

Recent spectroscopy measurements

Jibo HE (University of Chinese Academy of Sciences)

QCD@LHC 2026, Oxford

Outline

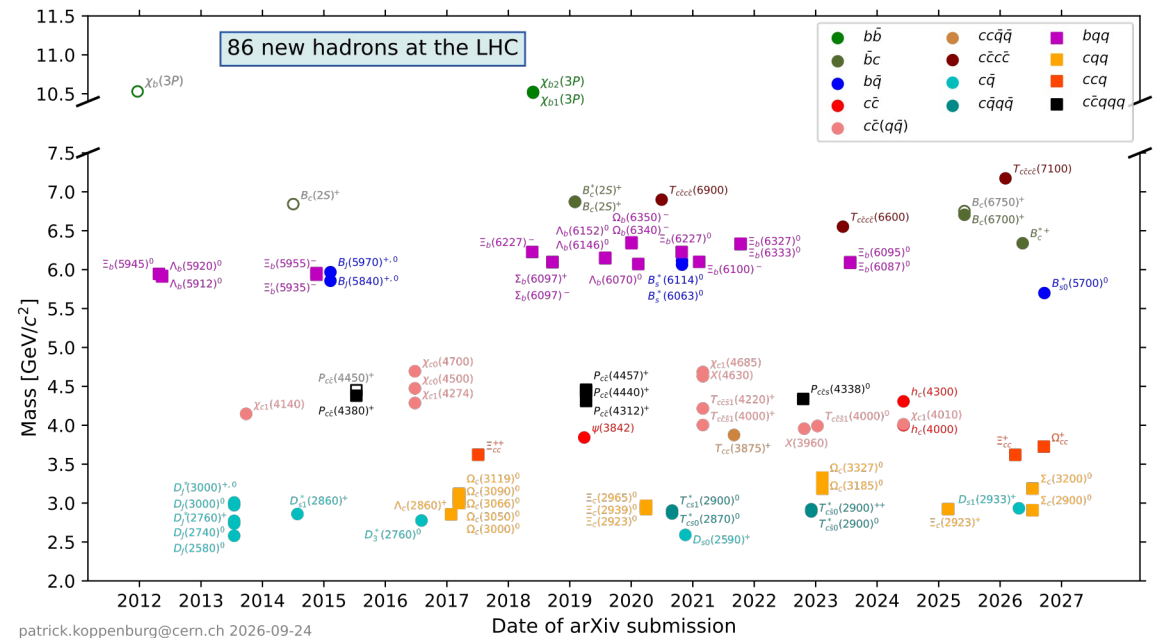
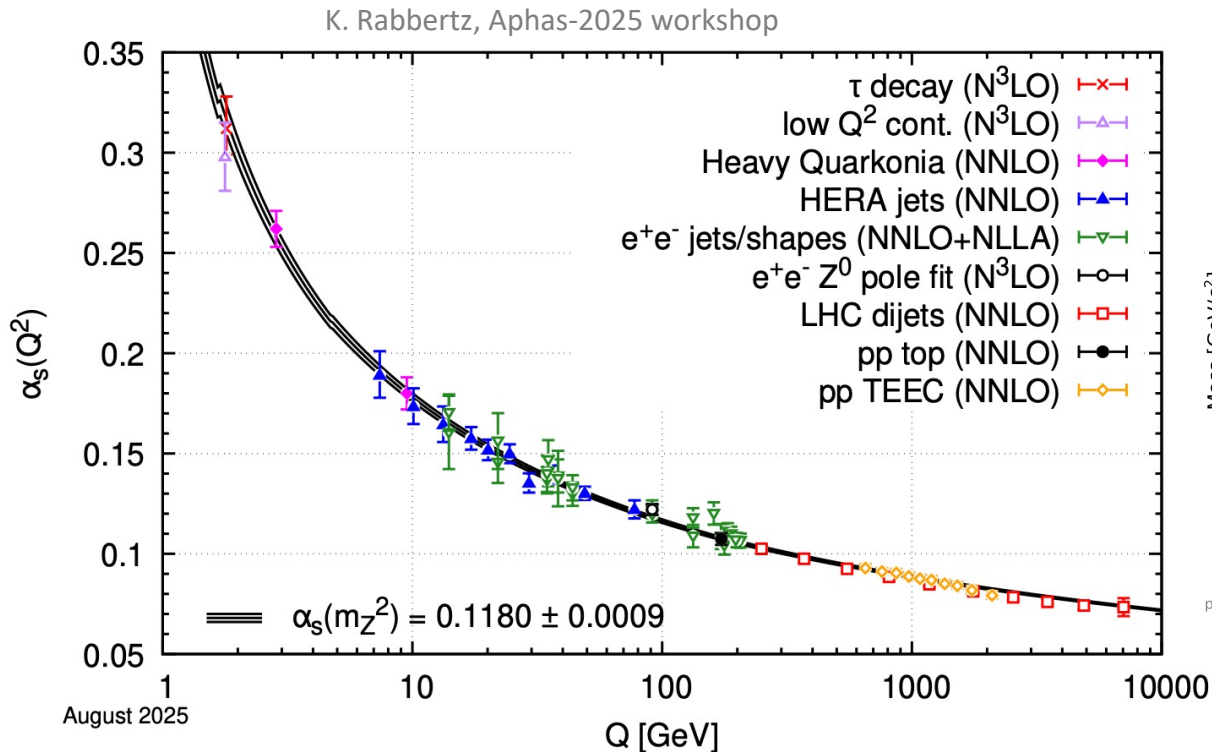
- Introduction
- Mesons: D_{sJ} , B_{sJ} , B_c
- Baryons: (Doubly) charmed baryon
- $X(6900)$ family
- $X(2317)$
- Summary

More on Thursday:

Recent Heavy-Flavor Spectroscopy and Rare Decay Results from ATLAS	<i>Yuxuan Zhang</i>
<i>Seminar Room 8, St Anne's College</i>	16:00 - 16:20
Recent results of hadron spectroscopy at LHCb	<i>Chen Chen</i>
<i>Seminar Room 8, St Anne's College</i>	16:20 - 16:40
Excited heavy mesons and exotics from lattice QCD	<i>Christopher Thomas</i>
<i>Seminar Room 8, St Anne's College</i>	16:40 - 17:00
Recent results in searches for tetraquark states in CMS	<i>Adriano Di Florio</i>
<i>Seminar Room 8, St Anne's College</i>	17:00 - 17:20
All-charm tetraquarks at hadron colliders: A high-precision fragmentation perspective	<i>Dr Francesco Giovanni Celiberto</i>
<i>Seminar Room 8, St Anne's College</i>	17:20 - 17:40

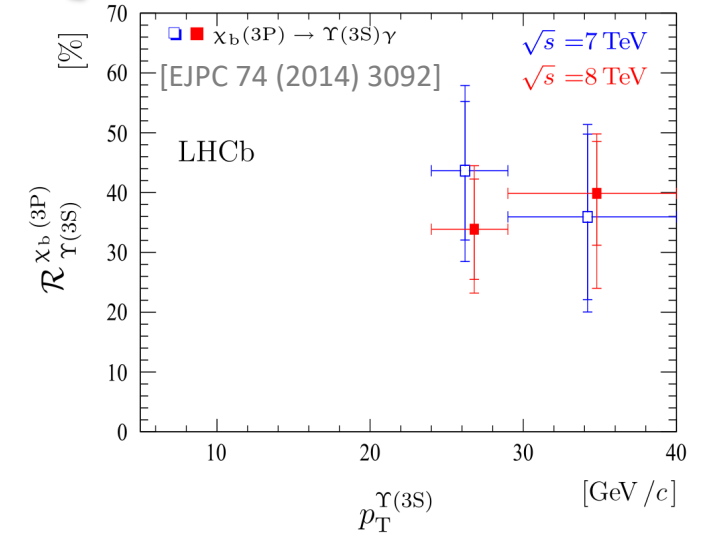
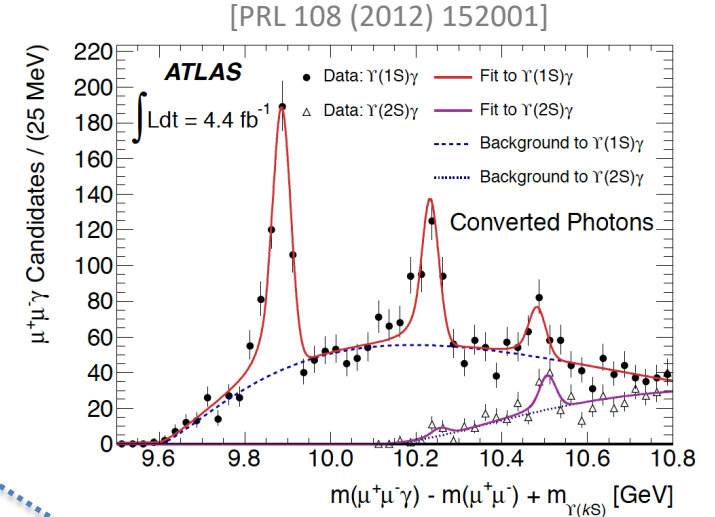
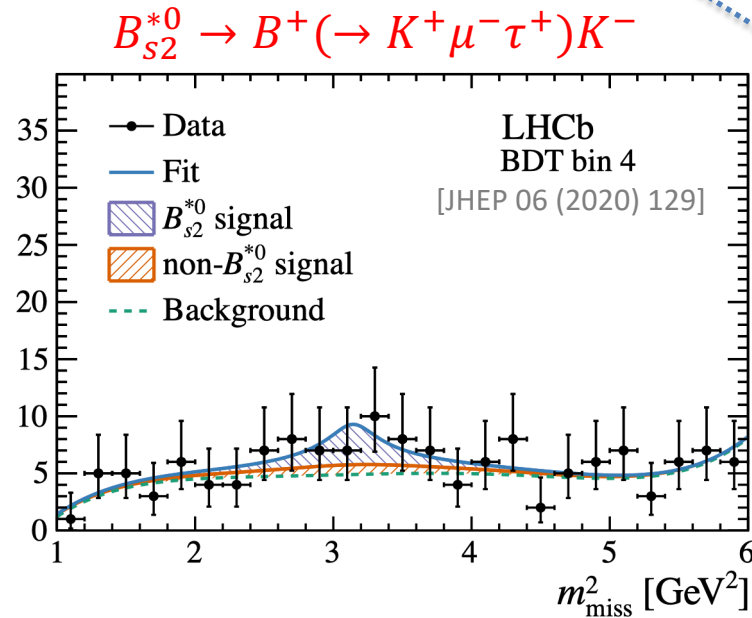
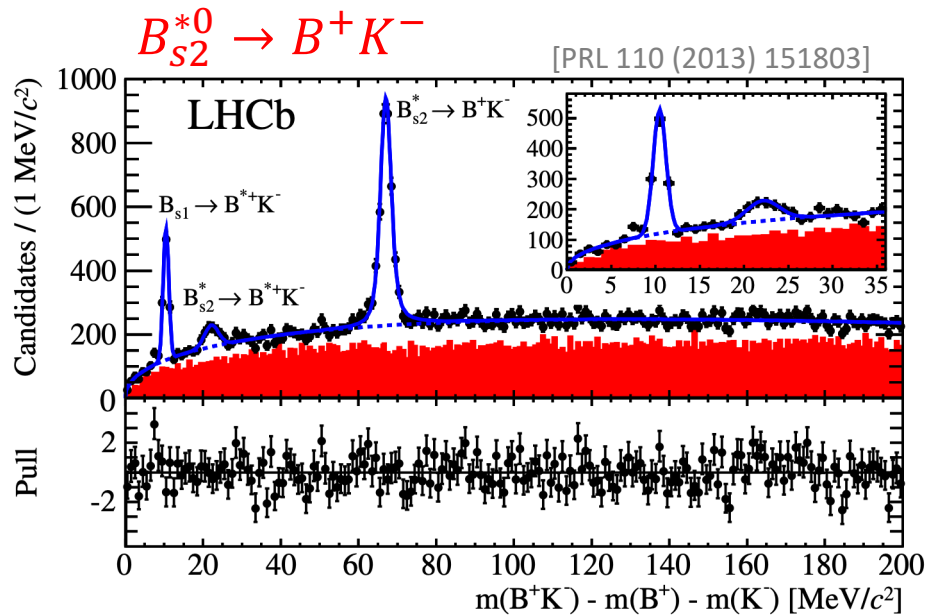
Introduction

- Particle zoo v1 $\Rightarrow$ Quark model; Particle zoo v2?
- Experimental measurements required to determine the nature of particles & calibrate LQCD

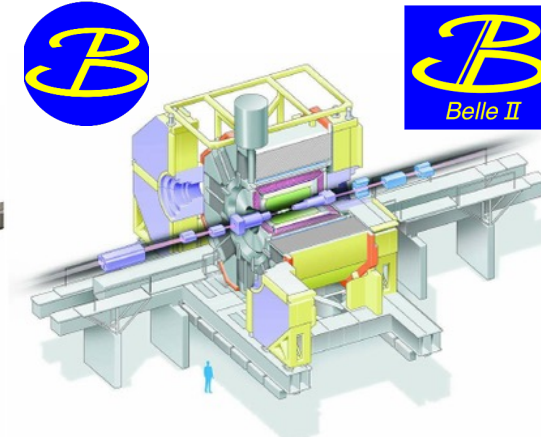
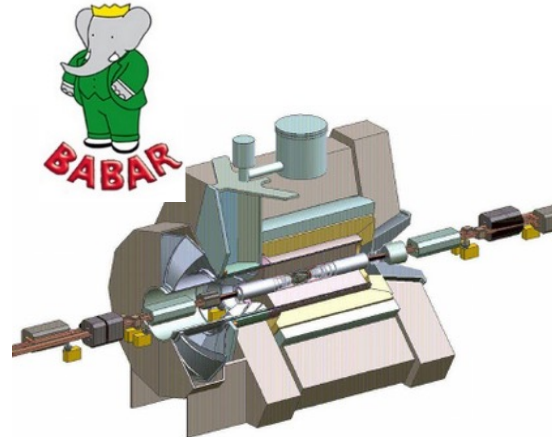
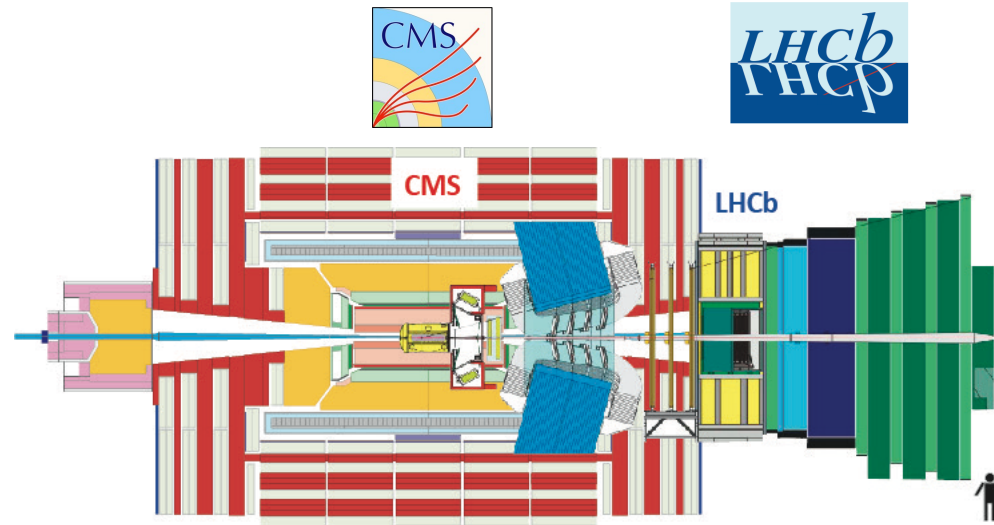
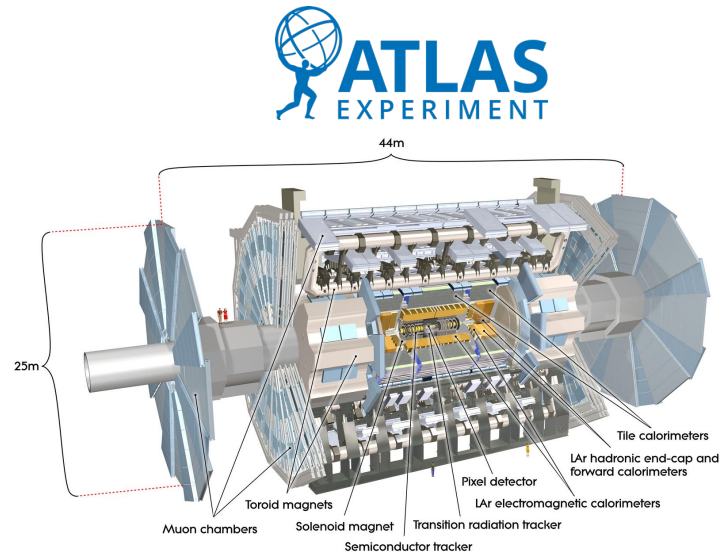


Introduction

- Today's discovery, tomorrow's precision tool
 - B_{s2}^{*0} state, used to tag B^+ , E_{miss} reconstruction
 - $\chi_b(3P)$; $\Upsilon(3S)$ NOT free from feed-down



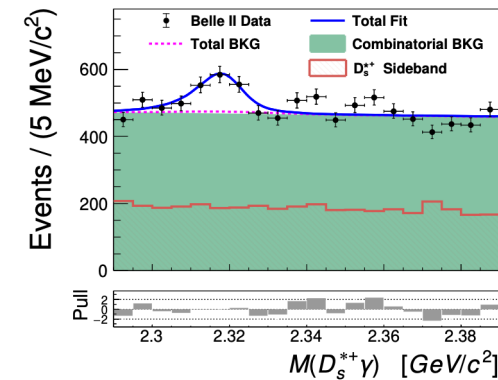
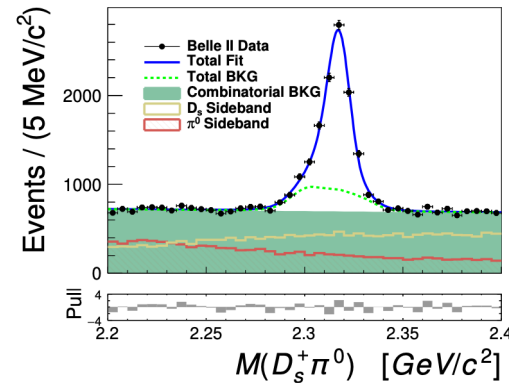
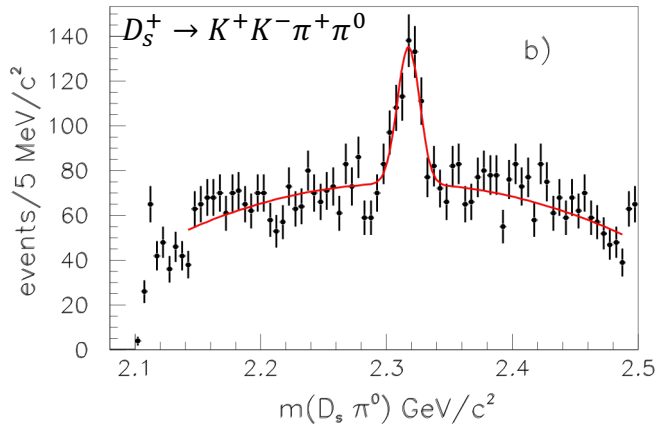
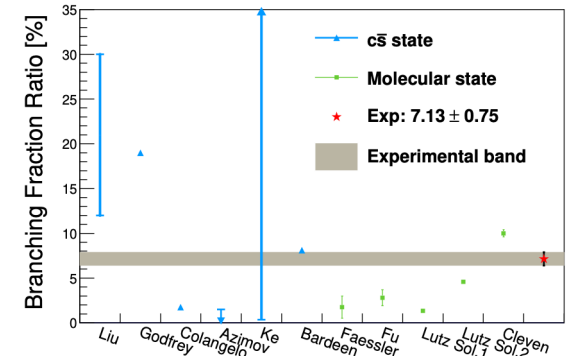
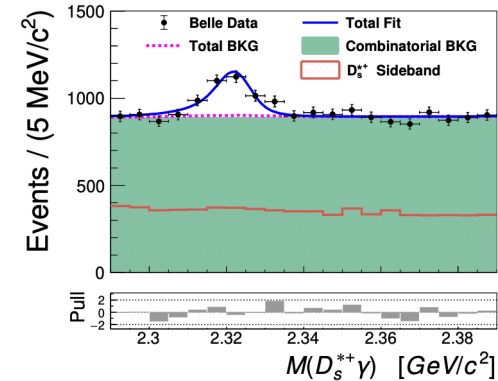
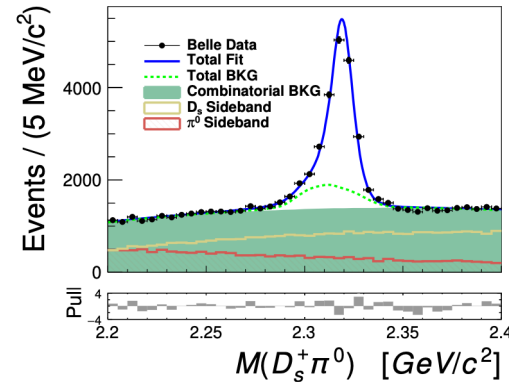
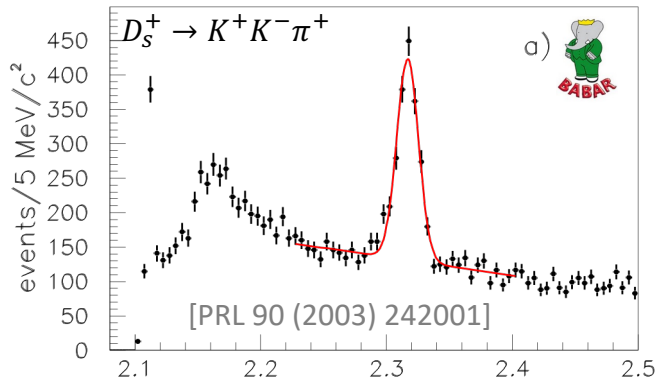
Recent main players



$D_{s0}^*(2317)^+$

$(c\bar{s})?$

- Observed in $m(D_s^+ \pi^0)$ by Babar in 2003, nature still unclear
- $D_{s0}^*(2317)^+ \rightarrow D_s^{*+} \gamma$ observed by Belle+Belle II [PRL 136 (2026) 241901]

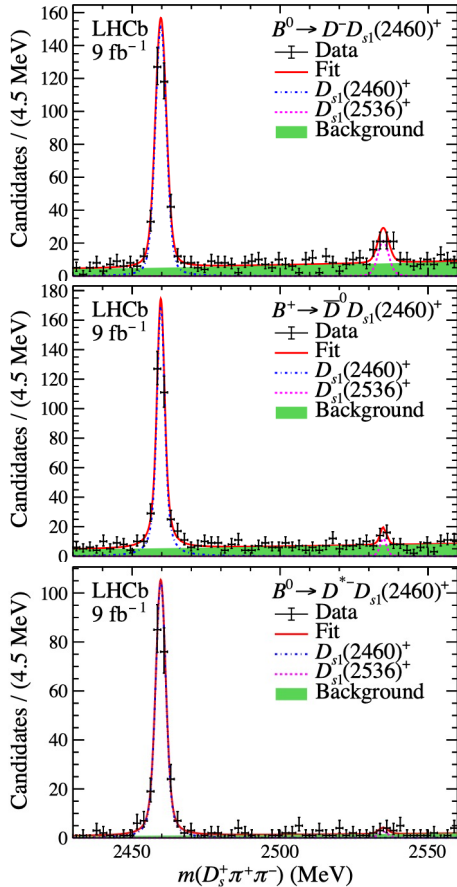


$$R = \frac{B(D_{s0}^*(2317)^+ \rightarrow D_s^{*+} \gamma)}{B(D_{s0}^*(2317)^+ \rightarrow D_s^+ \pi^0)} = (7.13 \pm 0.70 \pm 0.26)\%$$

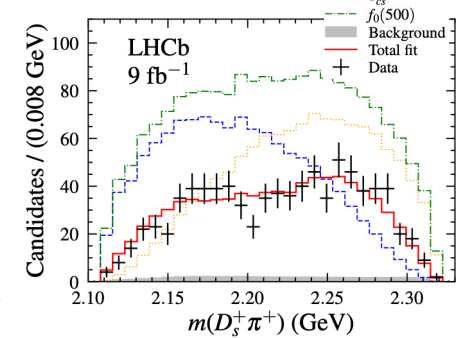
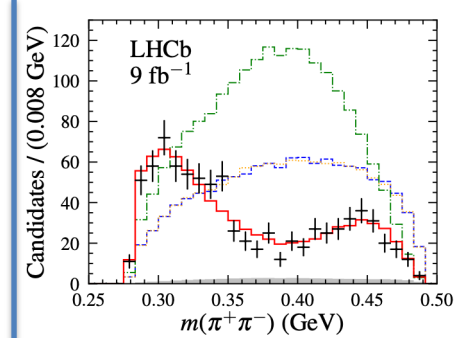
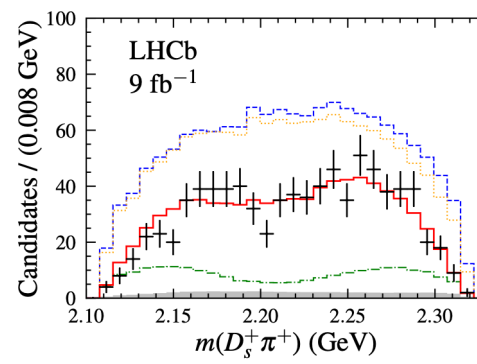
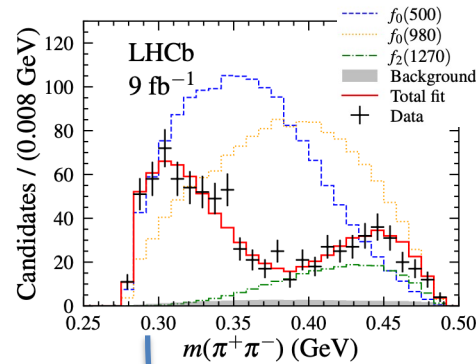
in between predictions for $c\bar{s}$ or molecular states, a mixture?

Study of $D_{s1}(2460)^+ \rightarrow D_s^+ \pi^+ \pi^-$

- Simultaneous amplitude analysis in $B \rightarrow \bar{D}^{(*)} D_s^+ \pi^+ \pi^-$ decays



Clear double peak structure in $m(\pi^+ \pi^-)$, indicating $D^* K$ component



Good description, but $f_0(980)$, $f_2(1270)$ unexpectedly large

$T_{c\bar{s}}^{++} \rightarrow D_s^+ \pi^+$, $T_{c\bar{s}}^0 \rightarrow D_s^+ \pi^-$ introduced, $J^P = 0^+$ favored

Model	Resonance	Mass (MeV)	Width (MeV)	Fractions (%)
$f_0(500) + f_0(980) + f_2(1270)$	$f_0(500)$	$376 \pm 9 \pm 16$	$175 \pm 23 \pm 16$	$197 \pm 35 \pm 23$
	$f_0(980)$	945.5	167	$187 \pm 38 \pm 43$
	$f_2(1270)$	1275.4	186.6	$29 \pm 2 \pm 1$
$f_0(500) + \text{RBW } T_{c\bar{s}}(0^+)$	$f_0(500)$	$464 \pm 23 \pm 14$	$214 \pm 28 \pm 8$	$199^{+42}_{-47} \pm 39$
	$T_{c\bar{s}}^{++}/T_{c\bar{s}}^0$	$2312 \pm 27 \pm 11$	$264 \pm 46 \pm 21$	$126^{+27}_{-17} \pm 20$
$f_0(500) + K\text{-matrix } T_{c\bar{s}}(0^+)$	$f_0(500)$	$474 \pm 30 \pm 18$	$224 \pm 23 \pm 16$	$248^{+40}_{-54} \pm 39$
	$T_{c\bar{s}}^{++}/T_{c\bar{s}}^0$	$2327 \pm 13 \pm 13$	$96 \pm 16 \pm 23$	$156^{+27}_{-38} \pm 25$

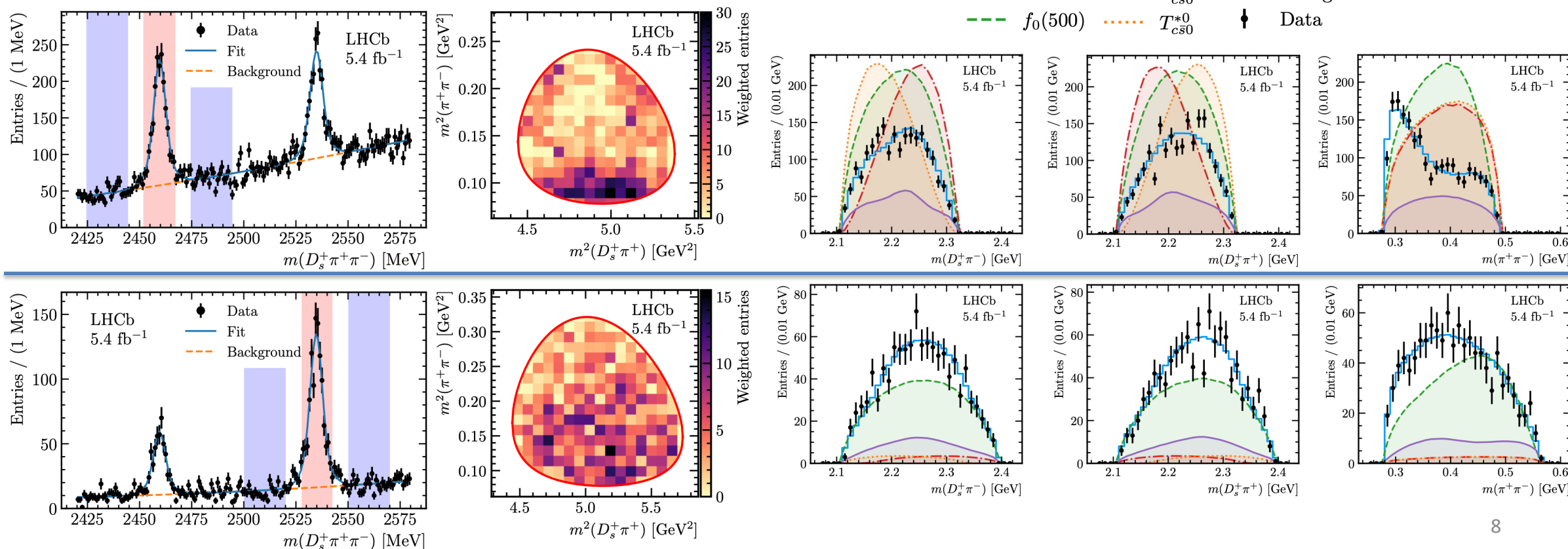
$D_{s1}(2460)^+ & D_{s1}(2536)^+$

- $B \rightarrow D_s^+ \pi^+ \pi^- \mu X$
 - Significantly different Dalitz-plot, different internal structure

Evidence of $T_{c\bar{s}}$ states as just discussed:

$$M = 2333 \pm 9 \pm 11 \text{ MeV}$$

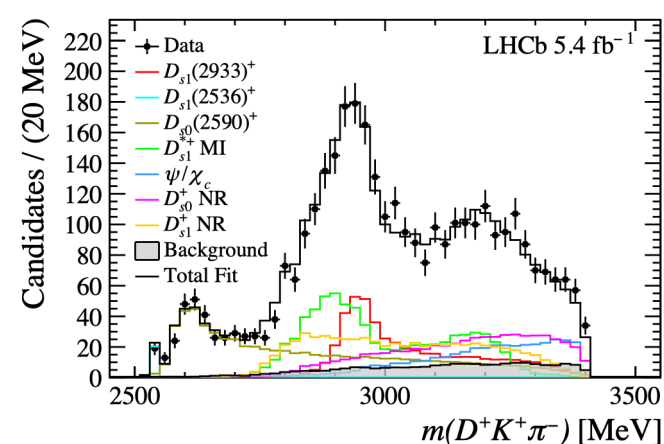
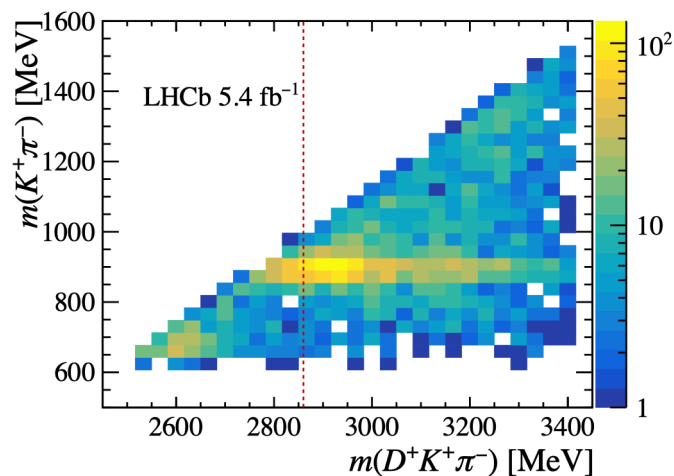
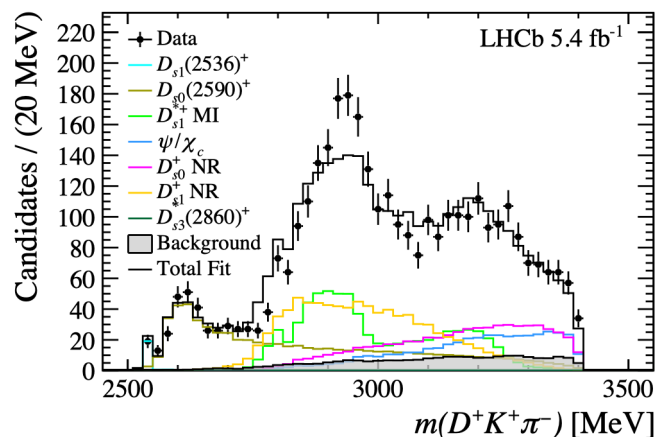
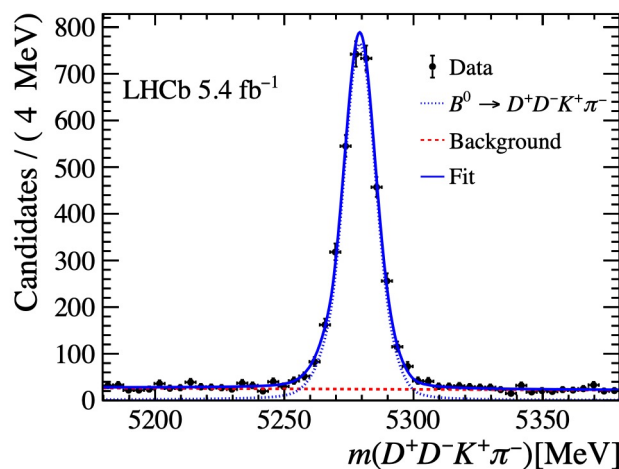
$$\Gamma = 68 \pm 12 \pm 14 \text{ MeV}$$



$$D_{s1}(2933)^+$$

$(c\bar{s})$

- Observed by LHCb in $B^0 \rightarrow D^- D^+ K^+ \pi^-$



Breit-Wigner mass and width:

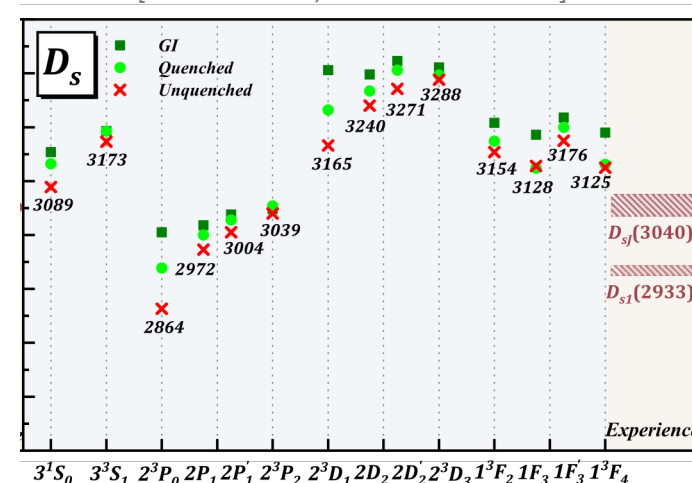
$$M = 2933_{-5}^{+6}(\text{stat})_{-3}^{+4}(\text{syst}) \text{ MeV}$$

$$\Gamma = 72_{-12}^{+18}(\text{stat})_{-10}^{+7}(\text{syst}) \text{ MeV}$$

$$J^P = 1^+$$

A candidate of $D_s(2P_1^{(\prime)})^+$

[R.-H. Ni *et al.*, arXiv:2605.17832]



“Masses significantly shifted down by the coupled-channel effects”

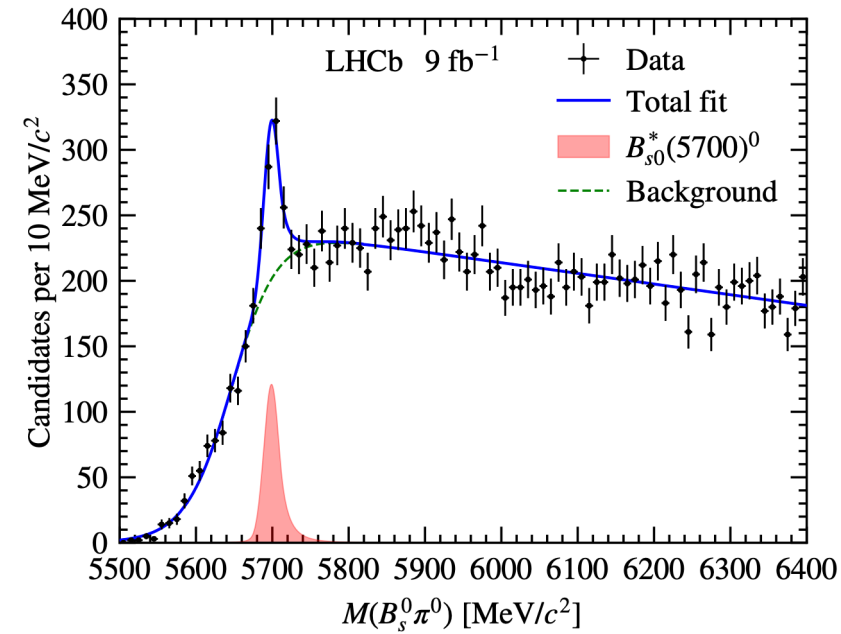
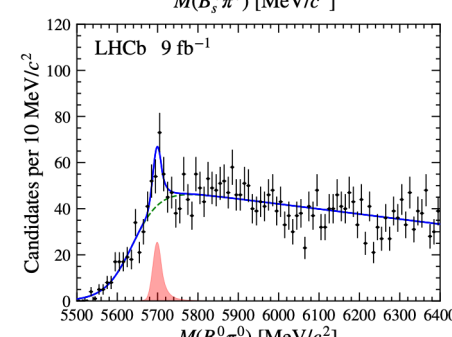
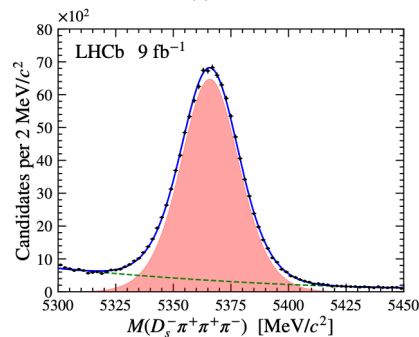
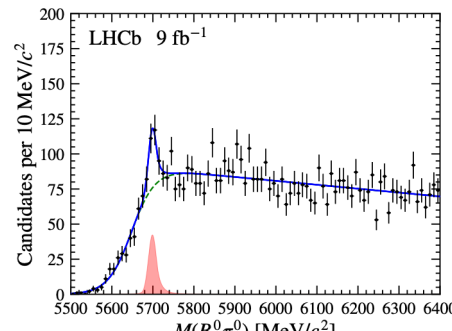
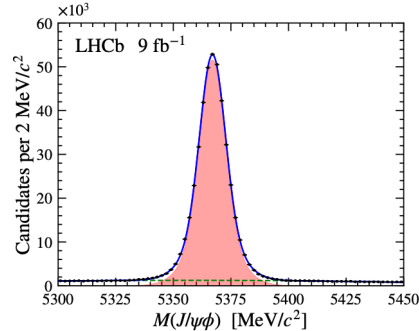
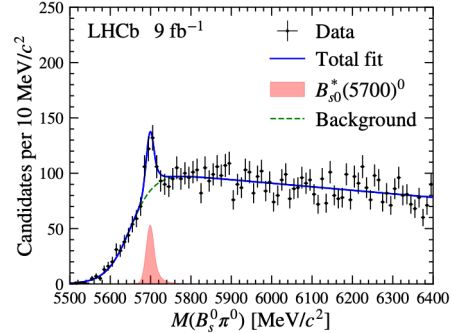
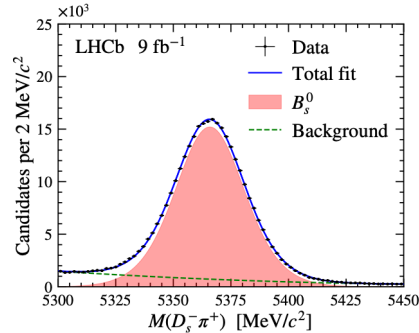
$(b\bar{s})?$

$$B_{s0}^*(5700)^0$$

- Observed by LHCb in $m(B_s^0 \pi^0)$ w/ $B_s^0 \rightarrow D_s^-(3)\pi^+, J/\psi\phi$

$$M = 5698.9 \pm 1.5 \pm 0.6 \text{ MeV}$$

$$\Gamma < 9.8 \text{ (11.8) MeV at 90\% (95\%) CL}$$



Meson, molecular? **Beauty counterpart of $D_{s0}^*(2317)^+$**

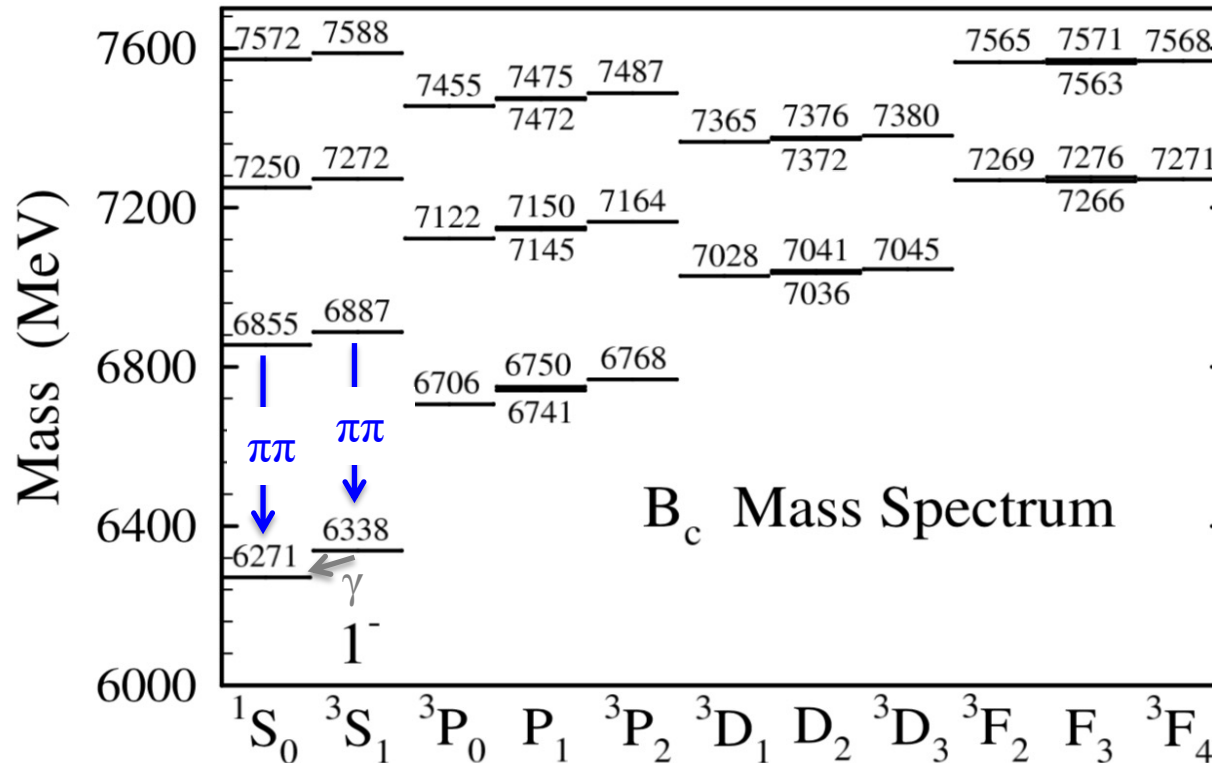
B_c family

$(\bar{b}c)$

- Production
- Spectrum

[C.-H. Chang, *et al.*, PRD 71 (2005) 074012]

-	$ (^1S_0)_1\rangle$	$ (^3S_1)_1\rangle$	$ (^1S_0)_{8g}\rangle$	$ (^3S_1)_{8g}\rangle$	$ (^1P_1)_1\rangle$	$ (^3P_0)_1\rangle$	$ (^3P_1)_1\rangle$	$ (^3P_2)_1\rangle$
LHC [†]	71.1	177.	(0.357, 3.21)	(1.58, 14.2)	9.12	3.29	7.38	20.4
TEVATRON	5.50	13.4	(0.0284, 0.256)	(0.129, 1.16)	0.655	0.256	0.560	1.35



[S.Godfrey, PRD 70 (2004) 054017]

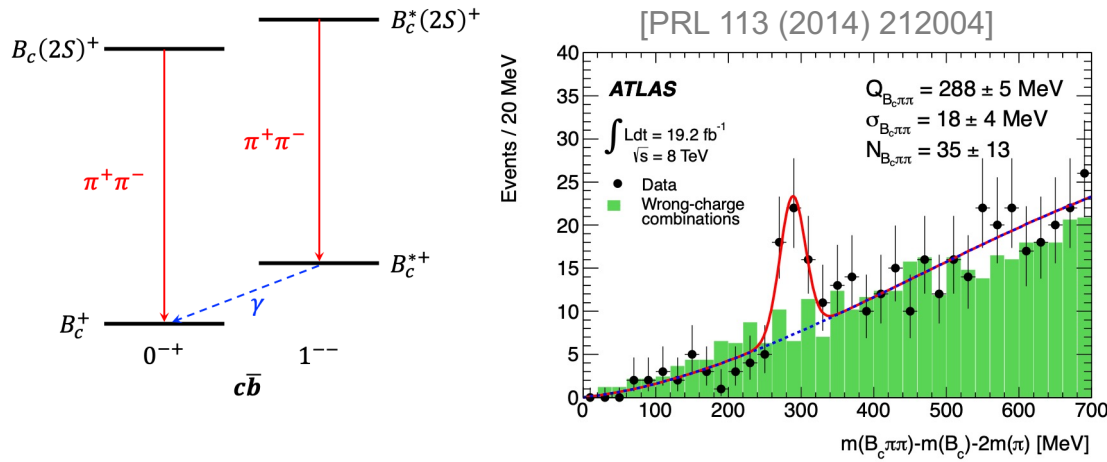
State	Decay	GKLRY *	Godfrey [†]
1^3S_1	$1^1S_0 + \gamma$	100	100
1^3P_2	$1^3S_1 + \gamma$	100	100
$1P'_1$	$1^3S_1 + \gamma$	6	12.1
	$1^1S_0 + \gamma$	94	87.9
$1P_1$	$1^3S_1 + \gamma$	87	82.2
	$1^1S_0 + \gamma$	13	17.8
1^3P_0	$1^3S_1 + \gamma$	100	100
2^1S_0	$1^1S_0 + \pi\pi$	74	88.1
	$1P'_1 + \gamma$		9.4
	$1P_1 + \gamma$		2.0
	$1^3S_1 + \gamma$		0.5
2^3S_1	$1^3S_1 + \pi\pi$	58	79.6
	$1^3P_2 + \gamma$		8.0
	$1P'_1 + \gamma$		1.0
	$1P_1 + \gamma$		6.6
	$1^3P_0 + \gamma$		4.0
	$2^1S_0 + \gamma$		0.01
	$1^1S_0 + \gamma$		0.8

*[I. P. Gouz, *et al.*, Phys. Atom. Nucl. 67 (2004) 1559]

[†][S.Godfrey, PRD 70 (2004) 054017]

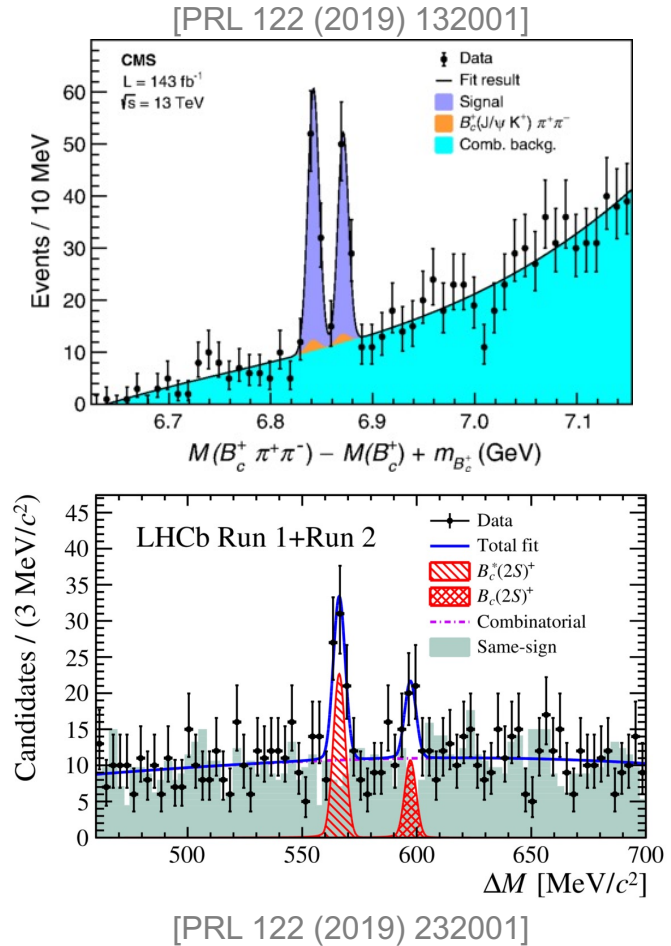
$B_c^{(*)}(2S)^+$

- Mixture (?) by ATLAS, then both states by CMS & LHCb, using $B_c^+ \rightarrow J/\psi \pi^+$



LHCb { $M(B_c(2^3S_1)^+)_{\text{rec}} = 6841.2 \pm 0.6(\text{stat}) \pm 0.1(\text{syst}) \pm 0.8(B_c^+) \text{ MeV}/c^2$
 $M(B_c(2S)^+) = 6872.1 \pm 1.3(\text{stat}) \pm 0.1(\text{syst}) \pm 0.8(B_c^+) \text{ MeV}/c^2$
 $M(B_c(2S)^+) - M(B_c^*(2S)^+)_{\text{rec}} = 31.0 \pm 1.4(\text{stat}) \pm 0.0(\text{syst}) \text{ MeV}/c^2$

CMS { $M(B_c(2^3S_1)^+)_{\text{rec}} = 6842.0 \pm 1.0(\text{stat}) \pm 0.0(\text{syst}) \pm 0.8(B_c^+) \text{ MeV}/c^2$
 $M(B_c(2S)^+) = 6871.0 \pm 1.2(\text{stat}) \pm 0.8(\text{syst}) \pm 0.8(B_c^+) \text{ MeV}/c^2$
 $M(B_c(2S)^+) - M(B_c^*(2S)^+)_{\text{rec}} = 29.0 \pm 1.5(\text{stat}) \pm 0.7(\text{syst}) \text{ MeV}/c^2$



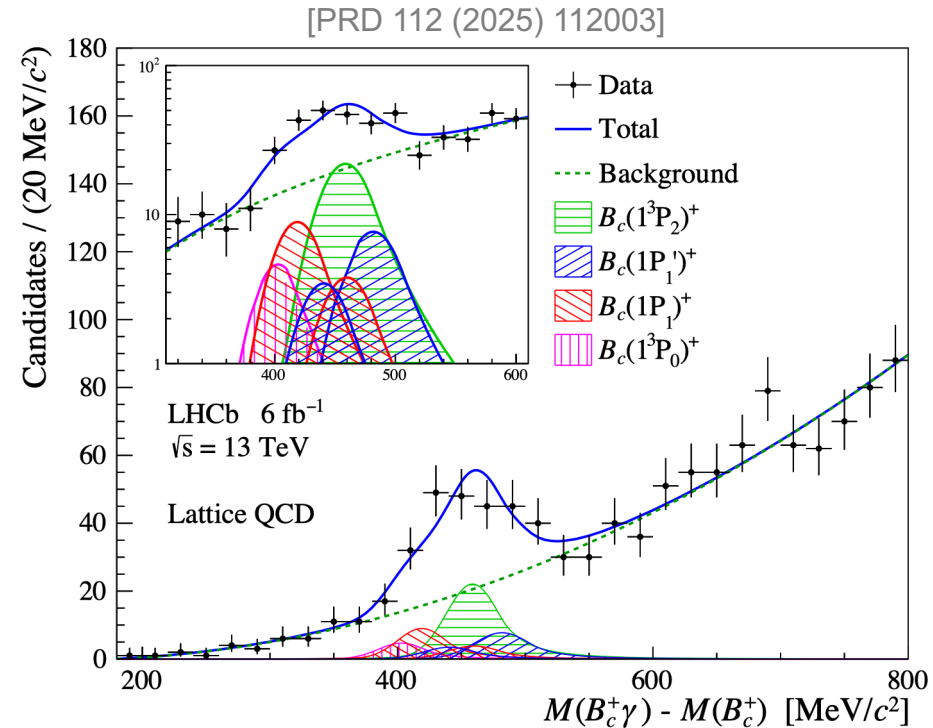
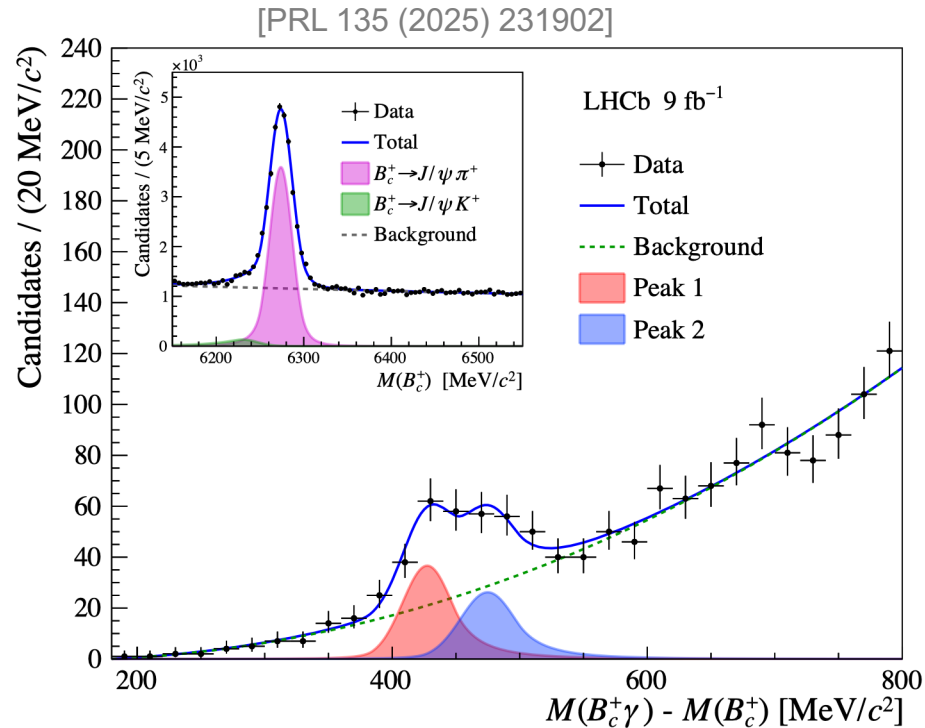
$B_c(1P)^+$

- Observed by LHCb w/ calorimeter photon

$$R = \sigma_{B_c(1P)^+} / \sigma_{B_c^+} = 0.20 \pm 0.03 \pm 0.03$$

[C.-H. Chang, *et al.*, PRD 71 (2005) 074012]

$ (^1P_1)_1\rangle$	$ (^3P_0)_1\rangle$	$ (^3P_1)_1\rangle$	$ (^3P_2)_1\rangle$
9.12	3.29	7.38	20.4



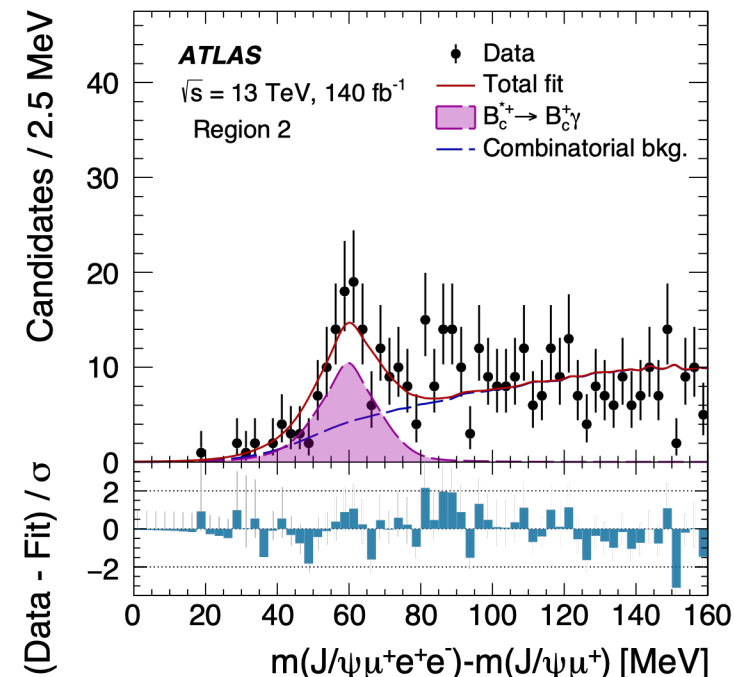
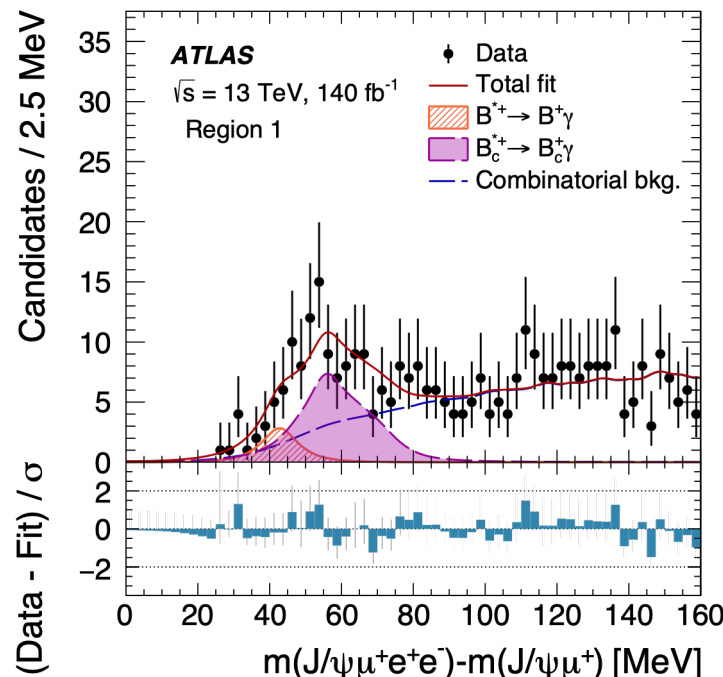
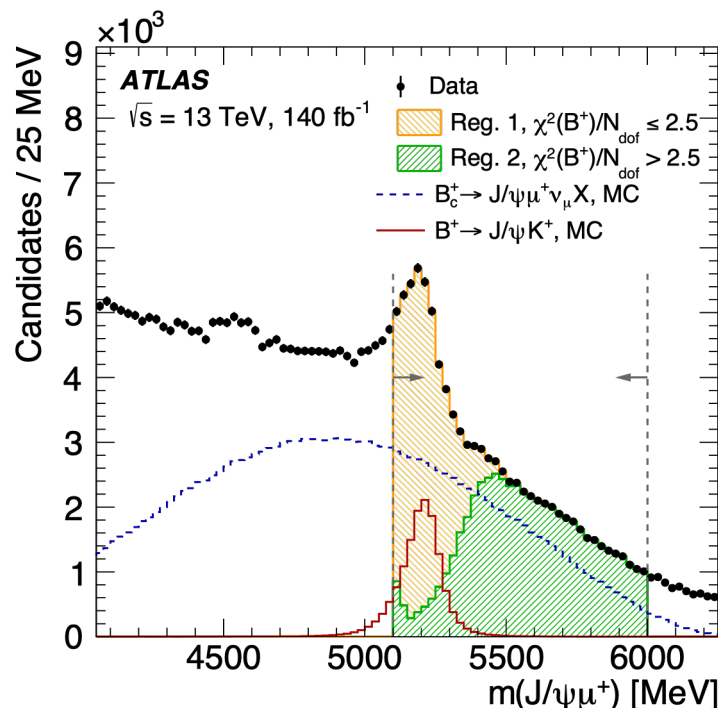
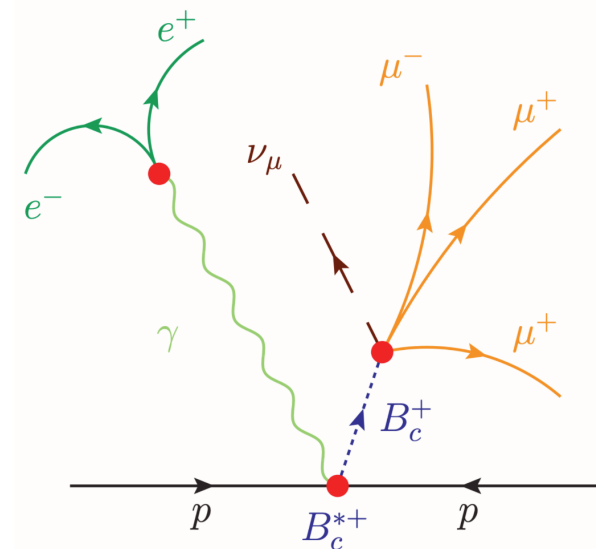
B_c^{*+}

- Using $B_c^+ \rightarrow J/\psi \mu^+ \nu_\mu X$, converted γ

$$M(B_c^{*+}) - M(B_c^+) = 64.5 \pm 1.4^{+1.0}_{-1.4} \text{ MeV}$$

[arXiv:2605.16228]

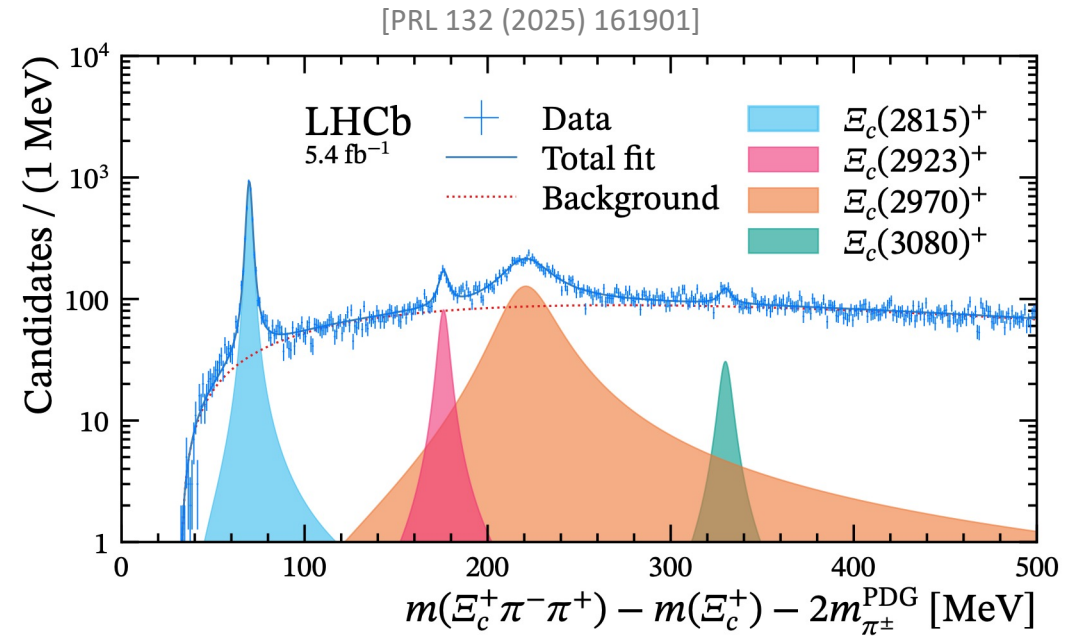
$$M(B_c^{*+}) = 6339.0 \pm 1.4^{+1.90}_{-1.30} \pm 0.3 (M_{B_c^+}) \text{ MeV}$$



* $\chi^2(B)/\text{ndf}$, Kaon mass hyperthesis, J/ψ and B^+ mass constraints, and PV constraint

$$(usc)$$

-
- (a) Charmed baryons
- Mass above baseline (GeV)
- 3/2⁻
- 5/2⁺
- 3/2⁺
- 3/2⁻
- 1/2⁻
- 3/2⁺
- 1/2⁺
- 3/2⁺
- 1/2⁺
- 3/2⁺
- 1/2⁺
- 1/2⁺
- 1/2⁺
- Λ_c Σ_c Ξ_c Ω_c
- Events / 10 MeV/c²
- M_{KΛ_c} (GeV/c²)
- Data
- Total Fit
- Total non-Ξ_c(2930) Bkg
- Phase Space
- Sideband
- Generic MC
- [EPJ C 78 (2018) 252]
- resolved to two states?
- Candidates / (1 MeV)
- m(Λ_c⁺K⁻) - m(Λ_c⁺) - m(K⁻) [MeV]
- LHCb (a)
- Ξ_c(2923)⁰ → Λ_c⁺K⁻
- Ξ_c(2939)⁰ → Λ_c⁺K⁻
- Ξ_c(2965)⁰ → Λ_c⁺K⁻
- Ξ_c(2923)⁰ → Λ_c⁺K⁻π⁺
- Ξ_c(3055)⁰ → Σ_c⁺(→ Λ_c⁺π⁰)K⁻
- Ξ_c(3055)⁰ → Σ_c⁺(→ Λ_c⁺π⁰)K⁻
- Ξ_c(3080)⁰ → Σ_c⁺(→ Λ_c⁺π⁰)K⁻
- Ξ_c(3080)⁰ → Σ_c⁺(→ Λ_c⁺π⁰)K⁻
- Background
- Additional component
- [PRL 124 (2020) 222001]
- $m(\Xi_c(2923)^0) = 2923.04 \pm 0.25 \pm 0.20 \pm 0.14 \text{ MeV}, \Gamma(\Xi_c(2923)^0) = 7$
- $m(\Xi_c(2939)^0) = 2938.55 \pm 0.21 \pm 0.17 \pm 0.14 \text{ MeV}, \Gamma(\Xi_c(2939)^0) = 10$
- $m(\Xi_c(2965)^0) = 2964.88 \pm 0.26 \pm 0.14 \pm 0.14 \text{ MeV}, \Gamma(\Xi_c(2965)^0) = 14$



$$m[\Xi_c(2923)^+] = 2922.8 \pm 0.3 \pm 0.5 \pm 0.2 \text{ MeV},$$

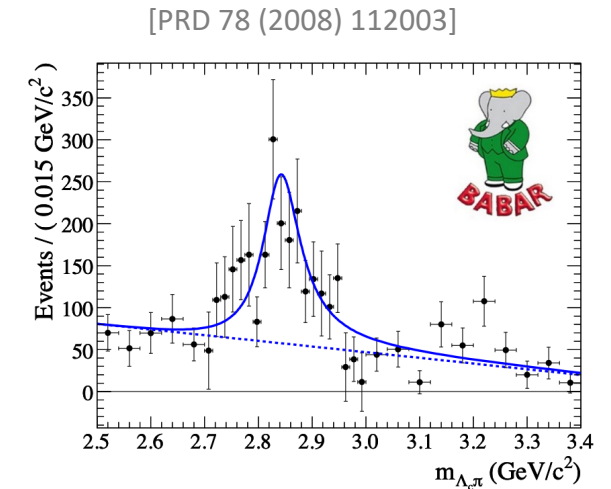
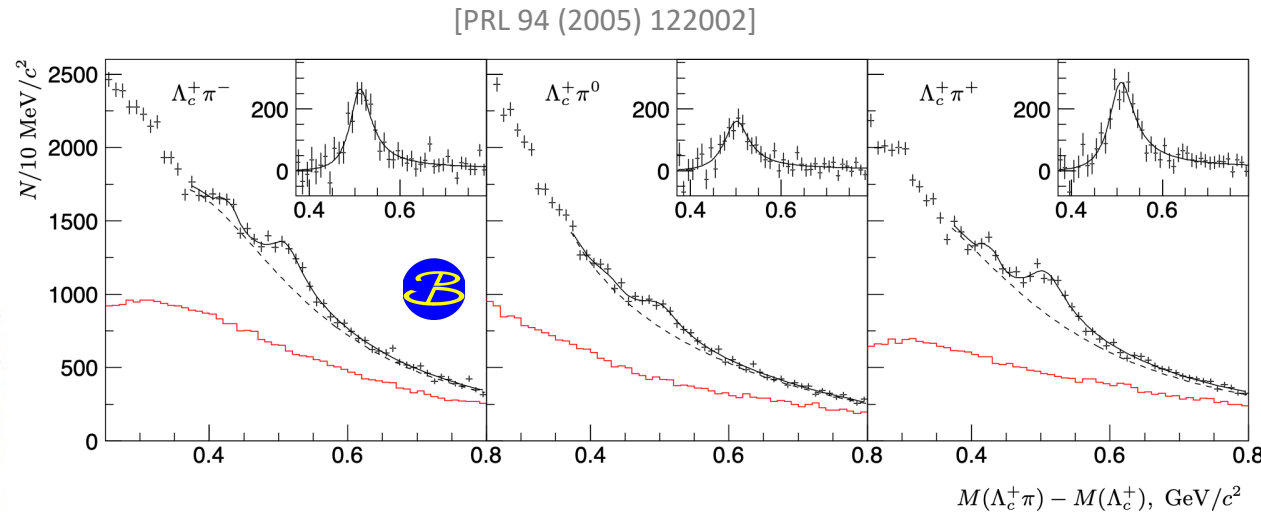
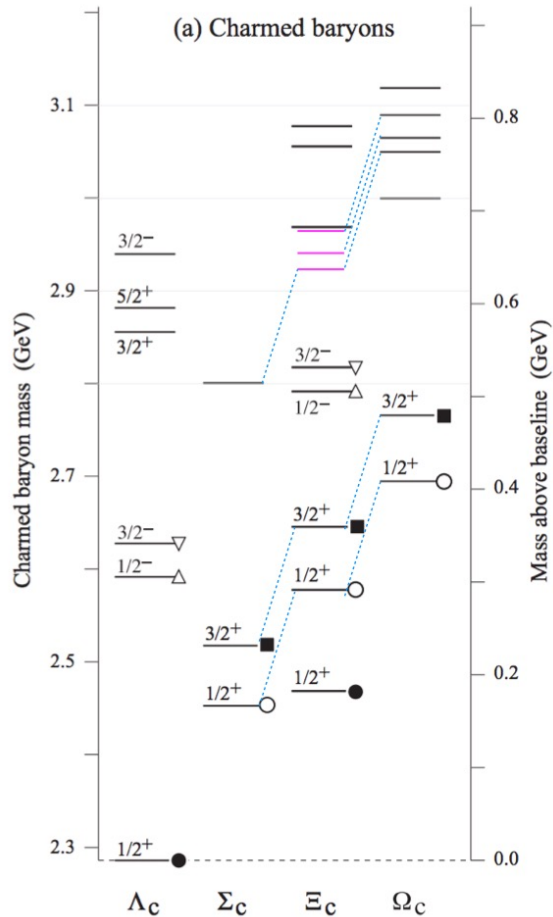
$$\Gamma[\Xi_c(2923)^+] = 5.3 \pm 0.9 \pm 1.4 \text{ MeV},$$

consistent with $\Xi_c(2923)^0$ partner

Σ_c spectrum

(ddc)

- Mostly unexplored. $\Sigma_c(2800)^0$, mass by Belle and Babar?



State	Yield / 10^3	ΔM , MeV/ c^2	Γ , MeV
$\Sigma_c(2800)^0$	$2.24^{+0.79+1.03}_{-0.55-0.50}$	$515.4^{+3.2+2.1}_{-3.1-6.0}$	61^{+18+22}_{-13-13}
$\Sigma_c(2800)^+$	$1.54^{+1.05+1.40}_{-0.57-0.88}$	$505.4^{+5.8+12.4}_{-4.6-2.0}$	62^{+37+52}_{-23-38}
$\Sigma_c(2800)^{++}$	$2.81^{+0.82+0.71}_{-0.60-0.49}$	$514.5^{+3.4+2.8}_{-3.1-4.9}$	75^{+18+12}_{-13-11}

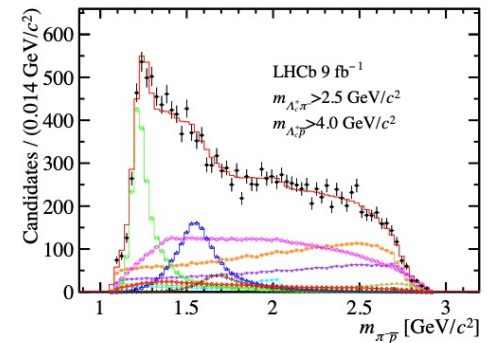
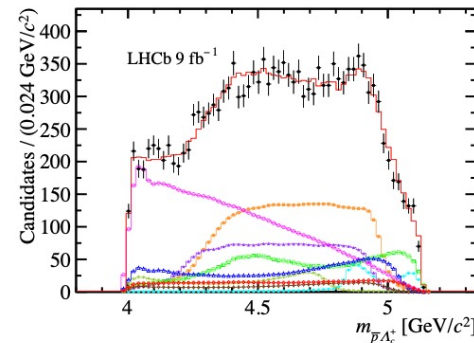
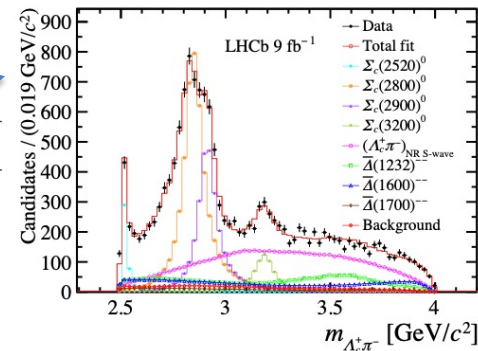
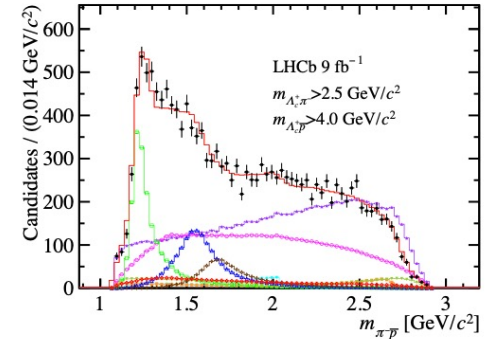
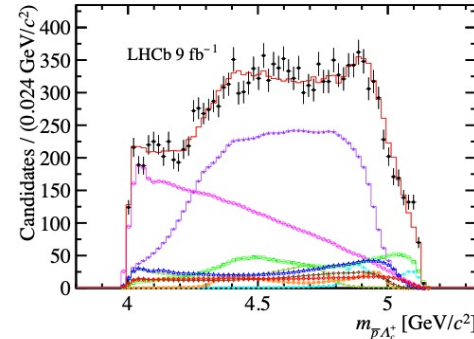
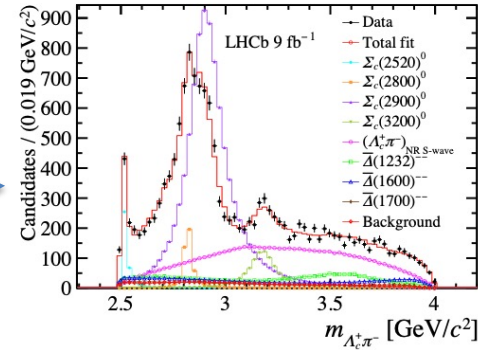
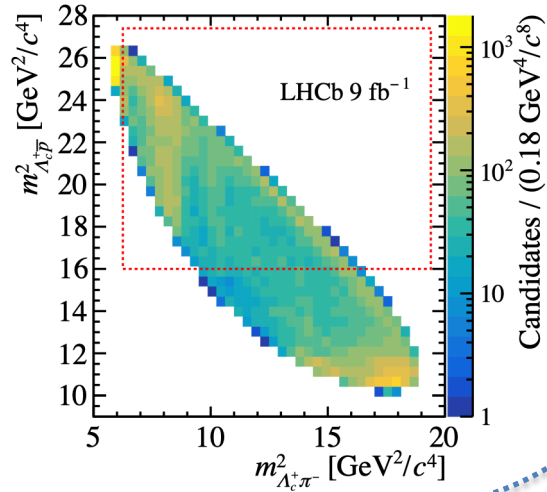
$$m(\Sigma_c(2800)^0) = 2846 \pm 8 \pm 10 \text{ MeV}$$

$$\Rightarrow m(\Sigma_c(2800)^0) = 2802^{+4}_{-7} \text{ MeV}$$

Σ_c spectrum

(*ddc*)

- First amplitude analysis of $B^- \rightarrow \Lambda_c^+ \bar{p} \pi^-$ in a subregion. Two solutions found, w/ two new states $\Sigma_c(2900)^0, \Sigma_c(3200)^0$



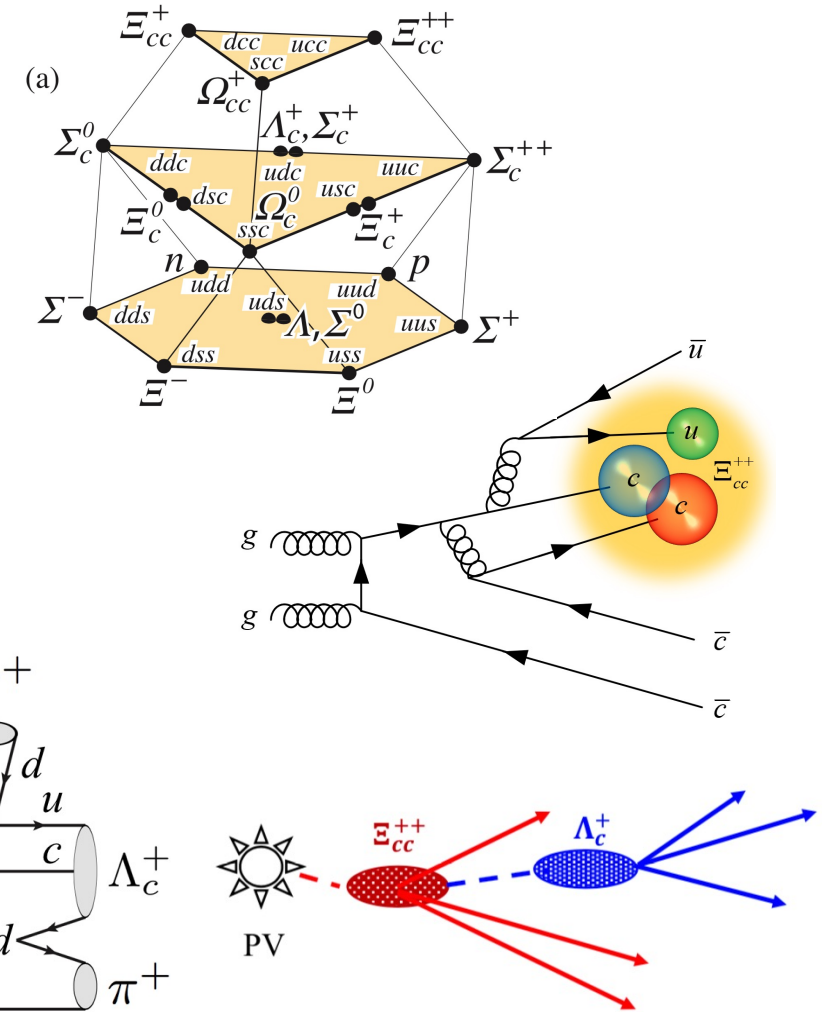
Parameter	Group A	Group B
$m_{\Sigma_c(2800)^0} [\text{GeV}/c^2]$	$2.819 \pm 0.006 \pm 0.002$	$2.848 \pm 0.004 \pm 0.006$
$\Gamma_{\Sigma_c(2800)^0} [\text{GeV}]$	$0.033 \pm 0.007 \pm 0.008$	$0.099 \pm 0.007 \pm 0.021$
$m_{\Sigma_c(2900)^0} [\text{GeV}/c^2]$	$2.908 \pm 0.005 \pm 0.009$	$2.914 \pm 0.003 \pm 0.008$
$\Gamma_{\Sigma_c(2900)^0} [\text{GeV}]$	$0.175 \pm 0.008 \pm 0.023$	$0.092 \pm 0.006 \pm 0.023$
$m_{\Sigma_c(3200)^0} [\text{GeV}/c^2]$	$3.186 \pm 0.006 \pm 0.014$	$3.190 \pm 0.005 \pm 0.011$
$\Gamma_{\Sigma_c(3200)^0} [\text{GeV}]$	$0.133 \pm 0.018 \pm 0.027$	$0.100 \pm 0.015 \pm 0.032$

$\Sigma_c(2800)^0$ by Babar resolved into two states
 $\Sigma_c(2800)^0$ from group-A consistent with the state by Belle

Doubly charmed baryon

(ccq)

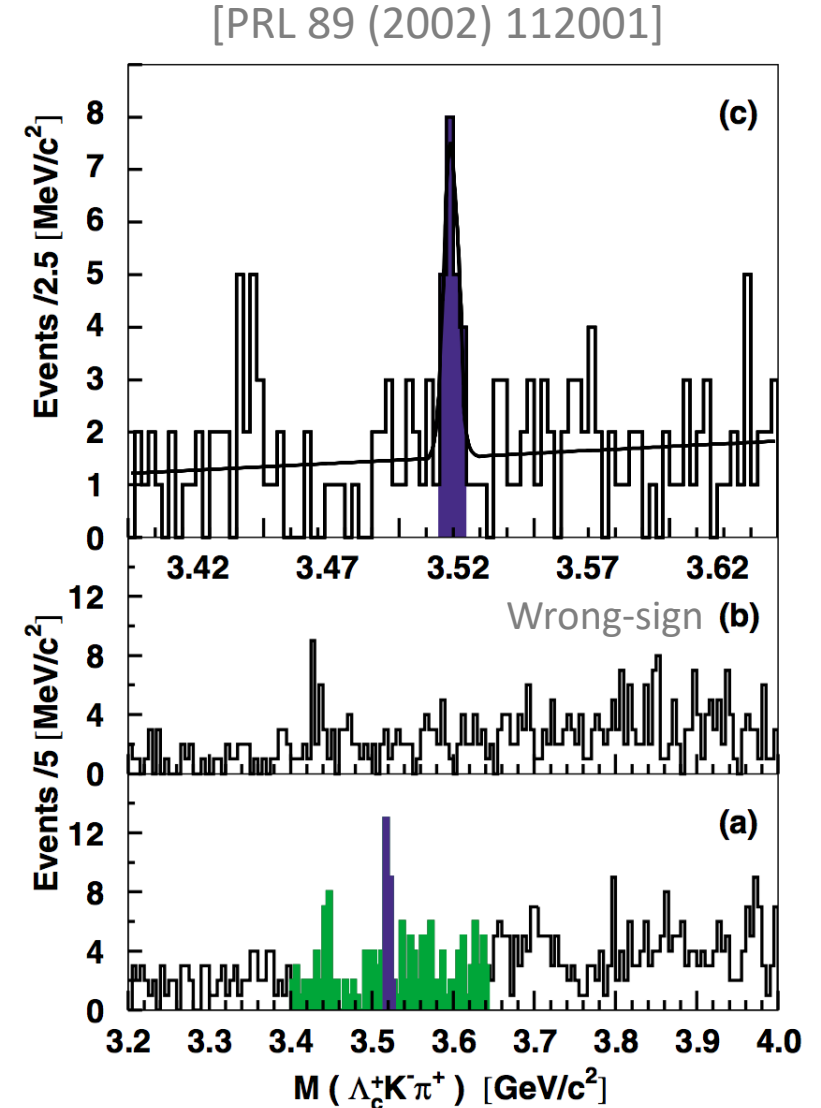
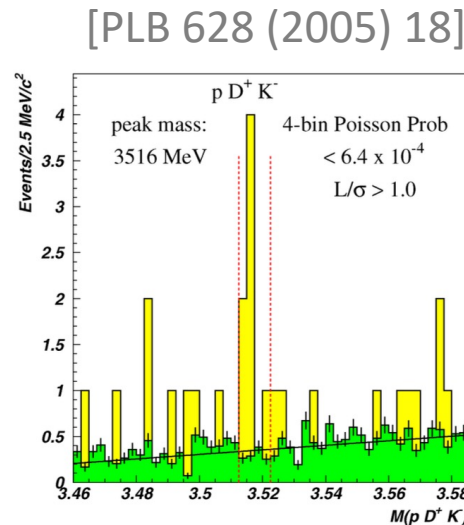
- Mass [e.g., S. Fleck, J.M. Richard, Prog. Theor. Phys. 82 (1989) 760]
 - $M(E_{cc}): 3.5\text{-}3.7\text{ GeV}; M(\Omega_{cc}^+): +0.1\text{-}0.2\text{ GeV}$
- Production at LHC [C.H. Chang *et al.*, PRD 73 (2006) 094022]
 - $\sigma(E_{cc}) \approx 40\text{ nb @ } 13\text{ TeV}$
- Lifetime [e.g., V.V. Kiselev *et al.*, PRD 60 (1999) 014007]
 - $\tau(E_{cc}^{++}) > \tau(\Omega_{cc}^+) > \tau(E_{cc}^+)$
- Decays [e.g., F.-S. Yu *et al.*, CPC 42 (2018) 051001]



Ξ_{cc}^+ @ SELEX

(*ccd*)

- SELEX claimed $\Xi_{cc}^+ \rightarrow \Lambda_c^+ K^- \pi^+$ (6.3σ)
 - M : 3519 ± 1 MeV
 - τ : < 33 fs @90%CL
 - σ_{prod} : 20% Λ_c^+ from Ξ_{cc}^+
- $\Xi_{cc}^+ \rightarrow p D^+ K^-$
- Not confirmed by
FOCUS, Babar, Belle,
& LHCb



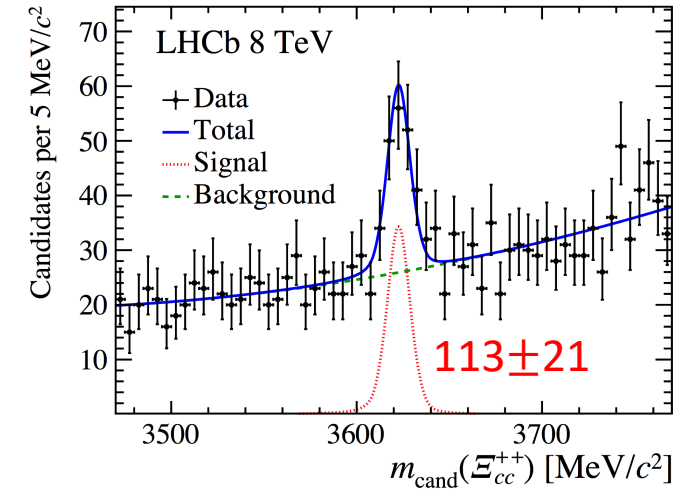
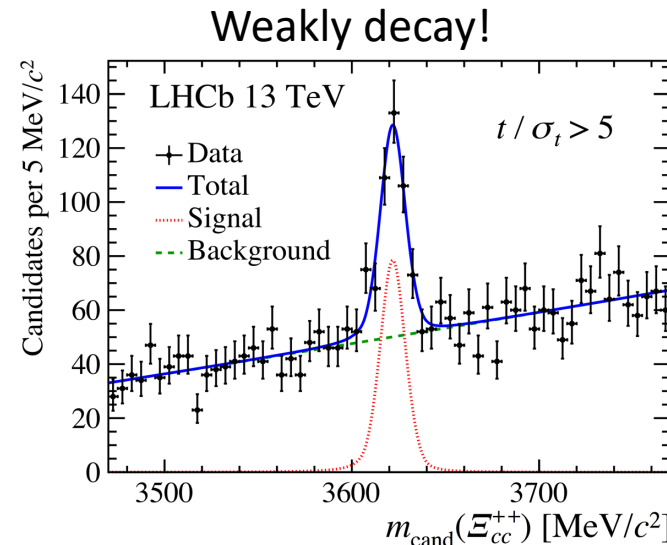
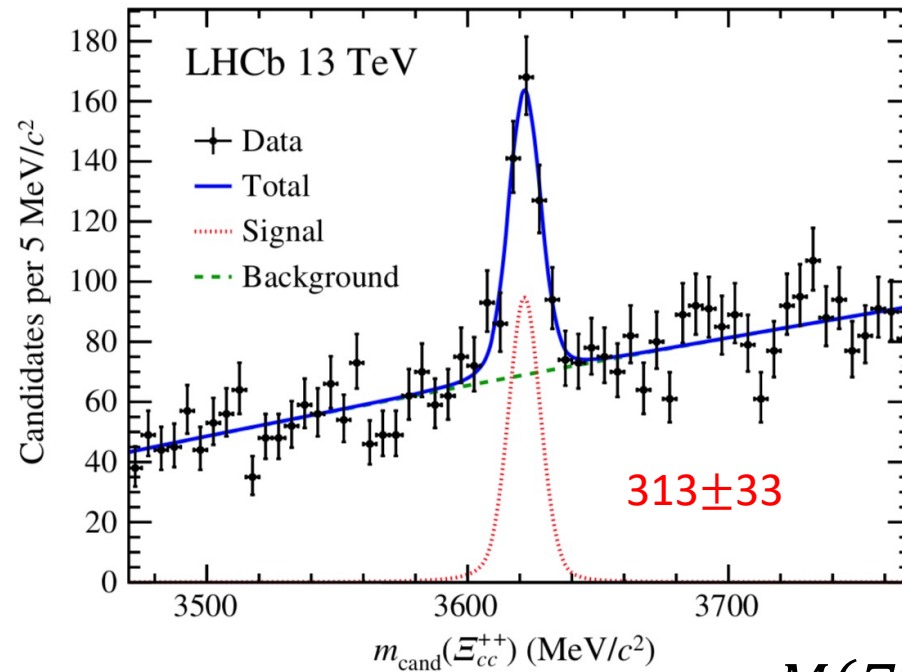
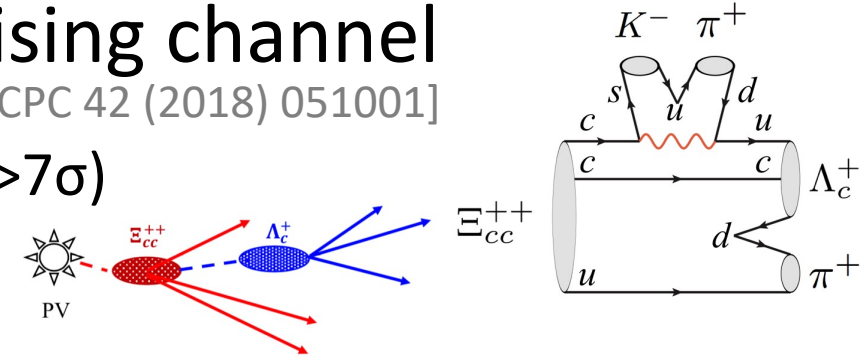
Ξ_{cc}^{++} observation

(ccu)

- $\Lambda_c^+ K^- \pi^+ \pi^+$ identified as the most promising channel

[F.-S. Yu *et al.*, CPC 42 (2018) 051001]

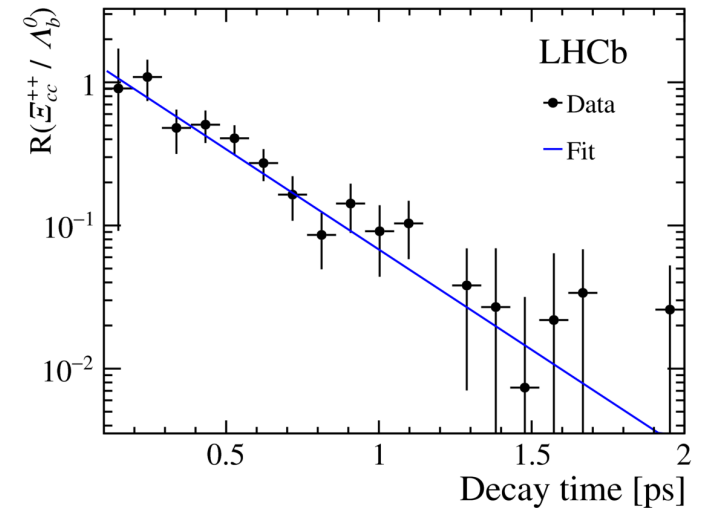
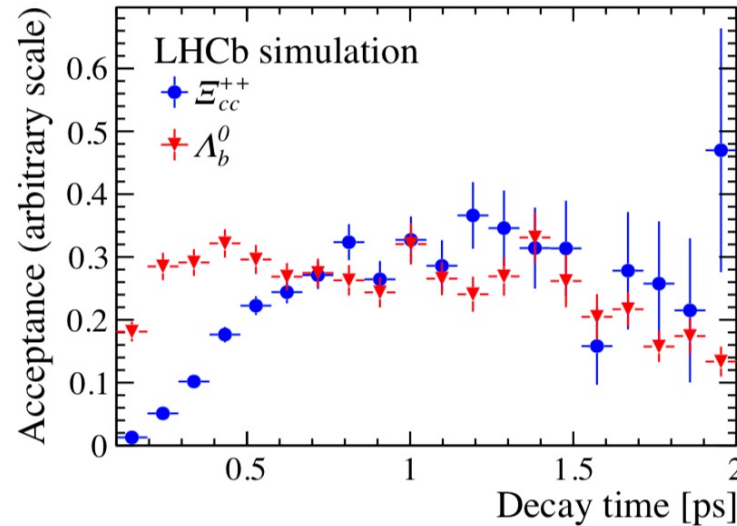
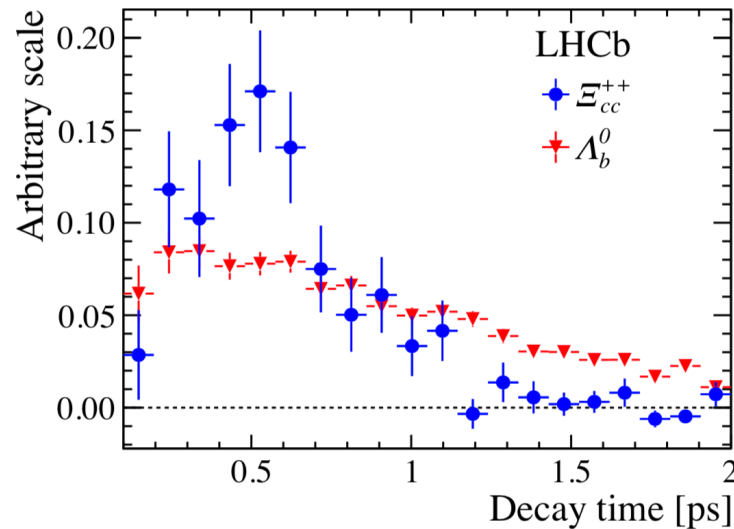
- First observation**, in 2016 ($>12\sigma$) & Run 1 ($>7\sigma$)



$$M(\Xi_{cc}^{++}) = 3621.40 \pm 0.72 \pm 0.27 \pm 0.14 (\Lambda_c^+) \text{ MeV}$$

Ξ_{cc}^{++} lifetime

- Measured wrt $\Lambda_b^0 \rightarrow \Lambda_c^+ 3\pi$, $\tau(\Xi_{cc}^{++}) = 256_{-22}^{+24} \pm 14$ fs

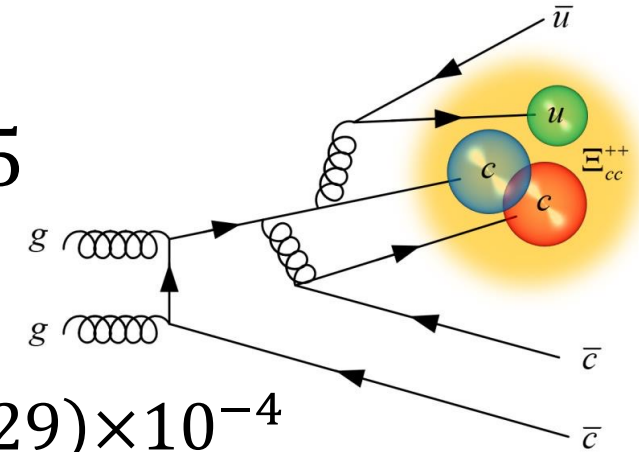


- Input to theoretical predictions, e.g., [H.-Y. Cheng, Y.-L. Shi, PRD 98 (2018) 113005]
[L. Dulibic *et al.*, JHEP 07 (2023) 061]
 - $\tau(\Xi_{cc}^+) \approx 45$ fs
 - $\tau(\Omega_{cc}^+) \approx 160$ fs
 which are used in the searches for Ξ_{cc}^+ and Ω_{cc}^+

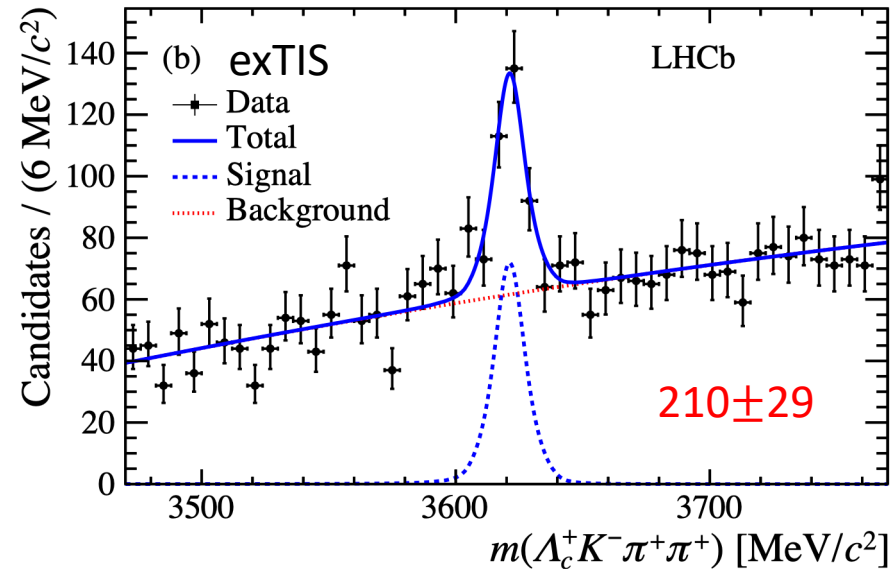
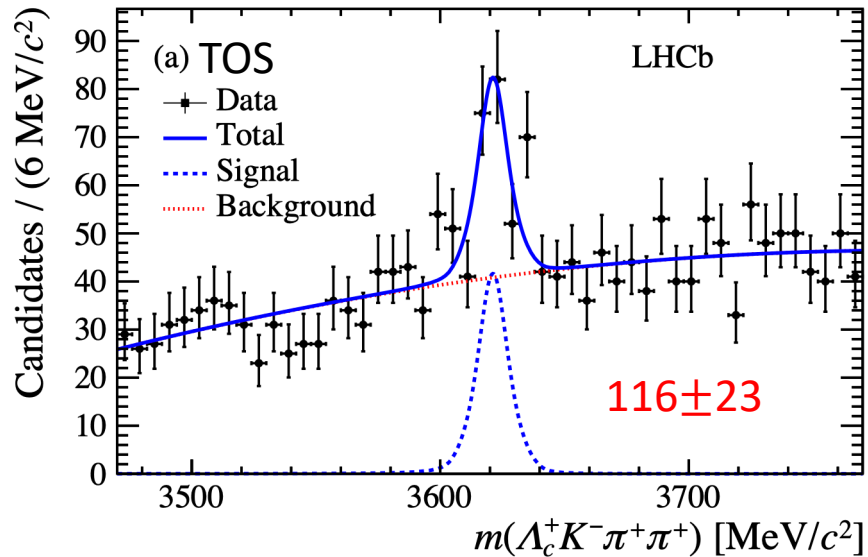
Ξ_{cc}^{++} production

- Relative to Λ_c^+ , in $4 < p_T < 15$ GeV, $2 < y < 4.5$
- Accompanying $\bar{c}\bar{c}$ dominates in trigger

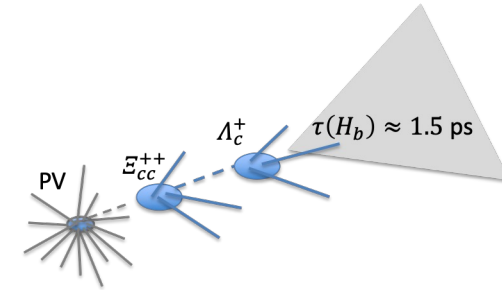
$$\frac{\sigma(\Xi_{cc}^{++})}{\sigma(\Lambda_c^+)} \mathcal{B}(\Xi_{cc}^{++} \rightarrow \Lambda_c^+ K^- \pi^+ \pi^+) = (2.22 \pm 0.27 \pm 0.29) \times 10^{-4}$$



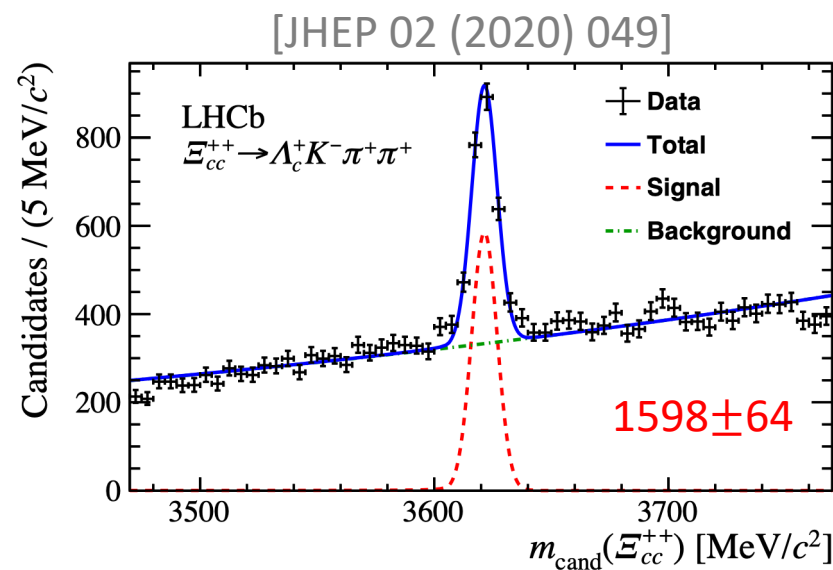
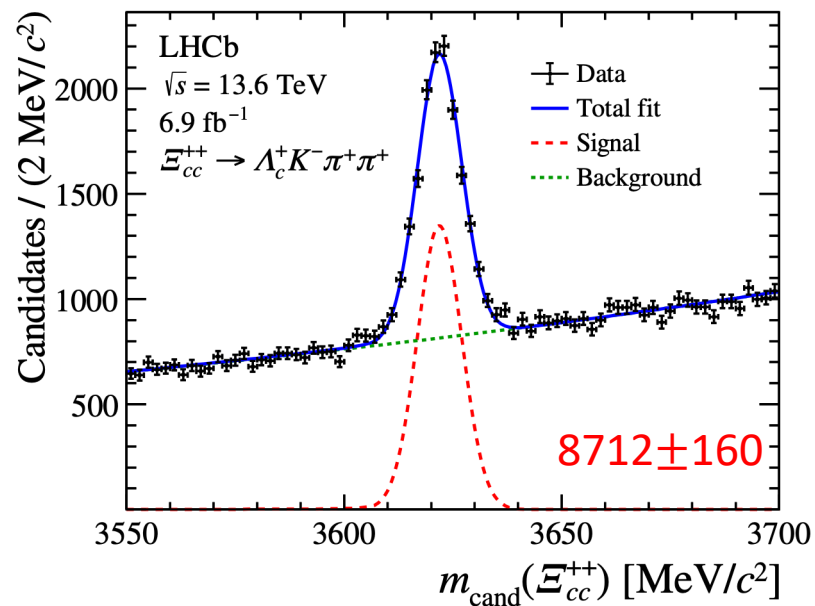
SELEX, 20% Λ_c^+ from Ξ_{cc}^+ ?



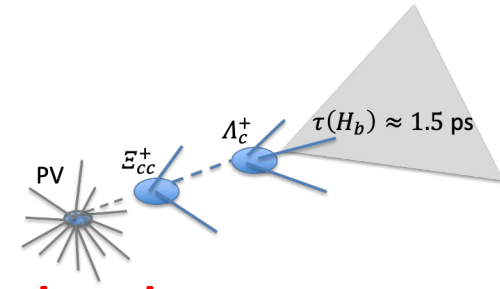
Ξ_{cc}^{++} in 2024



- Efficiency increased by a factor of 4, compared with Run 2, thanks to the removal of the hardware trigger
- Mass consistent with Run 2, $M(\Xi_{cc}^{++}) = 3621.74 \pm 0.10 \text{ MeV}$
c.f., $3621.55 \pm 0.23 \pm 0.30 \text{ MeV}$



Ξ_{cc}^+ in 2024



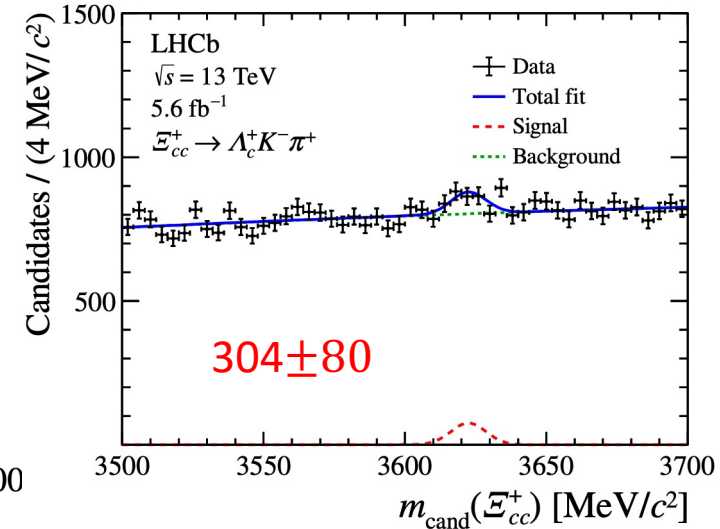
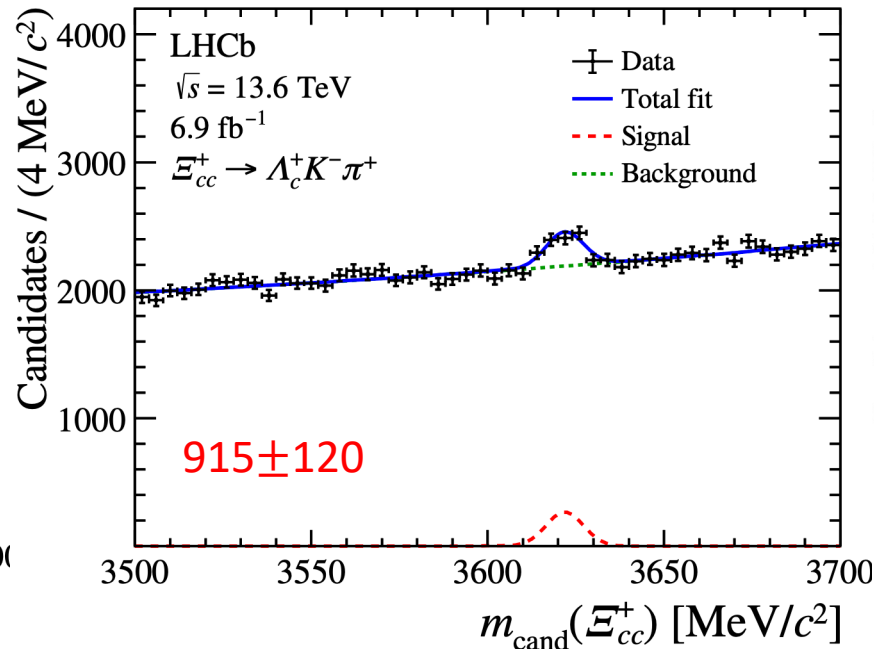
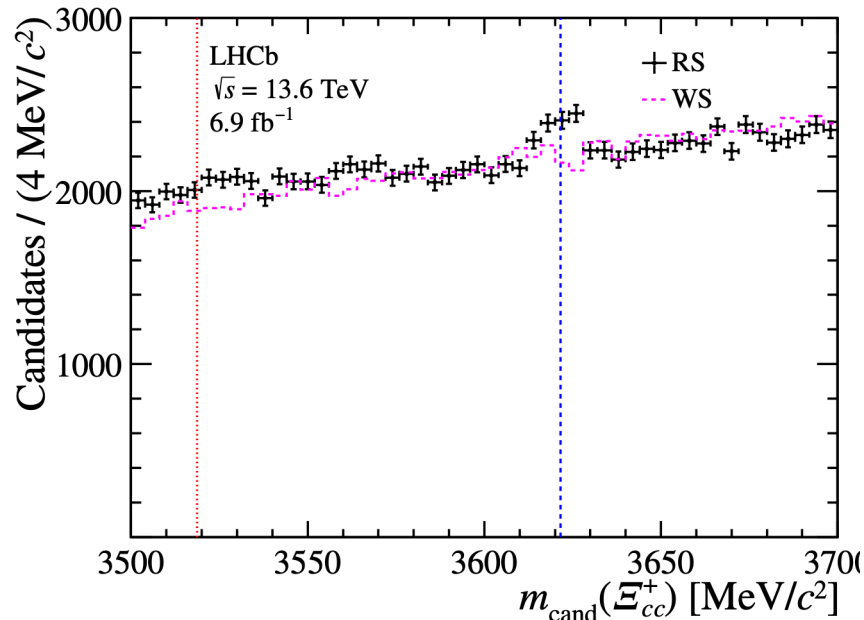
- First new particle observed w/ the upgraded LHCb detector

– Efficiency increased by a factor of 2.5, compared w/ Run 2

$$M(\Xi_{cc}^+) = 3619.97 \pm 0.83 \pm 0.26_{-1.30}^{+1.90} \text{ MeV}$$

$$M(\Xi_{cc}^+) - M(\Xi_{cc}^{++}) = -1.77 \pm 0.84 \pm 0.25_{-1.30}^{+1.90} \text{ MeV}$$

QED wins the competition with QCD!

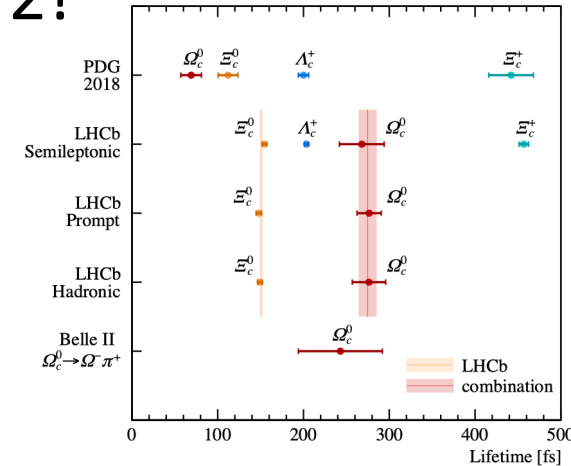
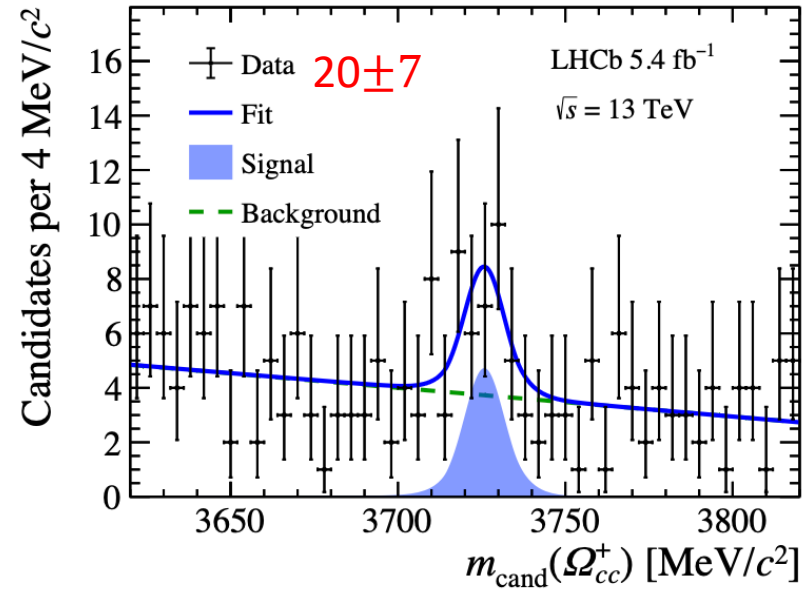
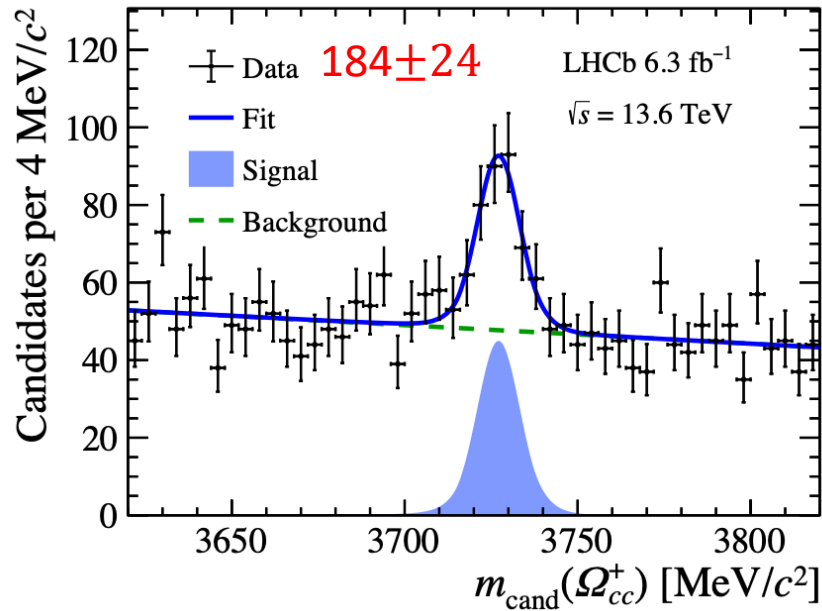


Ω_{cc}^+ in 2024

(*ccs*)

- First observation using $\Omega_c^0 \pi^+$, w/ $\Omega_c^0 \rightarrow p K^- K^- \pi^+$
 - Efficiency increased by a factor of 8, compared w/ Run 2!

$$M(\Omega_{cc}^+) = 3725.9 \pm 1.0 \pm 0.2 \pm 0.4 (\tau) \pm 0.6 (\text{ext}) \text{ MeV}$$



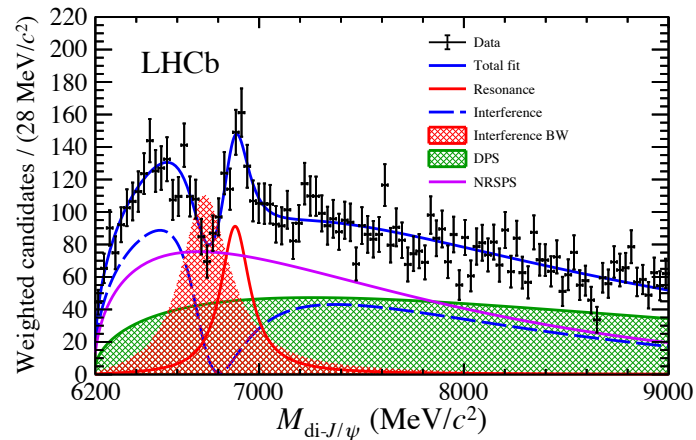
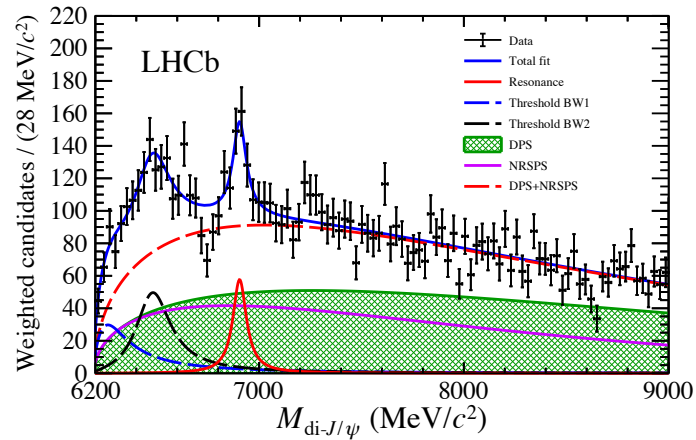
[JHEP 09 (2025) 157]

$X(6900)$

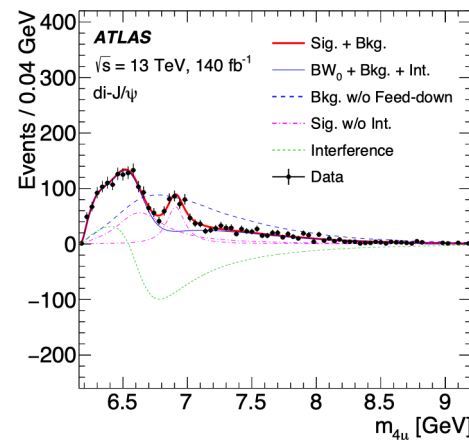
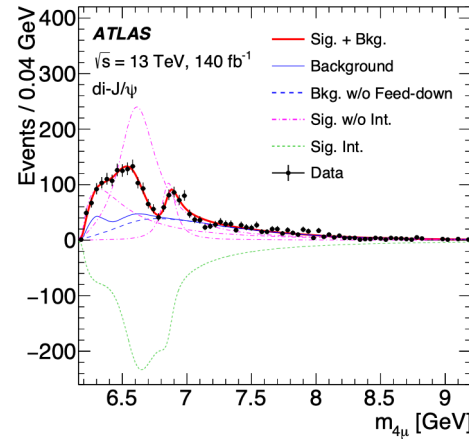
$(cc\bar{c}\bar{c})$

- $X(6900)$ observed by LHCb, ATLAS and CMS; $X(6600)$ by CMS

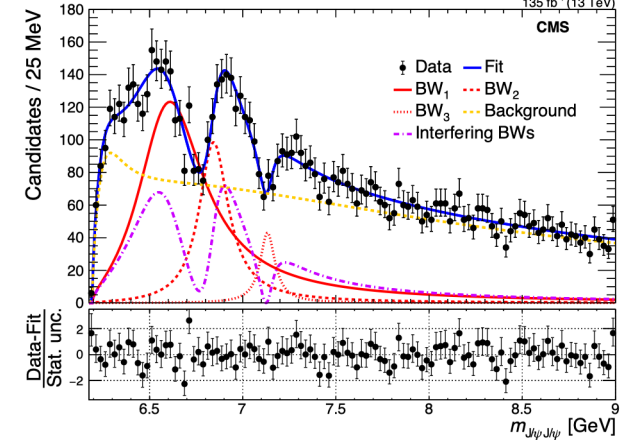
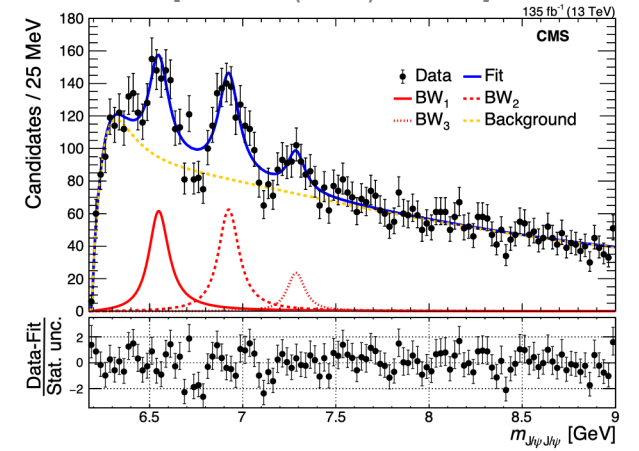
[Sci. Bull. 65 (2020) 1983]



[PRL 131 (2023) 151902]



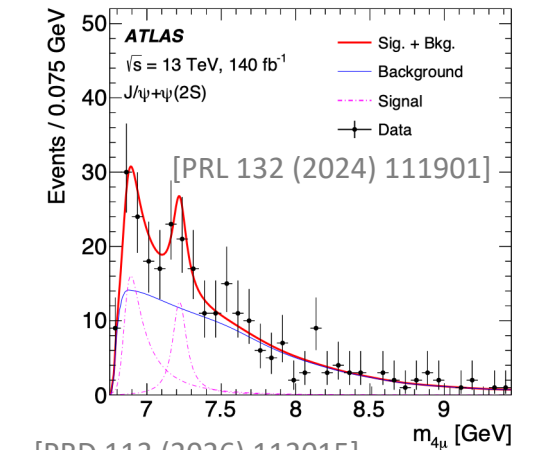
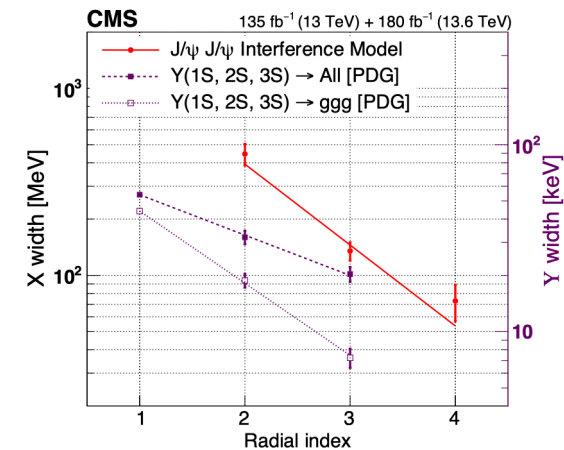
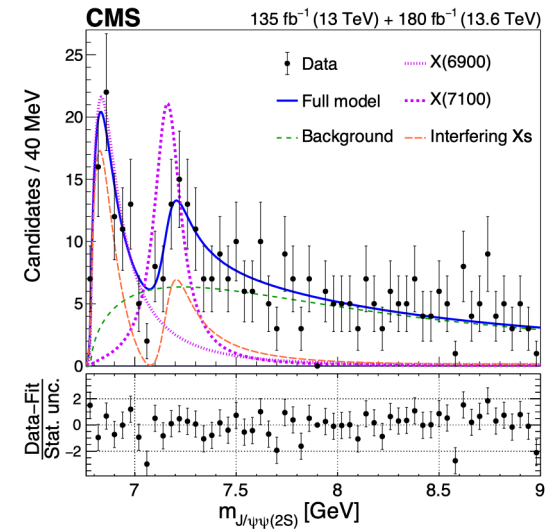
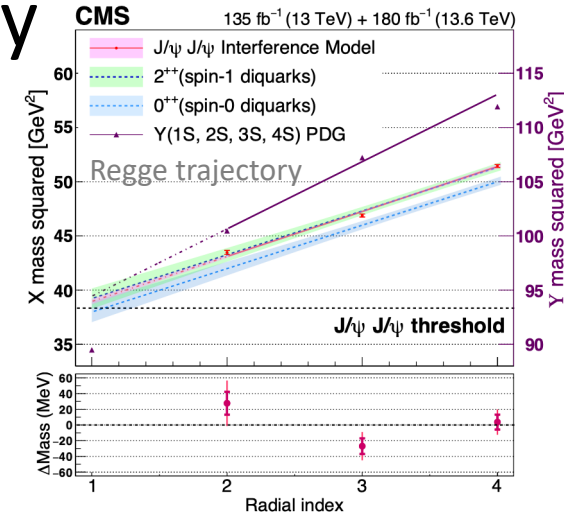
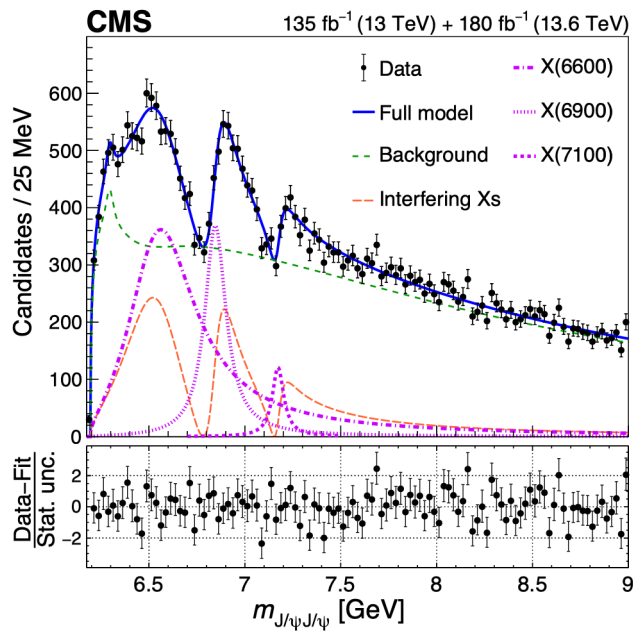
[PRL 132 (2024) 111901]



$X(6900)$ family

[arXiv:2602.02252]

- Establishing w/ more data & decay
 - All states and dips above 5σ
 - Interferences among structures, implying same J^{PC}

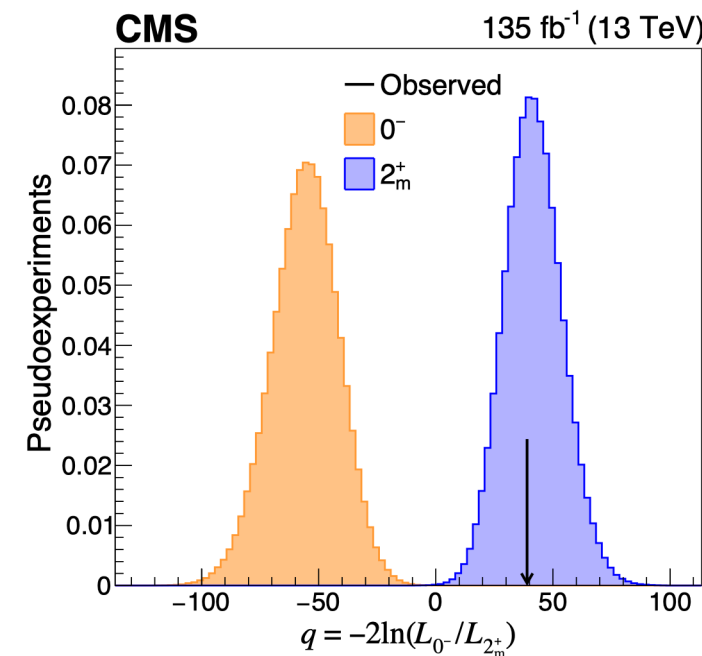
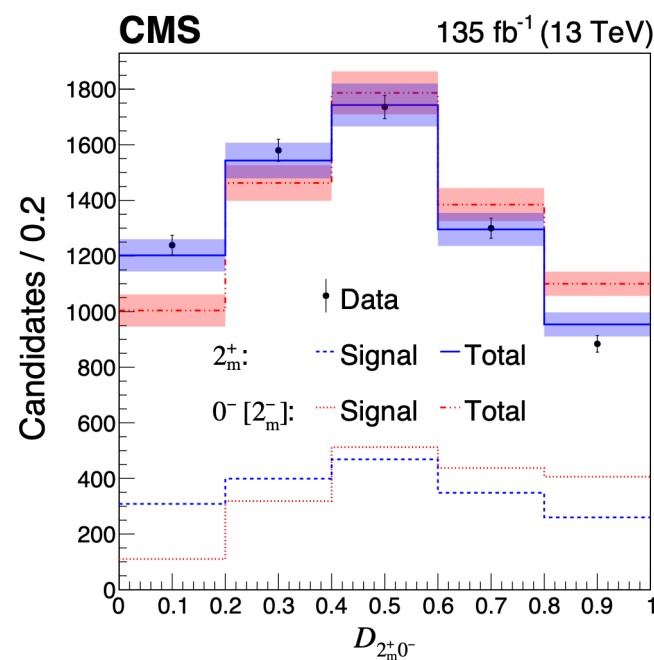
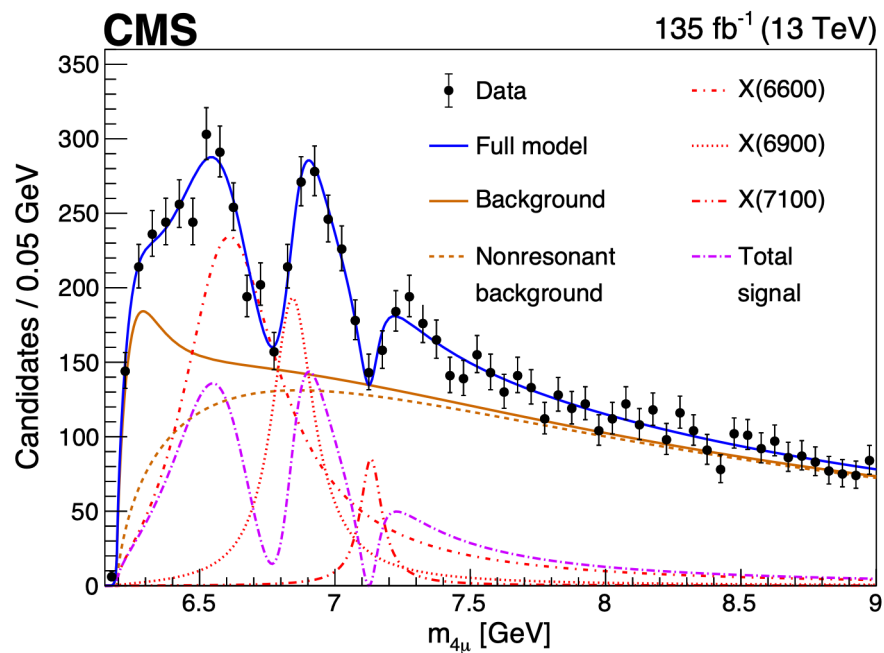
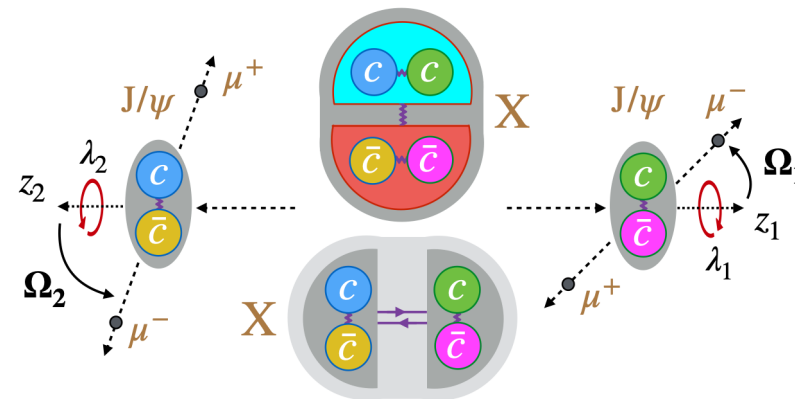


[PRD 113 (2026) 112015]

$$J^{PC}$$

- 2^{++} favoured, assuming the three states share the same quantum numbers

[Nature 648 (2025) 58]

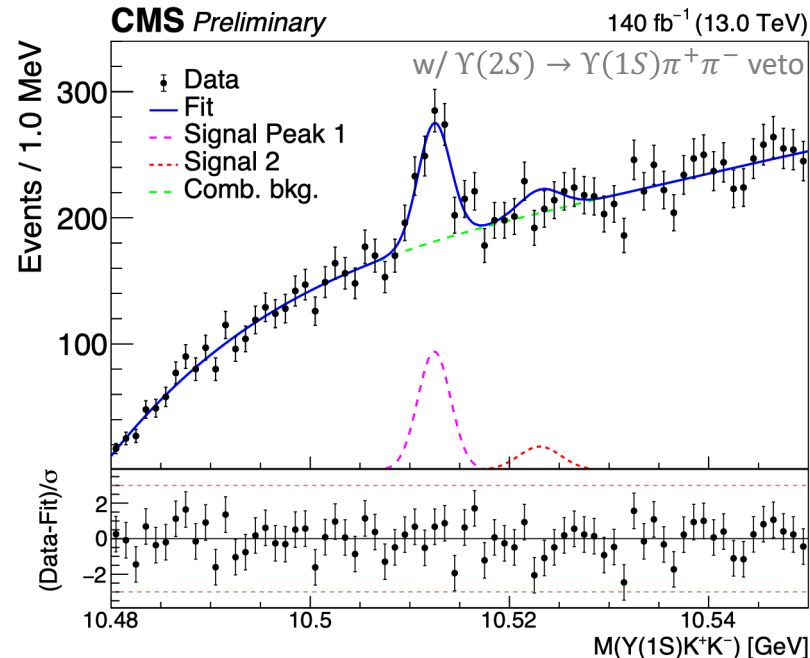
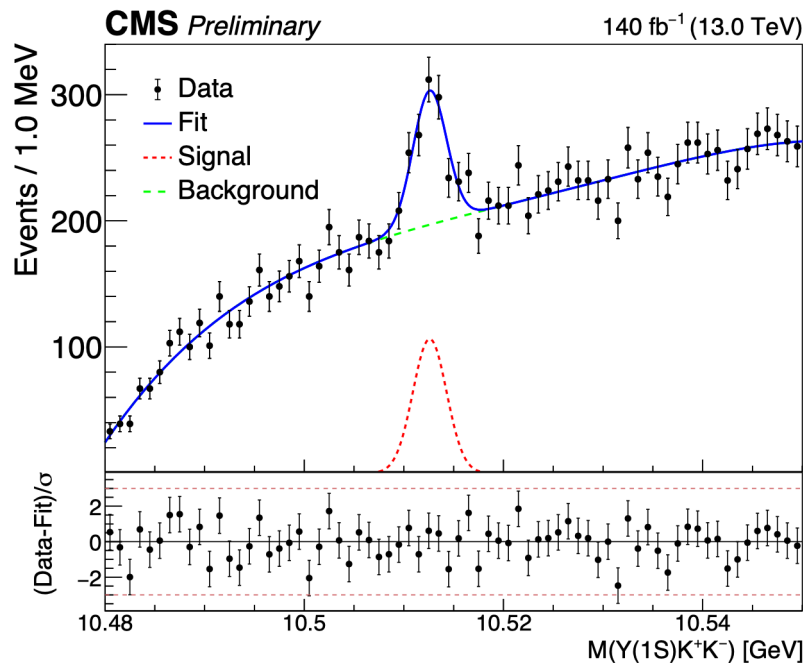


Structure in $m(\Upsilon(1S)\phi)$

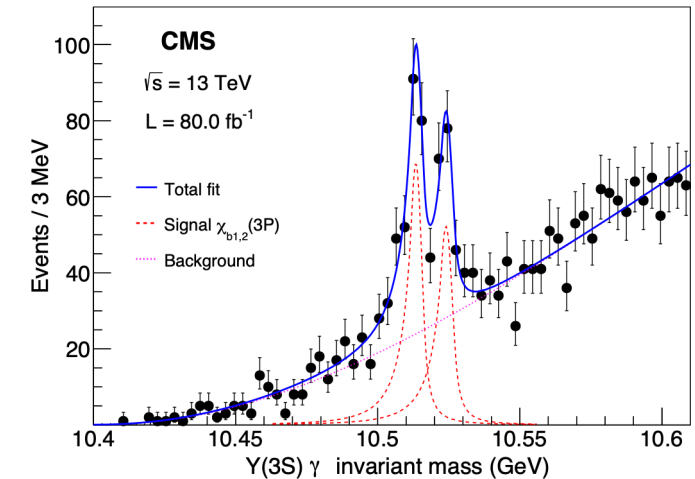
$(b\bar{b})?$

- Observed by CMS, w/ mass 10512.60 ± 0.21 (stat) ± 0.20 (syst) ± 0.11 (M_Υ) MeV
c.f. $M(\chi_{b1}(3P)) = 10513.42 \pm 0.41$ (stat) ± 0.18 (syst) MeV
– consistent w/ $\chi_{b1}(3P)$. No clear signal of $\chi_{b2}(3P)$, exotic contribution?

[CMS-PAS-BPH-25-009]



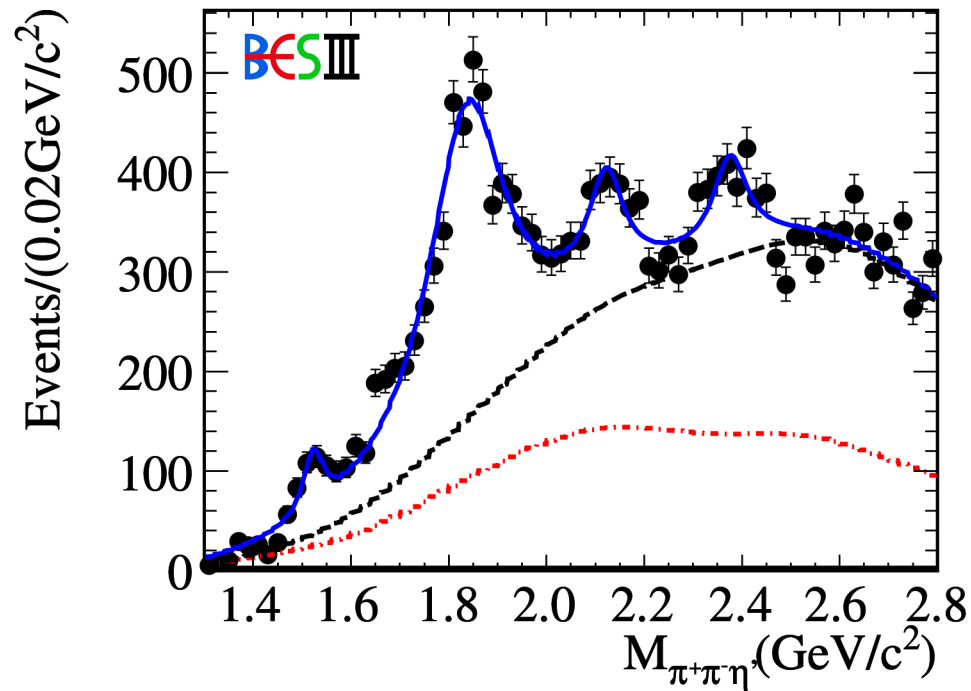
[PRL 121 (2018) 092002]



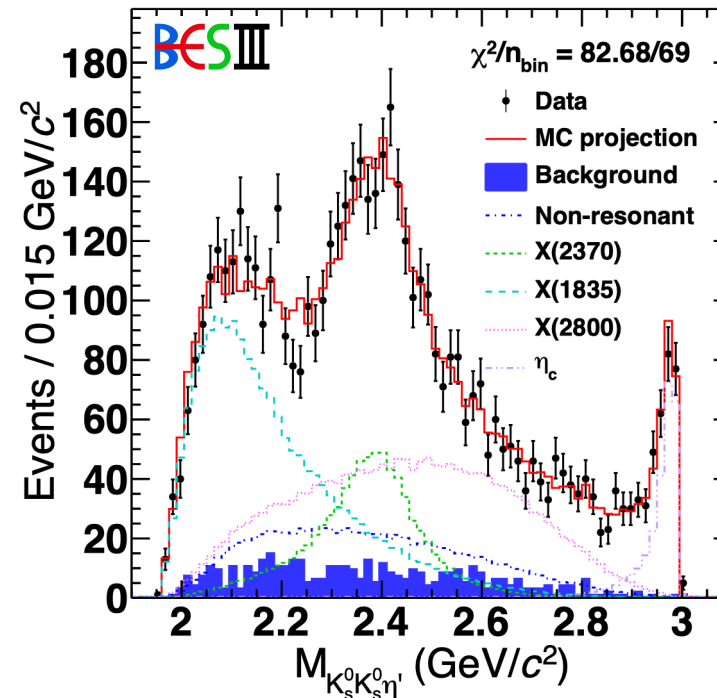
$X(2370)$, a glueball candidate

- Observed by BES-III in $J/\psi \rightarrow \gamma \pi^+ \pi^- \eta'$ in 2011, confirmed by BES-III with more data & in $J/\psi \rightarrow \gamma K \bar{K} \eta'$
- J^{PC} determined to be 0^{-+} with $J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta'$ in 2024

[PRL 106 (2011) 072002]



[PRL 132 (2024) 181901]

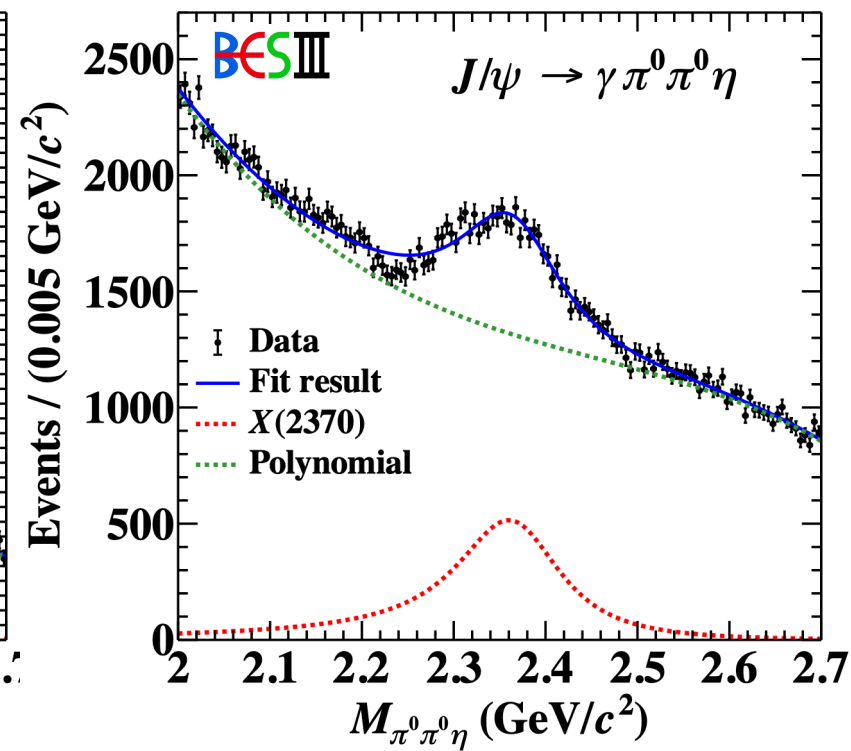
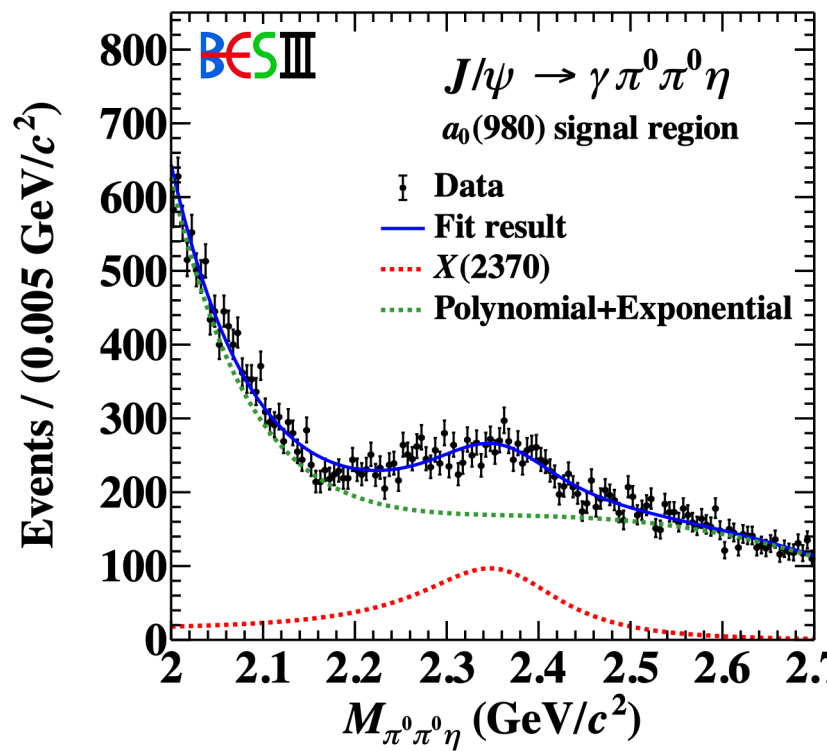
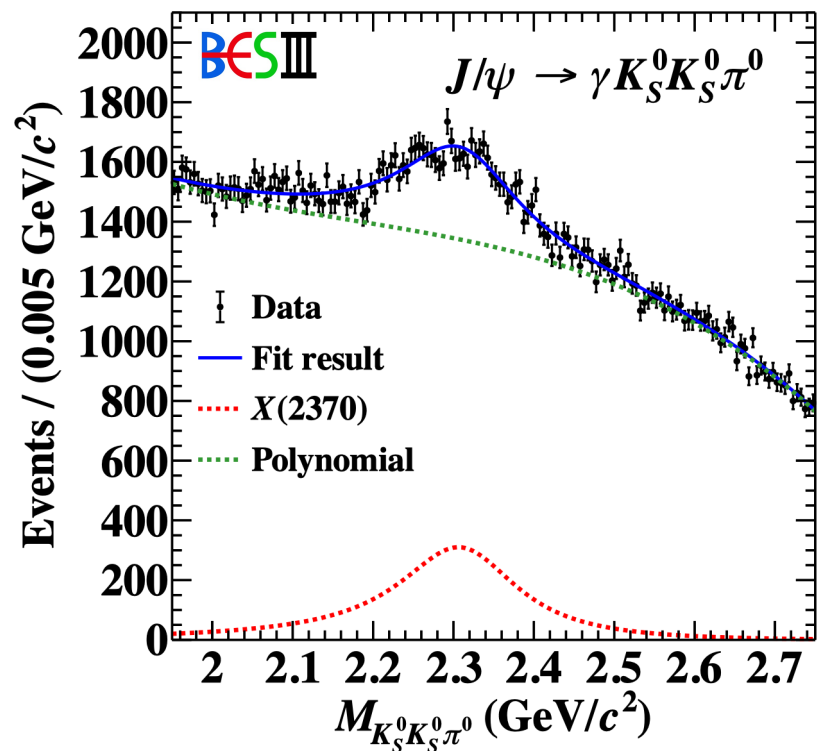


$X(2370)$, new decay modes

- $K_S^0 K_S^0 \pi^0, \pi^0 \pi^0 \eta, a_0(980) \pi^0$ observed by BES-III

- $M = 2359_{-14}^{+13} \text{ MeV}, \Gamma = 170_{-29}^{+44} \text{ MeV}$

[Chin. Phys. C 50 (2026) 101001]



$X(2370)$, a flavor-singlet

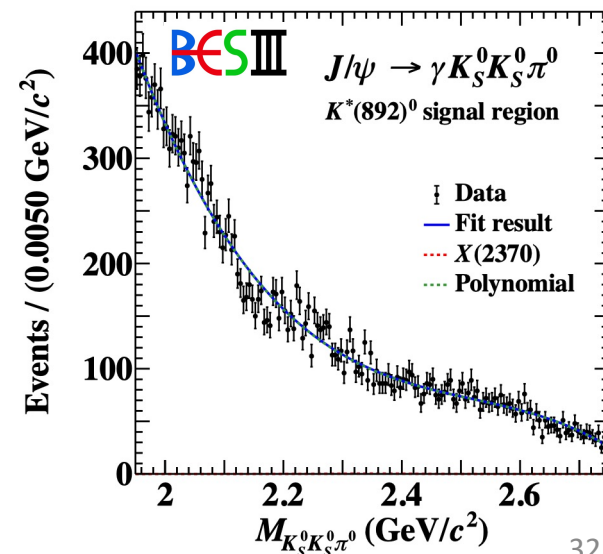
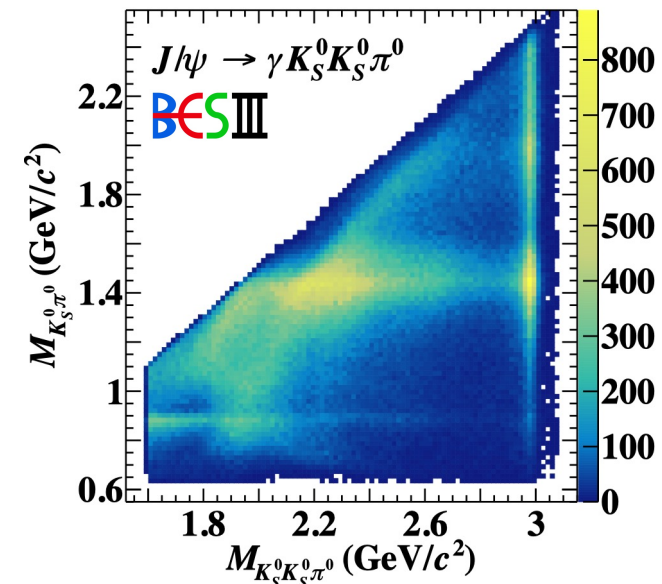
- Non-observation of $X(2370) \rightarrow K^*(892)\bar{K}$

[arXiv:2607.20366]

Lightest 0^{-+} Glueball as Dominant Constituent of $X(2370)$

BESIII Collaboration*

With 10 billion J/ψ events collected at BESIII, the decay of $X(2370) \rightarrow K^*(892)^0 \bar{K}^0 + \text{c.c.}$ is searched for via the $J/\psi \rightarrow \gamma K_S^0 K_S^0 \pi^0$ process. No evidence of this decay mode is found, with $\mathcal{B}[J/\psi \rightarrow \gamma X(2370)] \times \mathcal{B}[X(2370) \rightarrow K^*(892)^0 \bar{K}^0 + \text{c.c.} \rightarrow K_S^0 K_S^0 \pi^0] < 2.7 \times 10^{-6}$ at the 90% confidence level. The suppression of the $K^*(892)\bar{K}$ mode indicates the $X(2370)$ as a flavor-singlet state. It is the first flavor-singlet light hadron observed above $1 \text{ GeV}/c^2$. All BESIII measurements on the $X(2370)$ are summarized. A dominant component of the lightest 0^{-+} glueball is essential for a natural and complete explanation of the properties of the $X(2370)$ — the mass, spin-parity, high production rate in J/ψ radiative decays, decay pattern similarities to that of η_c , flavor-singlet property, narrow partial decay width, and suppression of radiative decays to ω and ϕ , since these properties are all consistent with the features of the lightest 0^{-+} glueball while other interpretations at present are disfavored. This supports that the lightest 0^{-+} glueball is the dominant constituent of the $X(2370)$.



Summary

- Great progress on the spectroscopy in the past years, leading to a more complete & consistent picture
 - $D_{s0}^*(2317)^+$, $D_{s1}(2460)^+$, $D_{s1}(2536)^+$, $D_{s1}(2933)^+$: $c\bar{s} + D^{(*)}K$?
 - $B_{s0}^*(5700)^0$, beauty counterpart of $D_{s0}^*(2317)^+$
 - $B_c^{(*)}(2S)^+$, $B_c(1P)^+$, B_c^{*+}
 - Ξ_{cc}^+ , Ω_{cc}^+
 - $X(6900)$, $X(6600)$, $X(7100)$
 - $X(2370)$, a glueball candidate
- More will come, stay tuned

