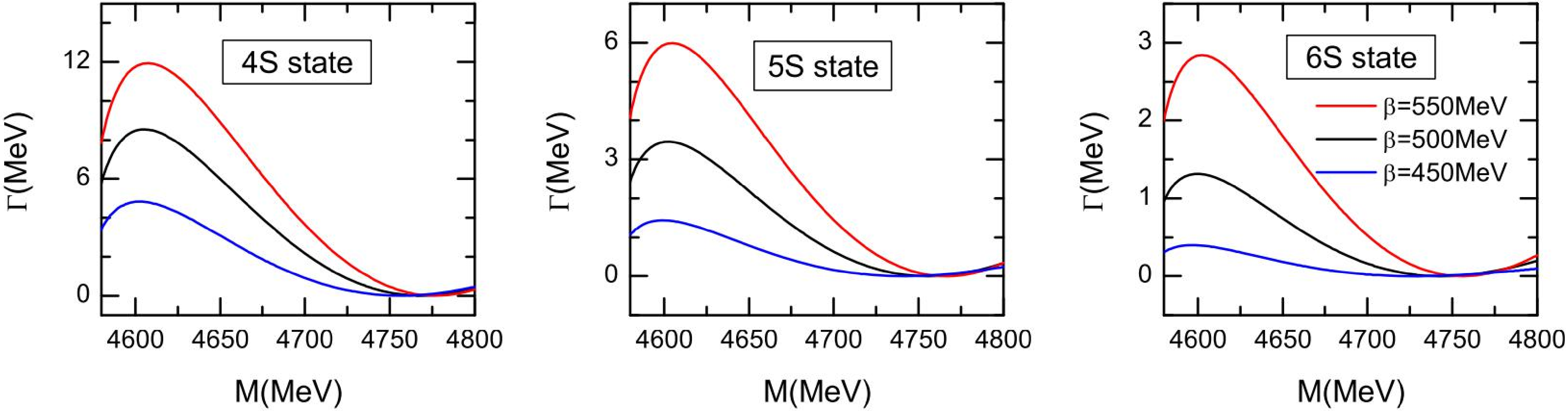
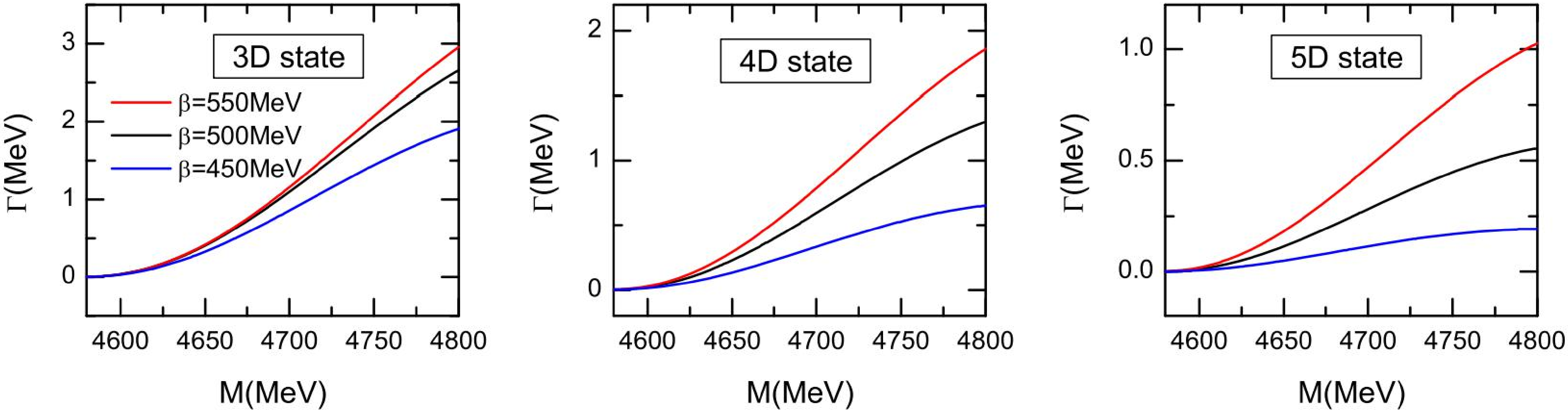


Fig. 3 The variation of the $\Lambda_c\overline{\Lambda}_c$ decay width with the mass of the S-wave vector charmonium. The blue, black, and red lines correspond to the predictions with different values of the harmonic oscillator strength $\beta = 450$, 500, and 550 MeV, respectively

Result:


3D state
β=550MeV
β=500MeV
β=450MeV
Γ(MeV)
M(MeV)
0
1
2
3
4600
4650
4700
4750
4800
4D state
Γ(MeV)
M(MeV)
0
1
2
5D state
Γ(MeV)
M(MeV)
0.0
0.5
1.0

Summary

- The $\Lambda_c\bar{\Lambda}_c$ partial decay width of the excited vector charmonium states around 4.6 GeV:

  ★ $\Gamma(\psi(4S/5S/6S)\rightarrow\Lambda_c\bar{\Lambda}_c)$ ∽ a few MeV

  ★ $\Gamma(\psi(3D/4D/5D)\rightarrow\Lambda_c\bar{\Lambda}_c)$ ∽ less than one MeV

- If the enhancement Y(4630) in the $\Lambda_c\bar{\Lambda}_c$ invariant-mass distribution is the same atructure as Y(4660), the Y(4660) resoannce is most likely to be a S-wave charmonium state.

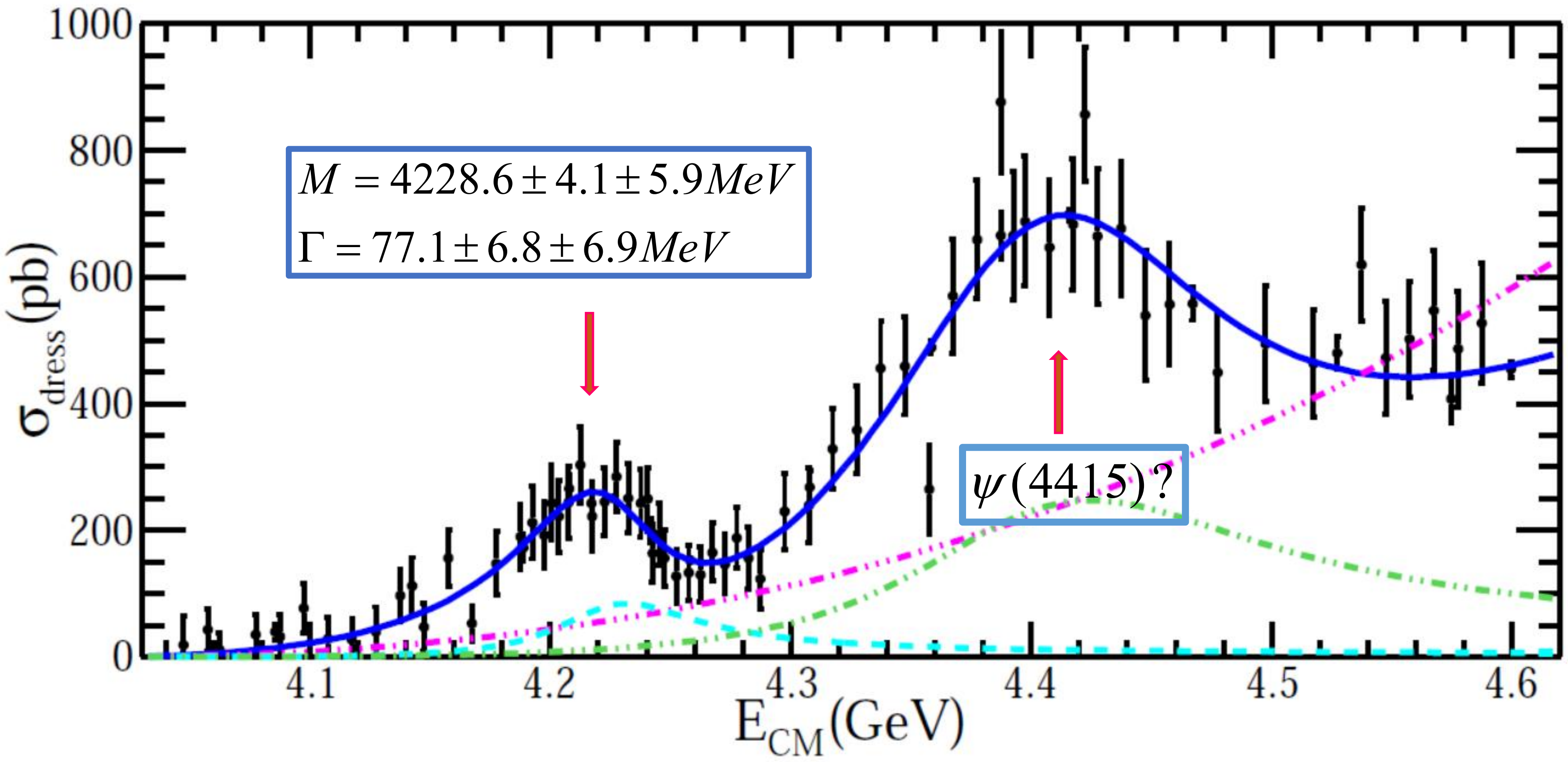
- This OZI allowed mode provides a new tool to explore the higer charmonium, which can be produced abundantly at Belle-II.

Outlook

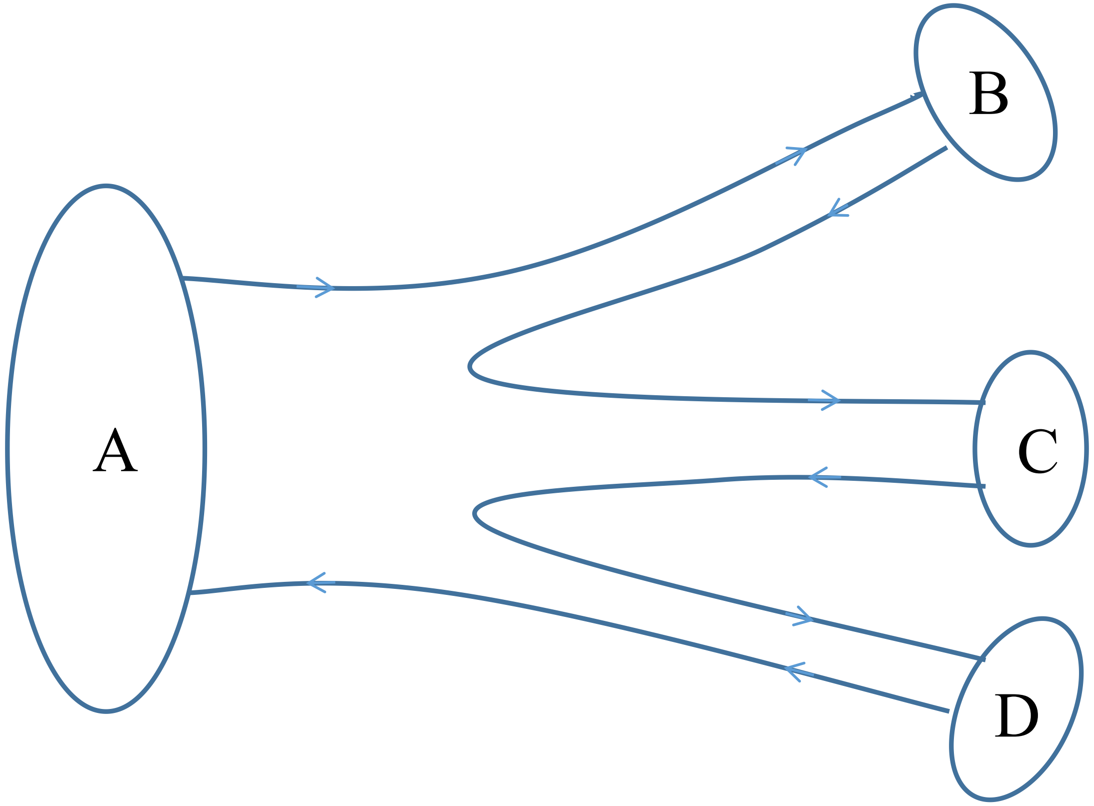
Evidence of a resonant structure in the $e^+e^- \to \pi^+ D^0 D^{*-}$ cross section between 4.05 and 4.60 GeV

(BESIII Collaboration)

arXiv:1808.02847



Outlook



D^0	D^+	D_s^+
$\pi^0/\pi^+/k^+$	$\pi^-/\pi^0/\bar{k}^0$	$k^-/k^0/\eta$
$\bar{D}^0/D^-/D_S^-$		

Thanks