



第十二届中国LHC物理会议



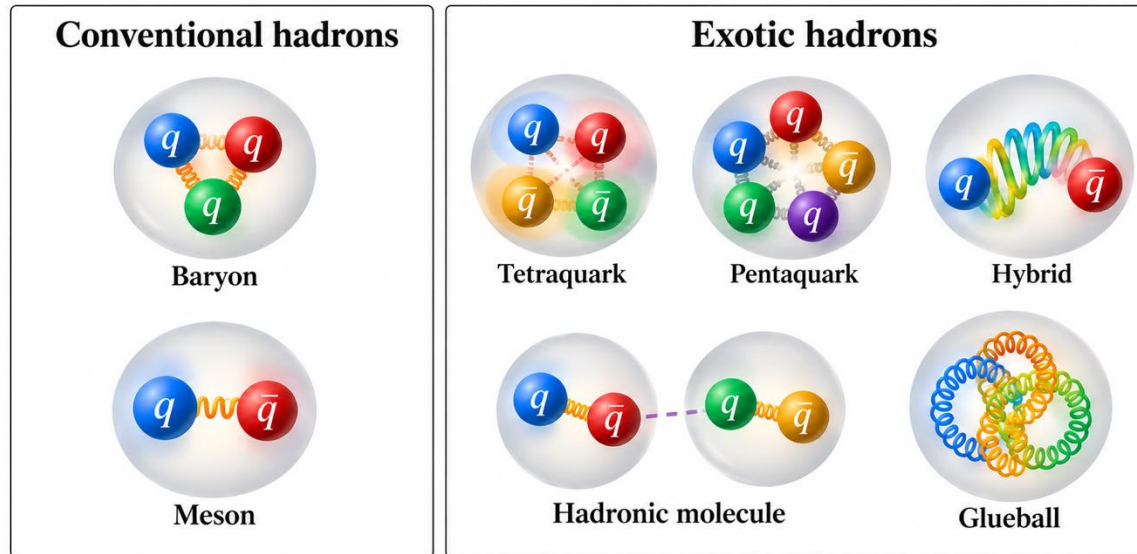
Recent results on hadron spectroscopy from LHCb

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Oct. 31th 2026 · 武汉理工大学 · 武汉

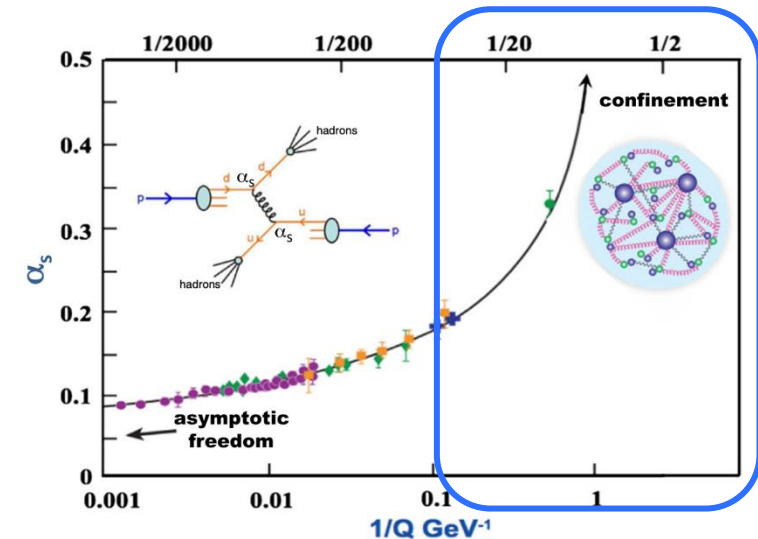
Introduction

- Hadrons exhibit a rich spectrum of quark flavours, inner structures and excitation patterns
- A key probe of strong interactions in the nonperturbative regime



Mass, Width, Quantum numbers, Decay rate ...

Nonperturbative QCD

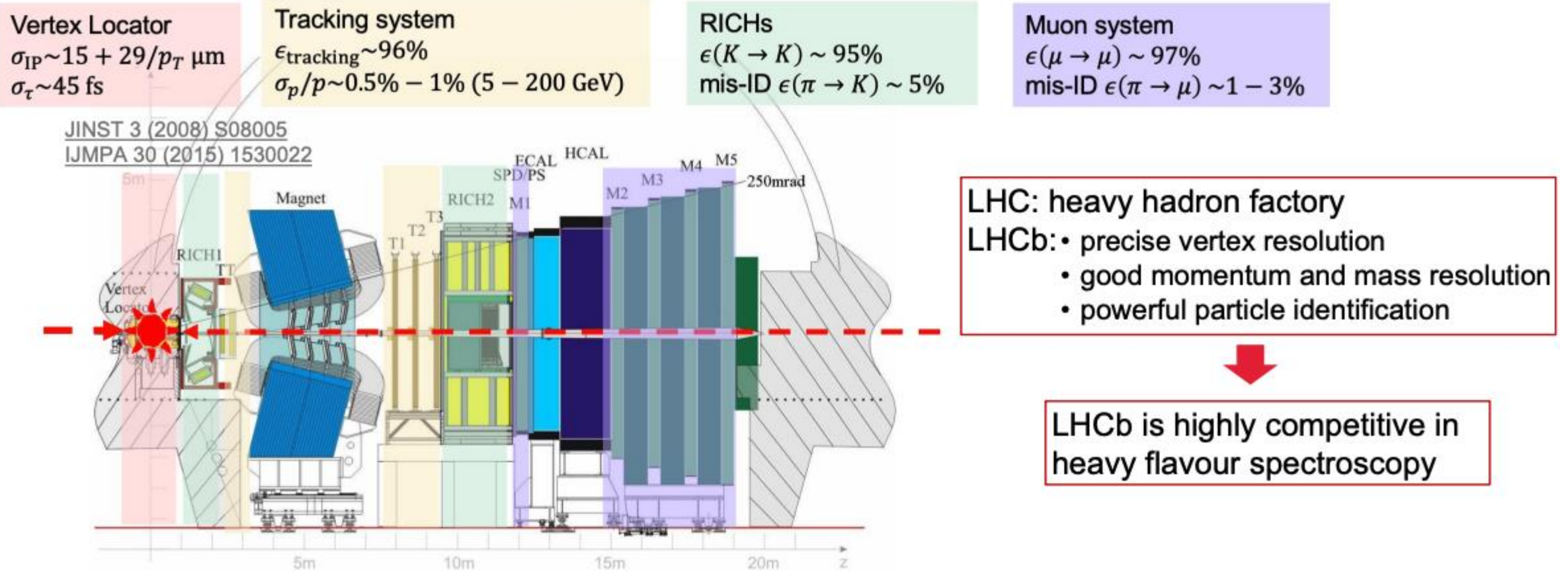


[Rev. Mod. Phys. 90 (2018) 1, 015003]

The LHCb detector @ Run1+2

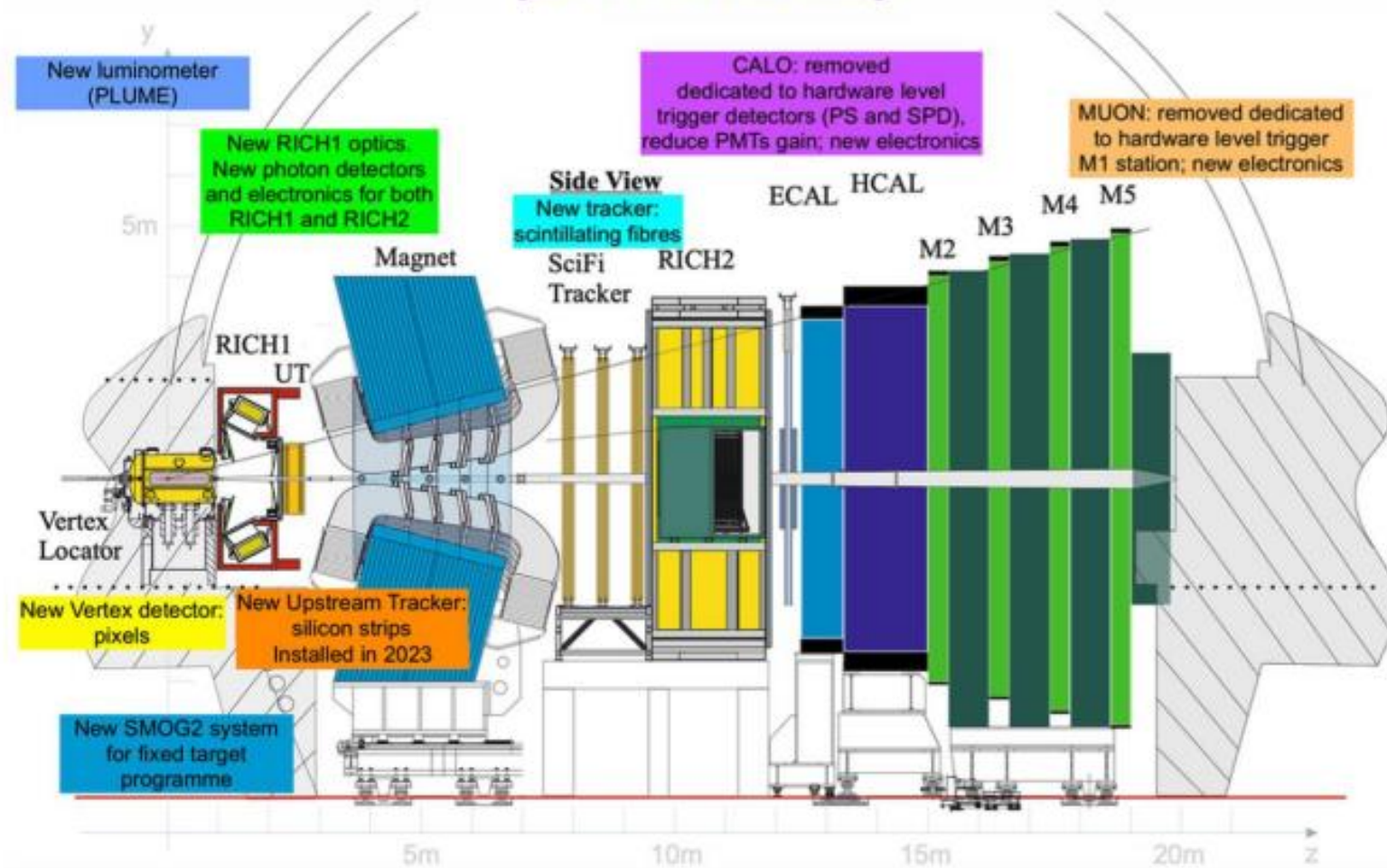
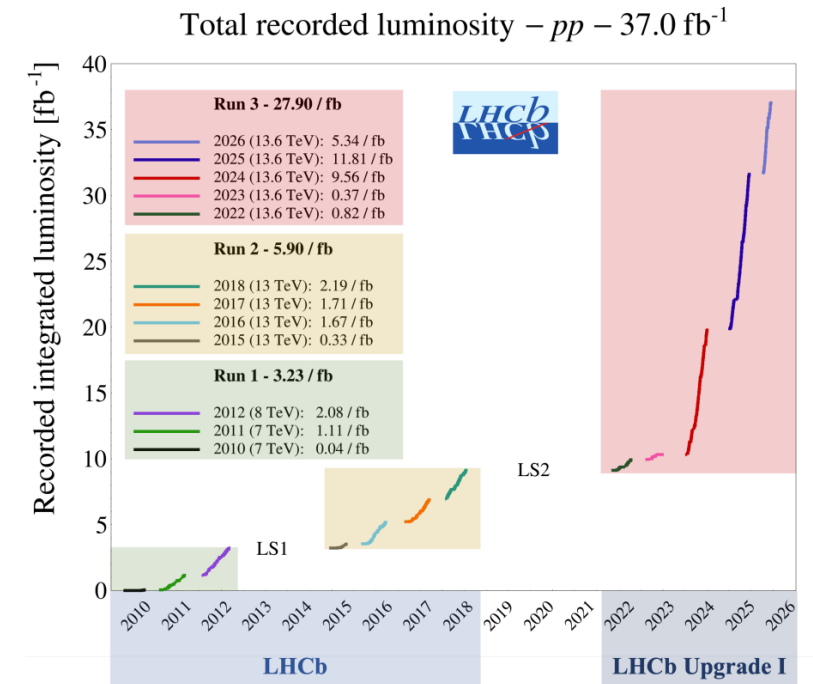
- A single-arm forward spectrometer covering $2 < \eta < 5$

Designed for heavy flavour physics expanded to spectroscopy



The upgraded LHCb detector in Run 3

[LHCb-DP-2022-002]

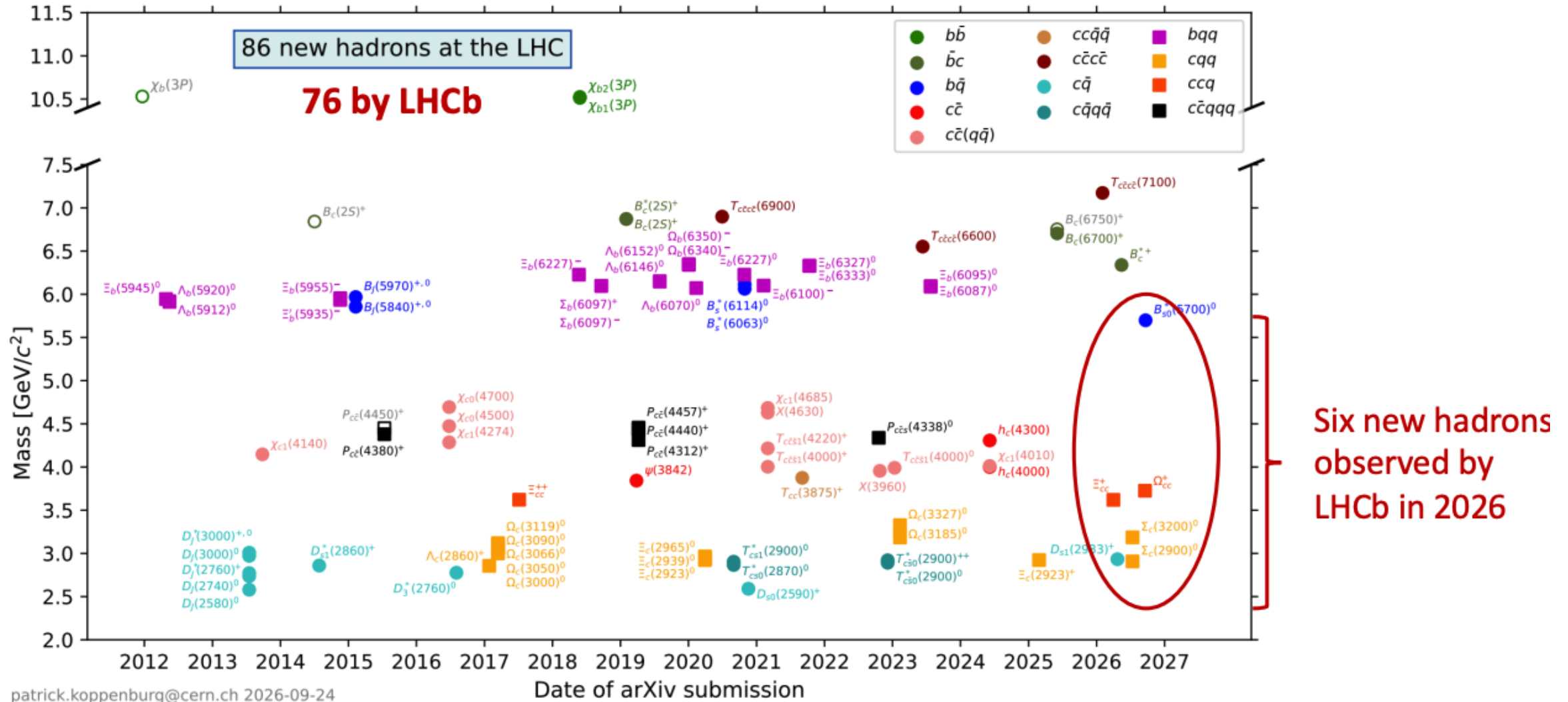


pp Collision data :

- 9 fb^{-1} in Run 1-2
- 28 fb^{-1} in Run 3

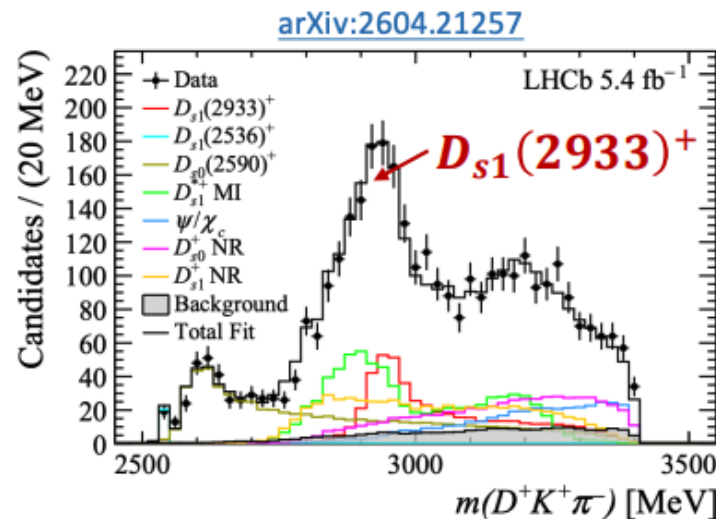
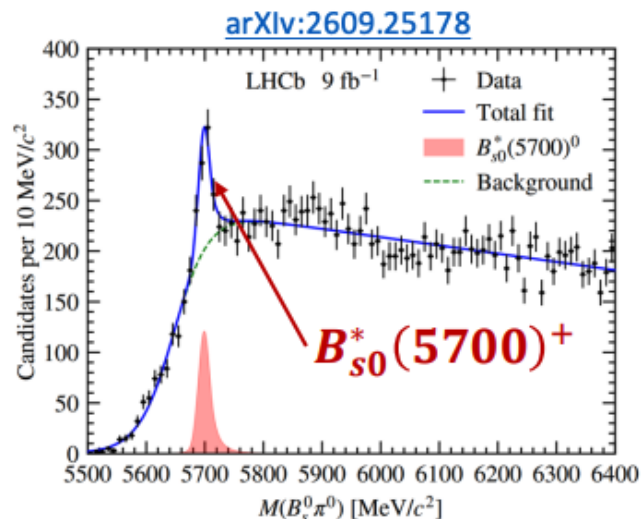
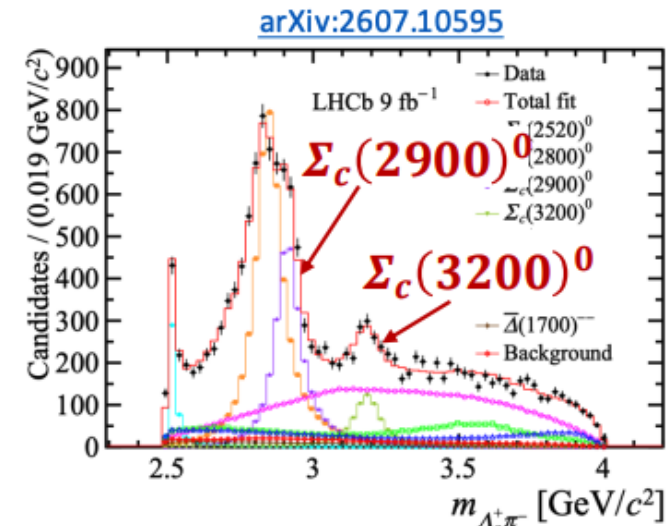
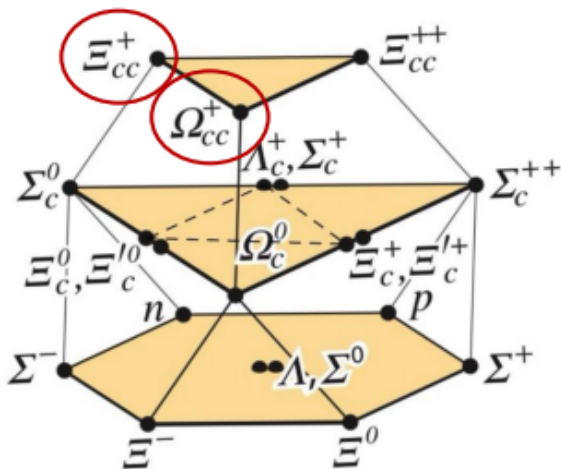
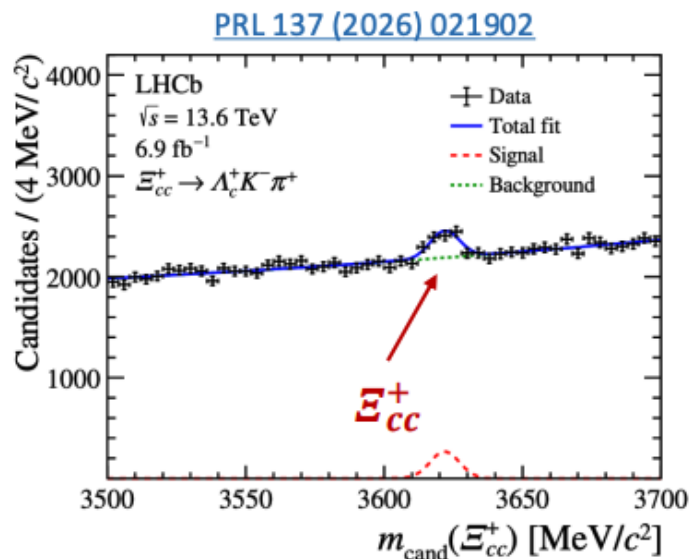
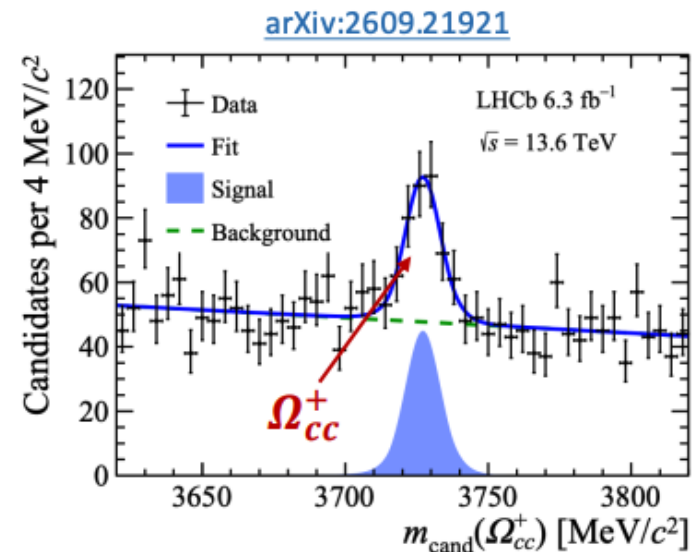
Running at $5 \times$ higher luminosity, with great potential in spectroscopy

New hadrons observed at LHCb



Beyond discovering, properties measurements

Six hadrons discoveries reported in 2026



Selected topics

- **Single charmed baryons**

- $\Sigma_c(2900)^0$ and $\Sigma_c(3200)^0$

[\[arXiv:2607.10595\]](#)

- **Doubly charmed baryons**

- Ξ_{cc}^+ and Ω_{cc}^+

[\[PRL 137 \(2026\) 021902\]](#) [\[arXiv:2609.21921\]](#)

- **Charm-strange meson**

- $D_{s1}(2460)^+$, $D_{s1}(2536)^+$ and $D_{s1}(2933)^+$

[\[arXiv: 2604.21257\]](#) [\[arXiv:2609.25178\]](#)

- **Charm-beauty meson**

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

[\[arXiv: 2608.10826\]](#)

- **Hidden-charm tetraquark**

- $T_{c\bar{c}1}(4430)^-$

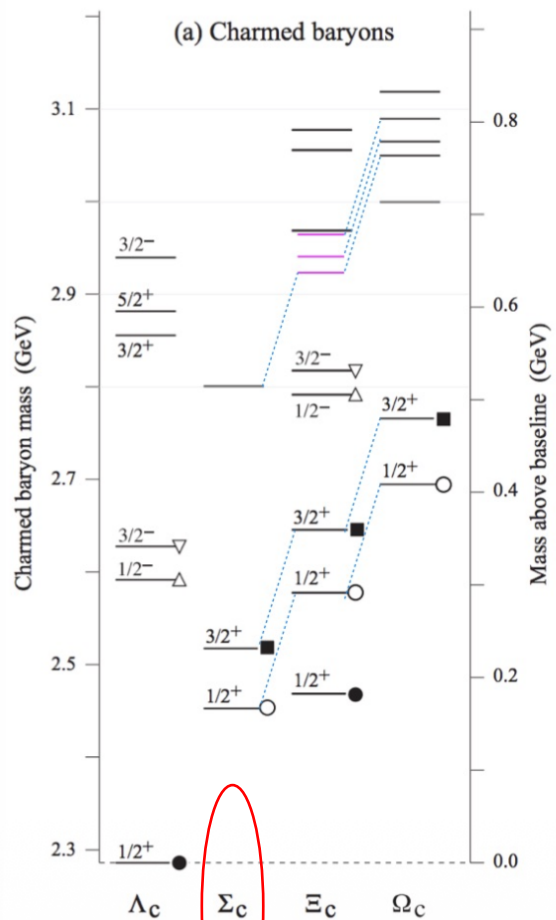
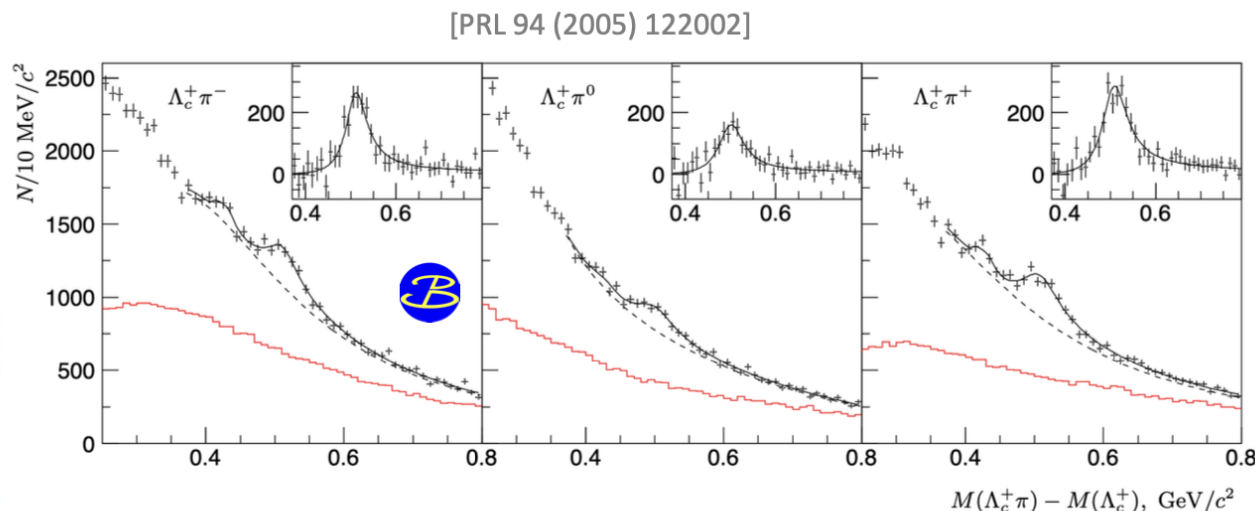
[\[arXiv: 2610.35239\]](#)

Other talks on spectroscopy

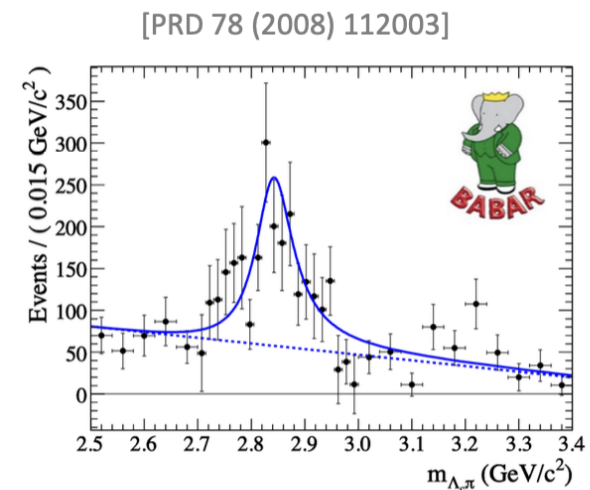
- Studies of charmed baryon spectroscopy and decays at LHCb Zeqing Mu
- Studies of doubly charmed baryons at LHCb Xingyu Tong
- Spectroscopy studies with $B \rightarrow DDX$ at LHCb Haoran Bao
- Observation of $B_S^{0*}(5700)$ at LHCb Yuhao Wang & Zifan Li
- Recent progress on baryonic decays of beauty hadrons at LHCb Zan Ren

$\Sigma_c(2800)$ spectroscopy

- Belle and Babar report different mass of $\Sigma_c(2800)$?



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}



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

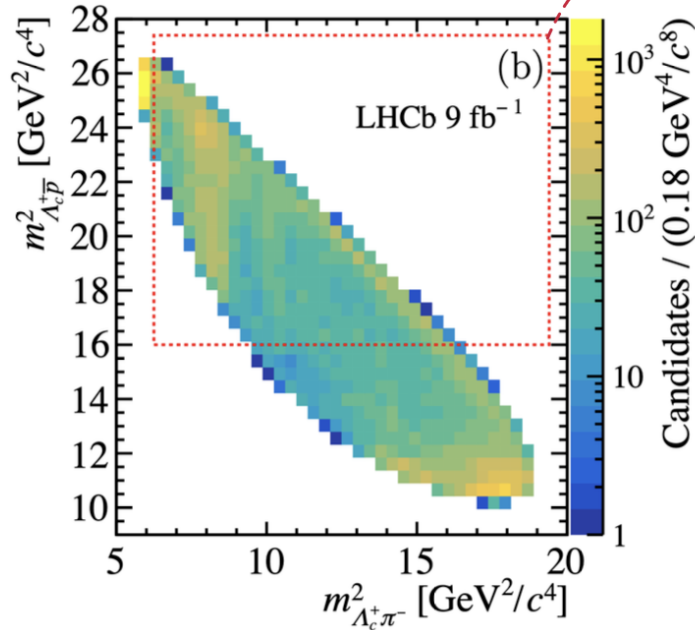
➡ $m(\Sigma_c(2800)^0) = 2802^{+4}_{-7} \text{ MeV}$

The same states or not?

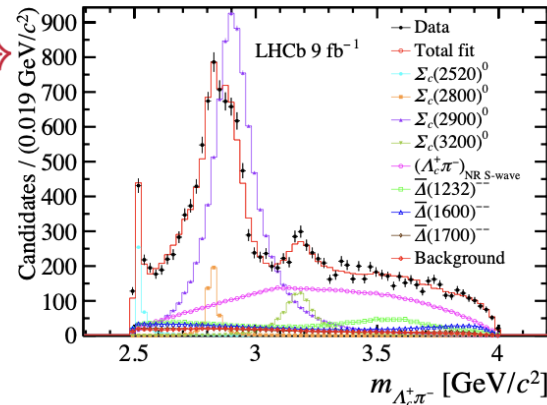
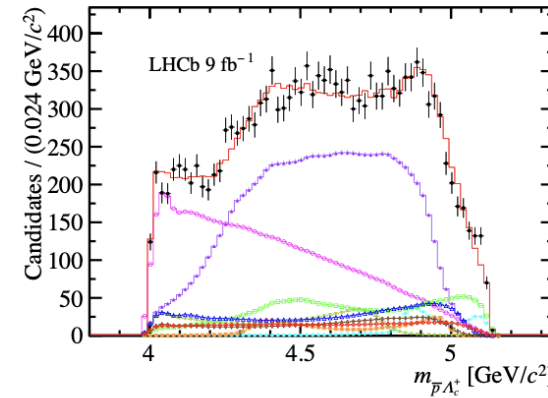
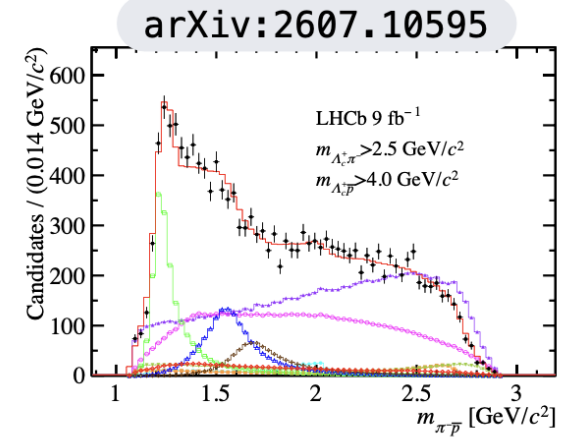
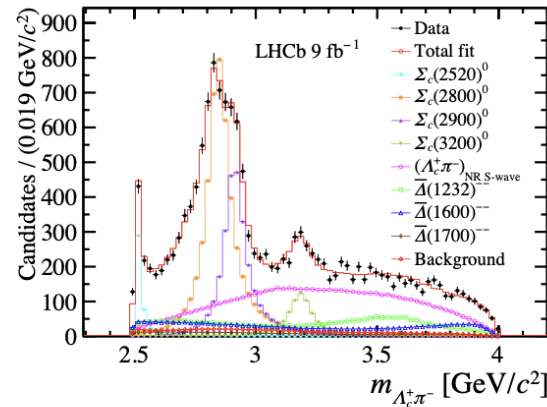
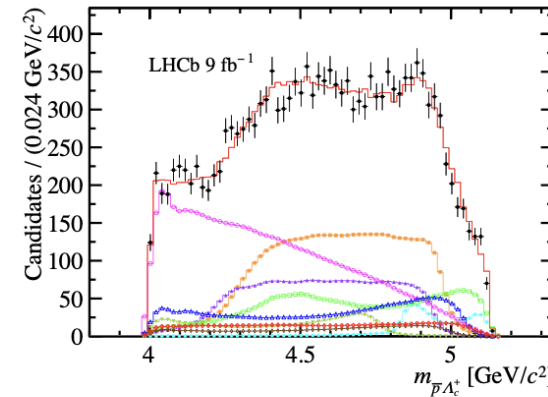
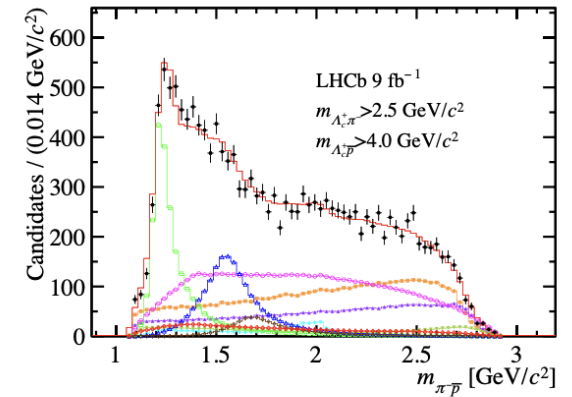
Mostly unexplored

New charmed baryons: $\Sigma_c(2900)^0$ and $\Sigma_c(3200)^0$

- Amplitude analysis of $B^- \rightarrow \Lambda_c^+ \bar{p} \pi^-$

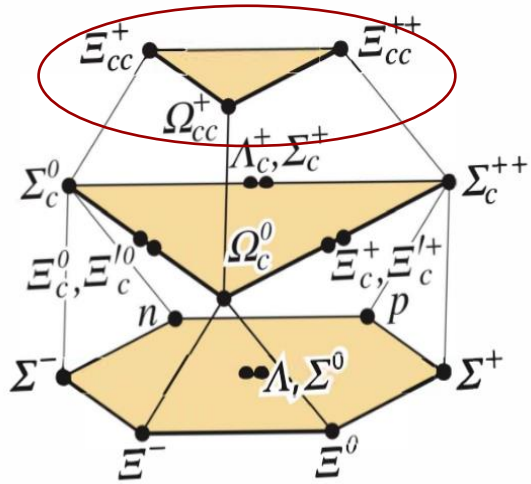


- Candidates within the red box are considered for the amplitude fit



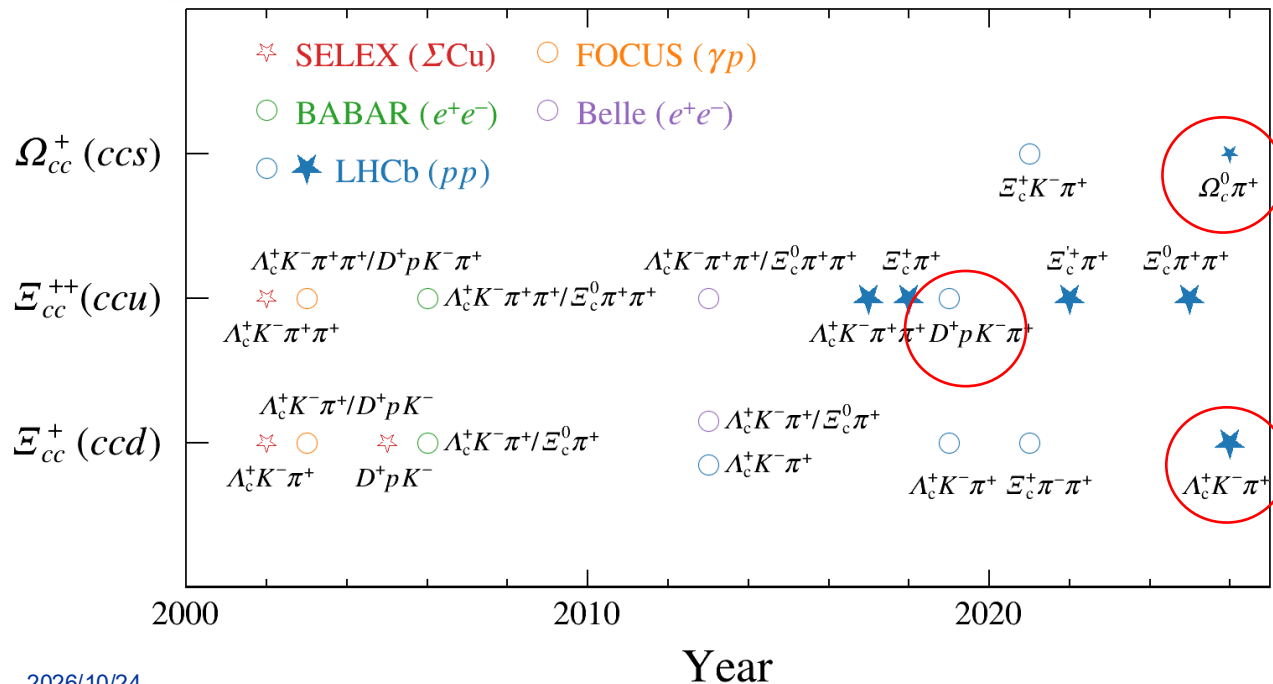
- The six panels show two equally good solutions: Group A (top) has a narrow $\Sigma_c(2800)^0$ and broad $\Sigma_c(2900)^0$, while Group B (bottom) gives them similar widths.

Doubly charmed baryon



- A E_{cc} iso-doublet (ccu ; ccd) and an Ω_{cc} iso-singlet (ccs)
- A unique system to test QCD calculations

First doubly charmed baryon Ξ_{cc}^{++} observed at LHCb in 2017



LHCb Run 3 :

- $5 \times \mathcal{L}(t)$ with the upgraded detector
- Yield per fb^{-1} improved factor ~ 4 thanks to improved fully-software trigger

► Observation of Ξ_{cc}^+ and Ω_{cc}^+

Observation of Ξ_{cc}^+ via $\Xi_{cc}^+ \rightarrow \Lambda_c^+ K^- \pi^+$

[PRL 137 (2026) 021902]

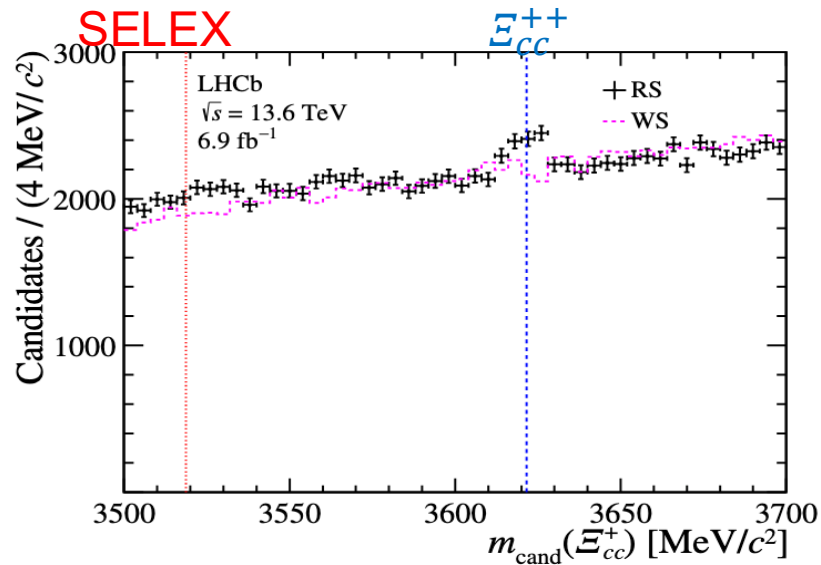
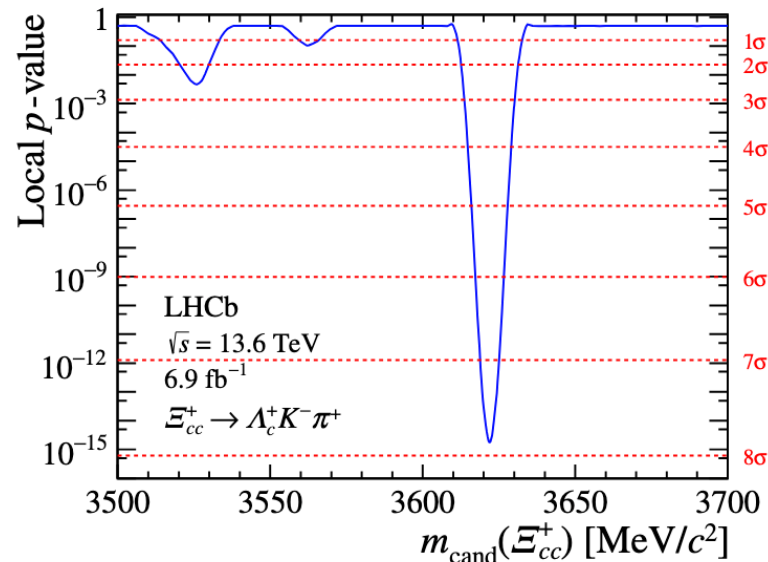
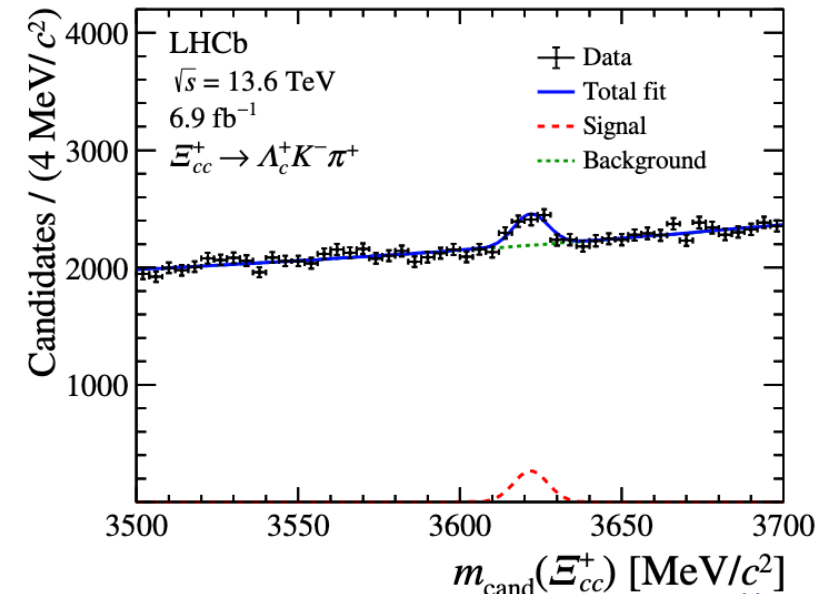
➤ Dataset: A subset collected in 2024 ($\sim 6.9 \text{ fb}^{-1}$)

➤ Mass difference between Ξ_{cc}^+ and Ξ_{cc}^{++} :

$$\Delta M = M(\Xi_{cc}^{++}) - M(\Xi_{cc}^+) = 1.77 \pm 0.84(\text{stat}) \pm 0.15(\text{syst})_{-1.30}^{+1.90}(\text{lifetime}) \text{ MeV}/c^2$$

✓ Consistent with predicted isospin splitting [PRD96(2017)033004]

➤ No structure at SELEX-claimed 3520 MeV



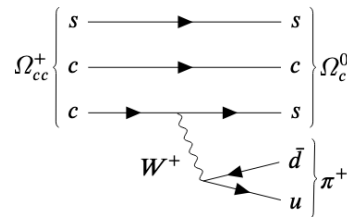
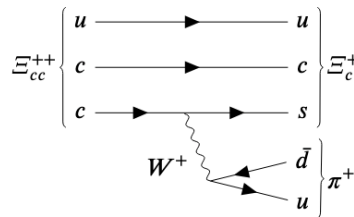
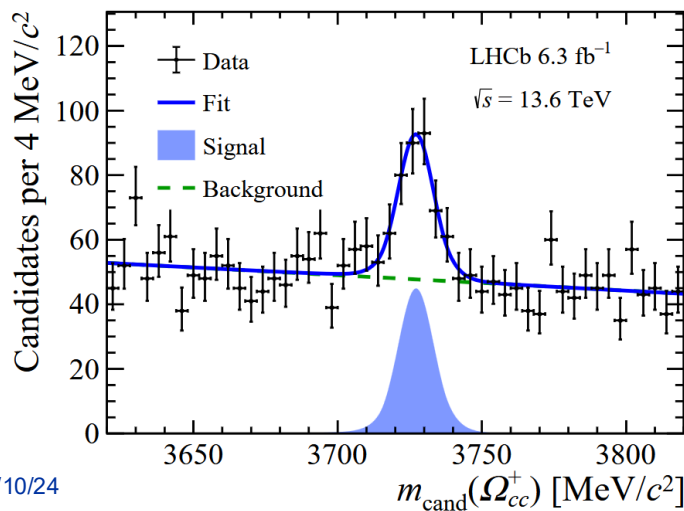
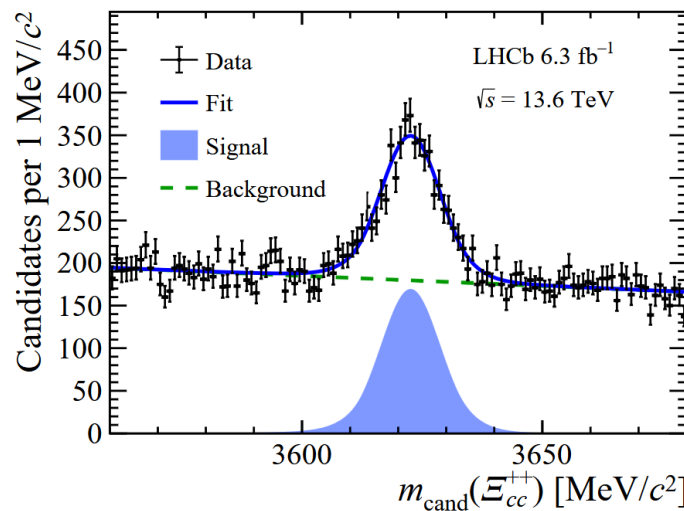
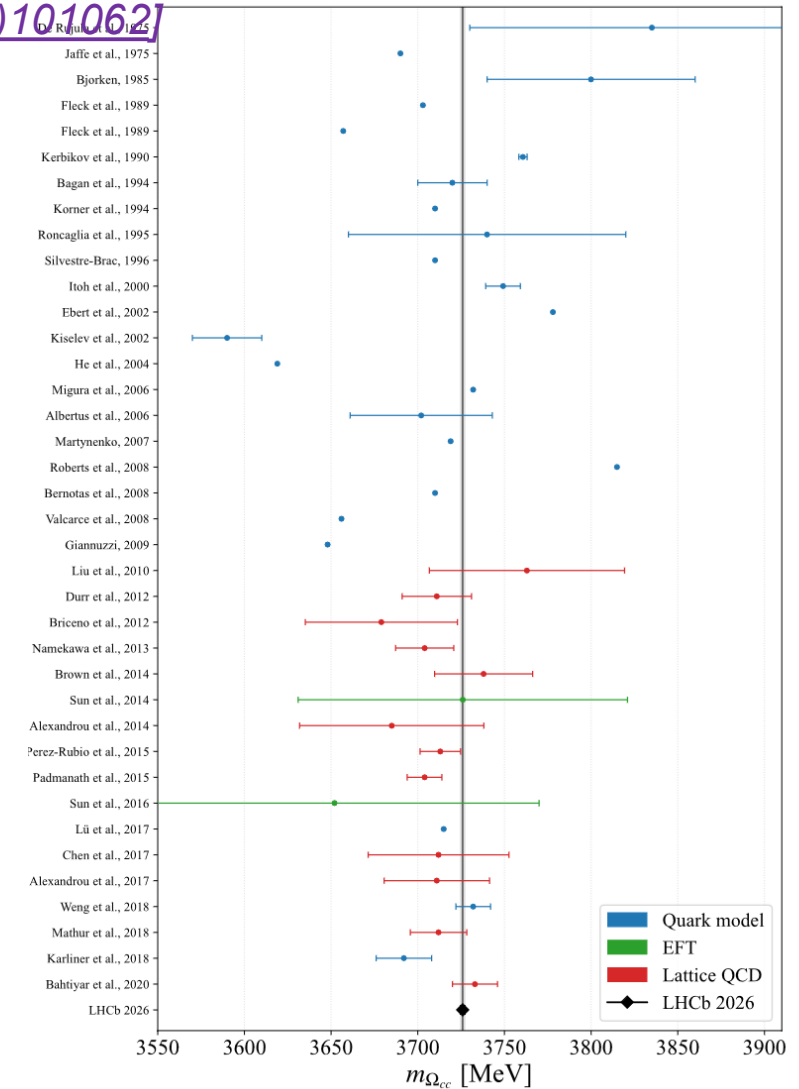
Observation of Ω_{cc}^+ via $\Omega_{cc}^+ \rightarrow \Omega_c^0 \pi^+$

[arxiv:2609.21921]

- Global significance $< 3\sigma$ in LHCb Run 2 data [SCPMA64(2021)101062]
- Search for Ω_{cc}^+ via $\Omega_{cc}^+ \rightarrow \Omega_c^0 \pi^+$ in LHCb 2024 data
- Ω_{cc}^+ mass:

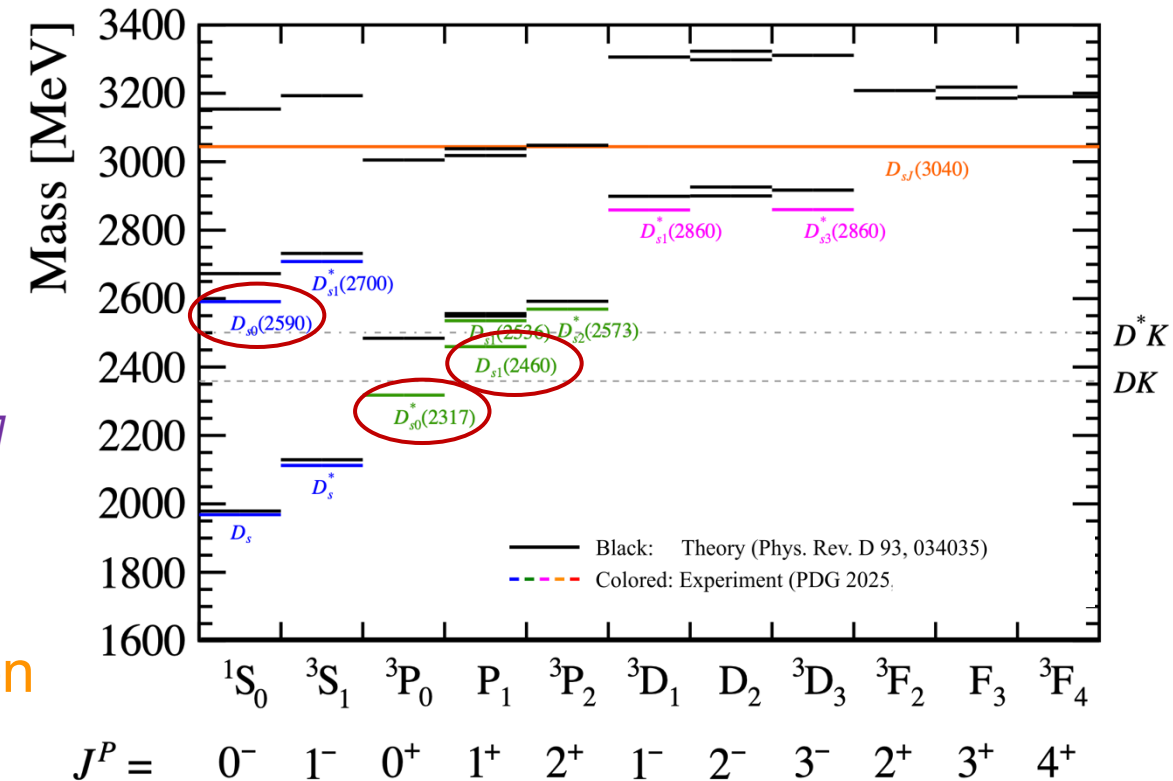
$$M(\Omega_{cc}^+) = 3725.9 \pm 1.0(\text{stat}) \pm 0.2(\text{syst}) \pm 0.4(\text{lifetime}) \pm 0.6(\text{ext}) \text{ MeV}/c^2$$

- Compatible with theoretical predictions



Low mass puzzles in D_s^+ spectrum

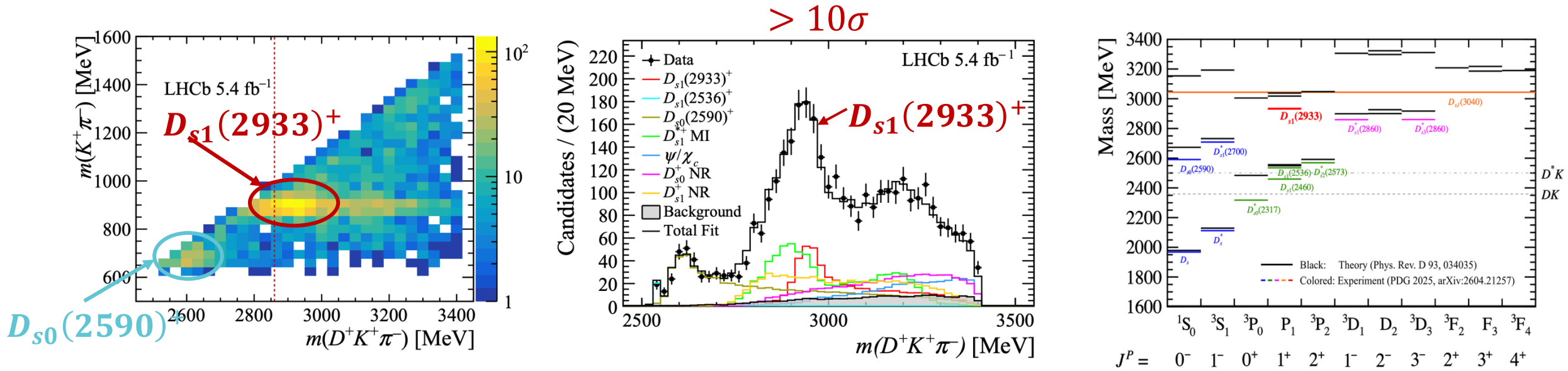
- $D_{s0}^*(2317)^+$ and $D_{s1}(2460)^+$ observed by Babar and CELSO in 2003
 - Masses significantly lower than quark-model predictions
- Tetraquark? [\[arXiv:2602.11744\]](#)
- Couple channel effect? [\[PRD 106 \(2022\) 074014\]](#)
- $D_{s0}(2590)^+$ observed in 2021
 - Mass also lower than quark-model prediction
- Coupled-channel effect? [\[PRD 106 \(2022\) 074014\]](#)



Need to investigate more decay modes

[arXiv:2604.21257]

➤ Amplitude analysis of $B^0 \rightarrow D^+ D^- K^+ \pi^-$ in the full phase space



- Mass and width: $M = 2933_{-5}^{+6}(\text{stat.})_{-3}^{+4}(\text{syst.}) \text{ MeV}$; $\Gamma = 72_{-12}^{+18}(\text{stat.})_{-10}^{+7}(\text{syst.}) \text{ MeV}$
- Spin-parity: $J^P = 1^+$, other J^P hypotheses rejected at $> 5\sigma$
- Mass also lower than quark-model prediction

Couple channel effect? [\[arXiv:2605.17832\]](https://arxiv.org/abs/2605.17832)

Muon-tagged $D_{s1}(2460)^+ / D_{s1}(2536)^+ \rightarrow D_s^+ \pi^+ \pi^-$

$D_s^+ \pi^+ \pi^- \mu^-$:

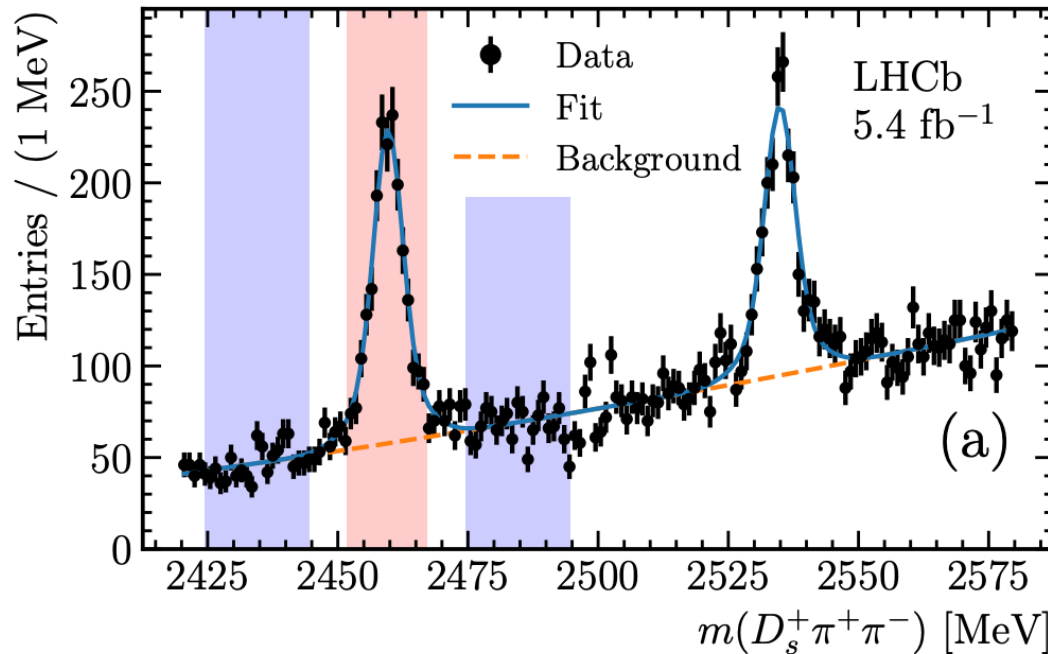
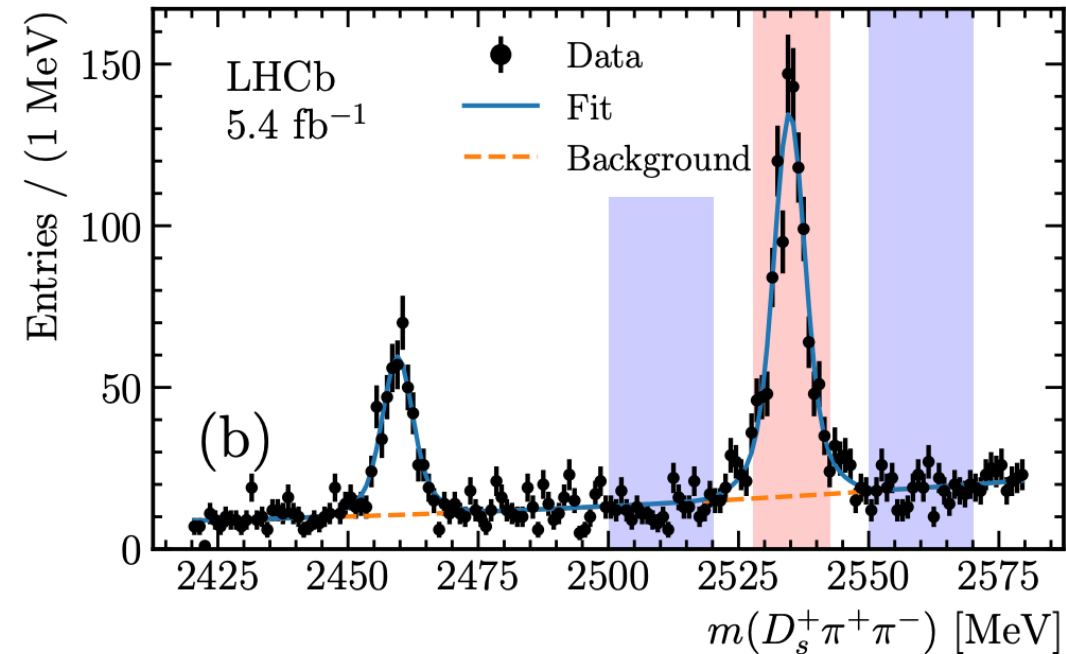
[arXiv:2608.10826]

Double charm enhanced sample:

$B \rightarrow D_s^+ \pi^+ \pi^- \bar{D} X, \bar{D} \rightarrow \mu^- X'$

Semileptonic enhanced sample:

$B \rightarrow D_s^+ \pi^+ \pi^- \mu^- X$



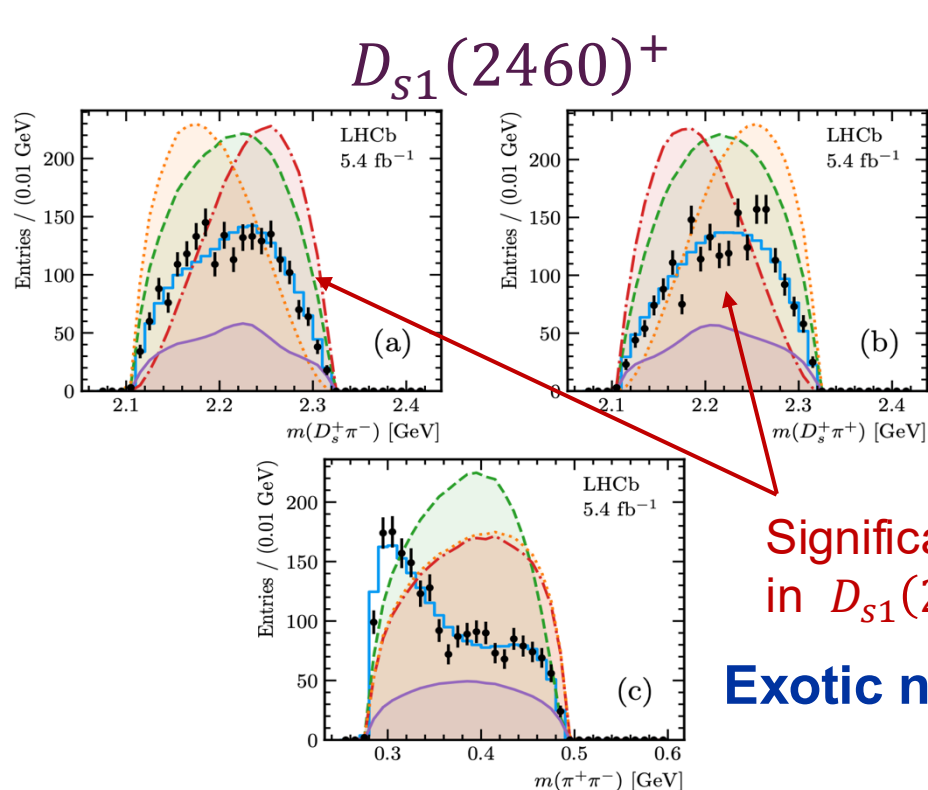
Parameter	DD selection	SL selection
$D_{s1}(2460)^+$ yield	1360 ± 70	376 ± 25
$D_{s1}(2536)^+$ yield	1180 ± 60	980 ± 40

$D_{s1}(2460)^+ / D_{s1}(2536)^+ \rightarrow D_s^+ \pi^+ \pi^-$ Dalitz analysis

[arXiv:2608.10826]

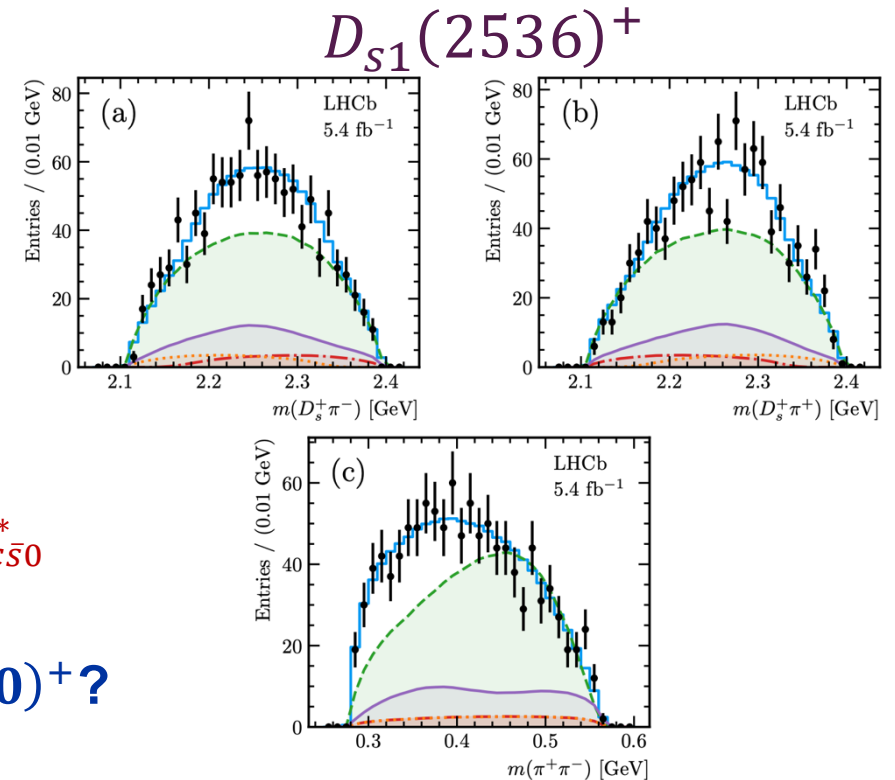
➤ Several models tested:

- f states + $T_{c\bar{s}0}^{++/0}$ (best fit)
 - $T_{c\bar{s}0}^{++/0}$ modelled with relativistic Breit-Wigner function (parameters poorly determined)
 - $T_{c\bar{s}0}^{++/0}$ modelled with K-matrix considering $DK \rightarrow D_s^+ \pi$ rescattering (most reasonable)



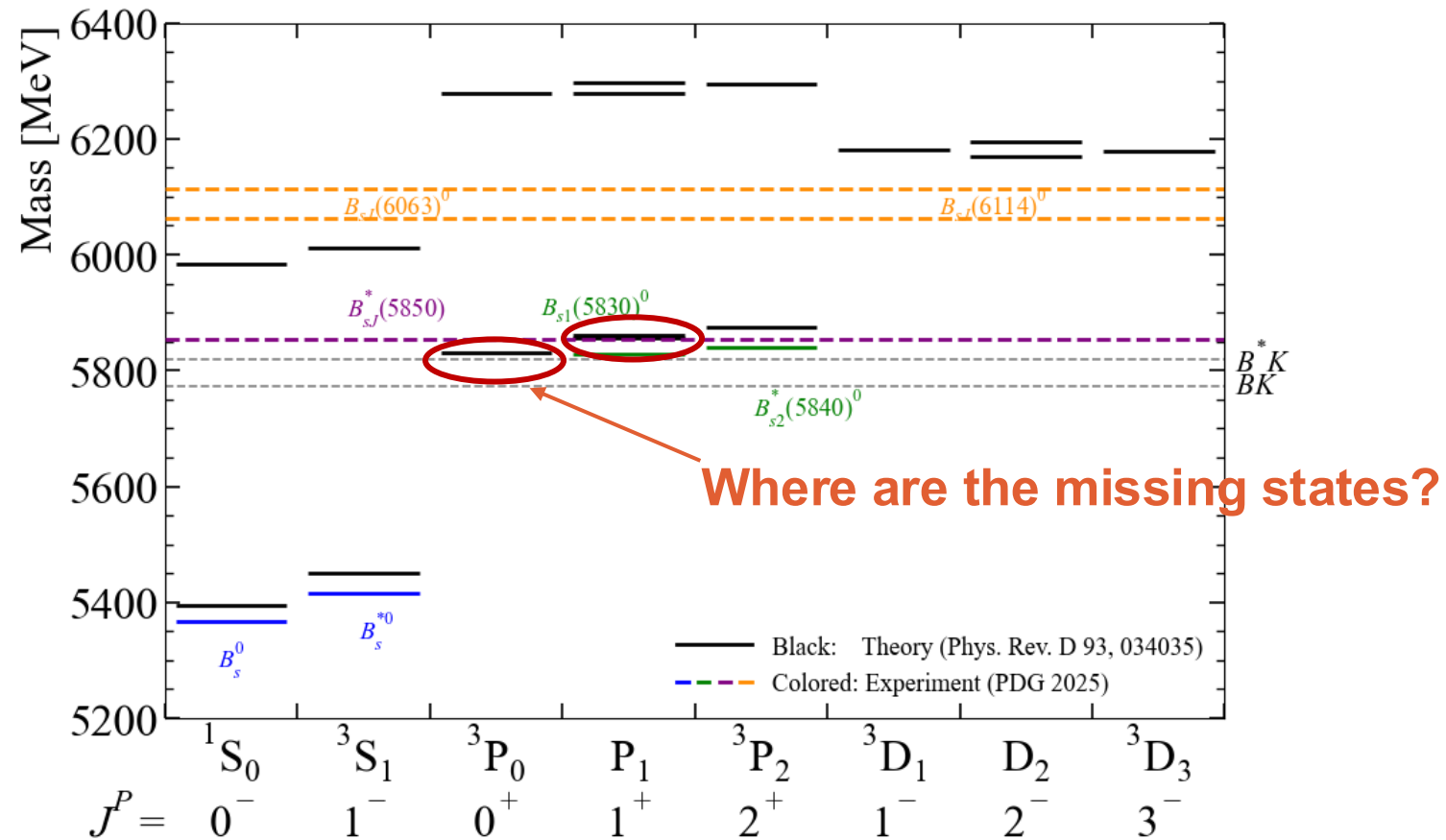
Significant contribution of $T_{c\bar{s}0}^*$
in $D_{s1}(2460)^+$ decay

Exotic nature of $D_{s1}(2460)^+$?



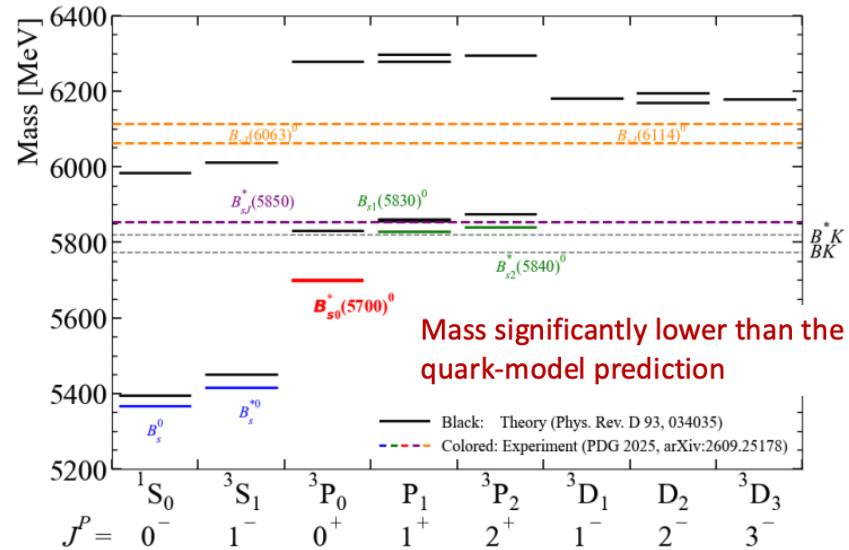
$T_{c\bar{s}0}^*$ in $D_{s1}(2536)^+$ decay: 4 σ

From D_s^+ to B_s^0 spectrum

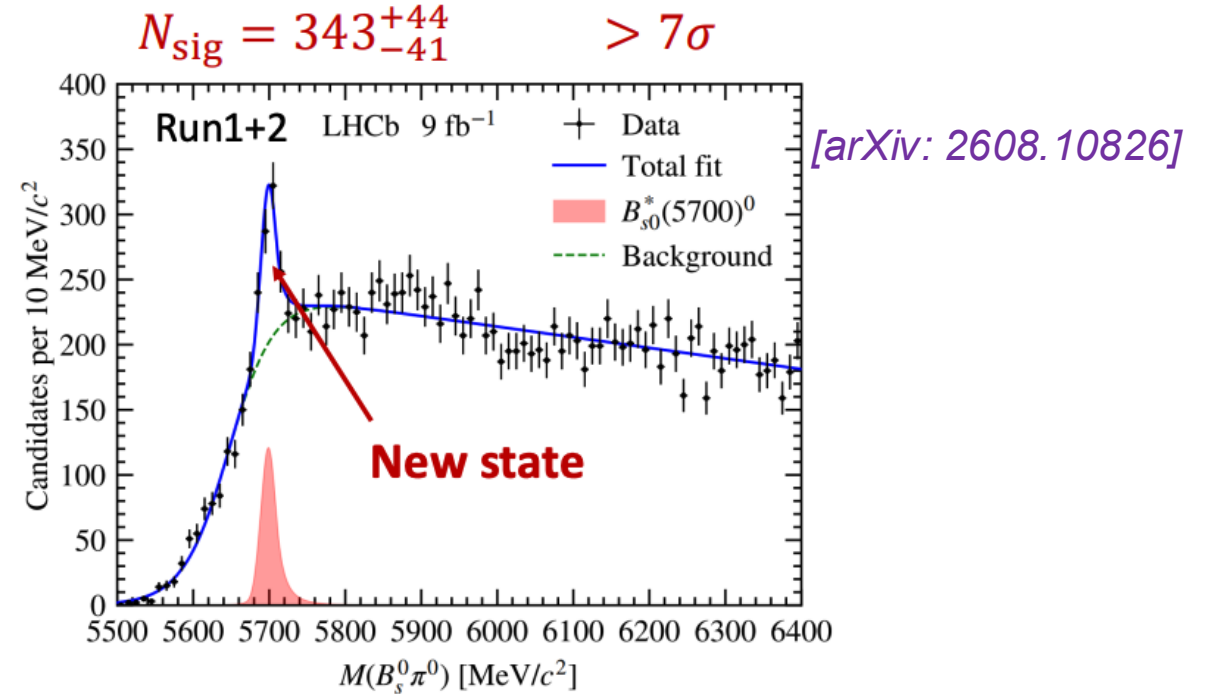


New state in the $B_s^0 \pi^0$ final state

➤ $B_s^0 \rightarrow D_s^- \pi^+, J/\psi \phi, D_s^- 3\pi$;



Similar pattern to that of $D_{s1}(2460)^+$ under the $J^P = 1^+$ interpretation



• Two interpretations:

$$B_{s0}^{*0} \rightarrow B_s^0 \pi^0 \quad m = 5698.9 \pm 1.5 \text{ (stat)} \pm 0.6 \text{ (syst) MeV} \\ \Gamma < 11.8 \text{ MeV} \quad (95\% \text{ CL})$$

$$B_{s1} \rightarrow B_s^{*0} \pi^0 \quad m = 5748.3 \pm 1.5 \text{ (stat)} \pm 0.6 \text{ (syst) MeV} \\ \Gamma < 11.8 \text{ MeV} \quad (95\% \text{ CL})$$

- Similar mass splitting as $D_{s0}^{*0}(2317)^+$
 - the same heavy-flavour independent mechanism?

$$m(D_{s0}^{*0}(2317)) - m(D_s) = 349.5 \text{ MeV}$$

$$m(B_{s0}^{*0}(5700)) - m(B_s) = 332.0 \text{ MeV}$$

Exotic nature?

$T_{c\bar{c}1}(4430)^-$

Formerly $Z_c(4430)$

➤ First observed in $B^0 \rightarrow \psi(2S)\pi^-K^+$ by Belle in 2008

Spin-parity later determined as $J^P = 1^+$

➤ Confirmed by LHCb in $\psi(2S)\pi^-$ of several decays

$B^0 \rightarrow \psi(2S)\pi^-K^+$; $B^+ \rightarrow \psi(2S)\pi^-\pi^+K^+\pi^+$; $B^- \rightarrow \psi(2S)\pi^-K_S^0$

[\[PRL 112 \(2014\) 222002\]](#), [\[JHEP 01 \(2025\) 054\]](#), [\[PRD 113 \(2026\) L071101\]](#)

• Discussions about $T_{c\bar{c}1}(4430)^-$

• Manifestly exotic states of four quarks

• **Structure remains unknown**

• $D^*\bar{D}_1$ molecular?

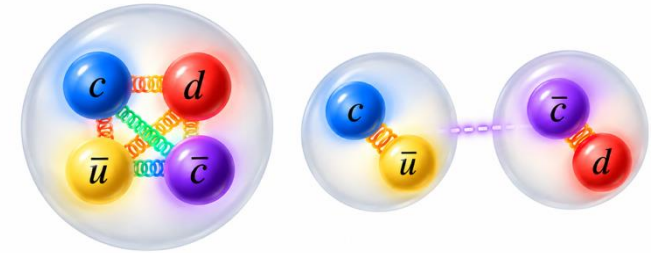
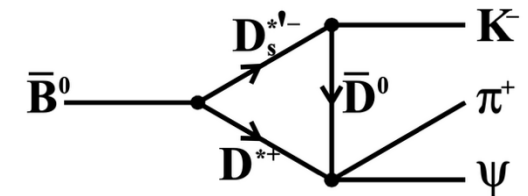
[\[PRD 77 \(2008\) 094015\]](#)

• Compact tetraquark?

[\[PRD 89 \(2014\) 114010\]](#)

• Triangle singularity involving open-charm final states?

[\[PLB 702 \(2011\) 139\]](#)

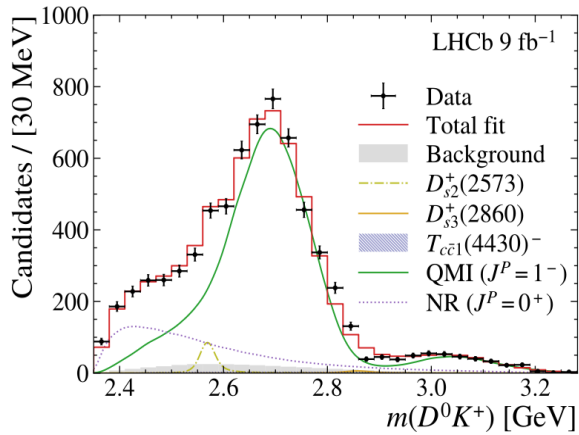
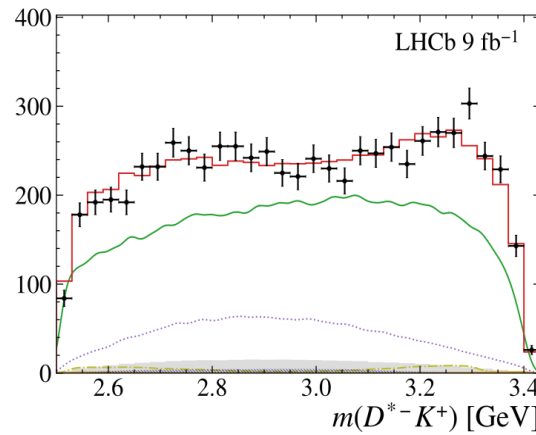
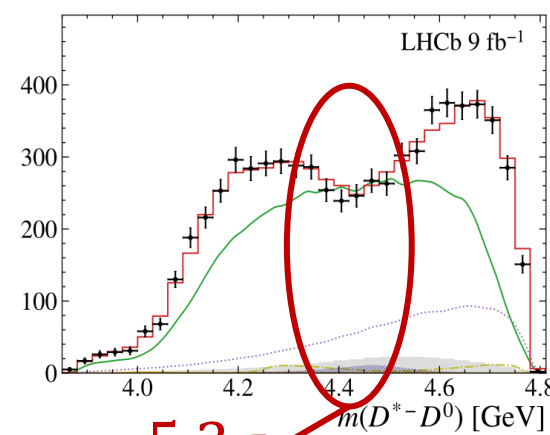
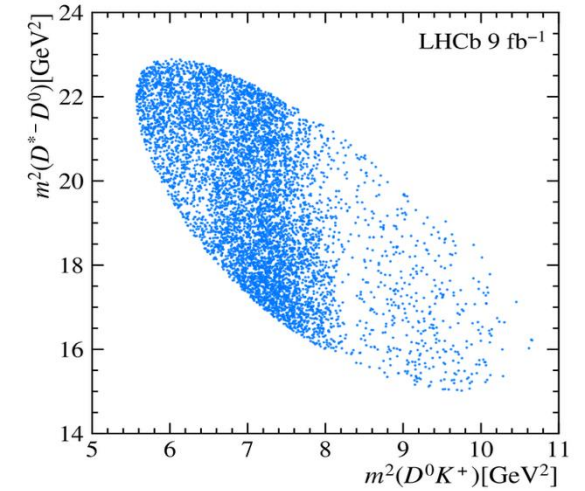
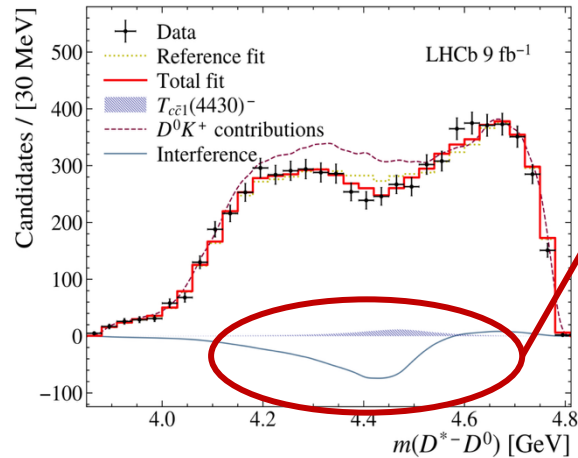


Search for $T_{c\bar{c}1}(4430)^-$ in open-charm final state?

Amplitude analysis of $B^0 \rightarrow D^{*-} D^0 K^+$

[arXiv: 2610.35239]

Run 1+2 data



Need $T_{c\bar{c}1}(4430)^-$ to account for the dip via negative interference

5.3 σ

No evidence of other $T_{c\bar{c}}$ states or $T_{c\bar{s}} \rightarrow D^{*-} K^+$

$$\mathcal{B}(B^0 \rightarrow T_{c\bar{c}1}(\rightarrow D^{*-} D^0) K^+) = (3.28 \pm 0.99^{+0.71}_{-1.58} \pm 0.28) \times 10^{-5}$$

$$\frac{\Gamma(T_{c\bar{c}1} \rightarrow D^{*-} D^0)}{\Gamma(T_{c\bar{c}1} \rightarrow \psi(2S) \pi^-)} = 0.96 \pm 0.29^{+0.22+0.30}_{-0.48-0.57}$$



Comparable couplings to open-charm and hidden-charm final states disfavour a pure $D^* \bar{D}_1$ molecular interpretation

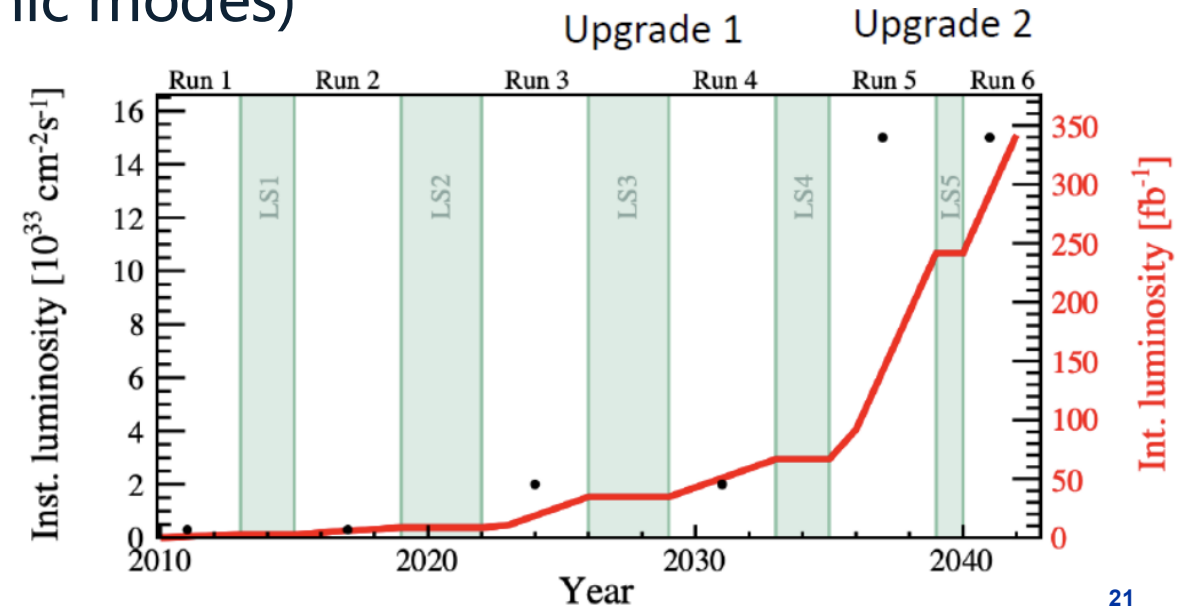
Summary and prospects

- Also a hadron factory at LHC: **6 new hadrons observed in 2026**
- Results presented in this talk:
 - New single and doubly charmed baryons $\Sigma_c^0(2900)$, $\Sigma_c^0(3000)$, Ξ_{cc}^+ , Ω_{cc}^+
 - New Charm/beauty-strange mesons $D_{s1}(2933)^+$, $B_s^{0*}(5700)^0$
 - Hidden-charm tetraquark $T_{c\bar{c}1}(4430)^-$

- Run3 opportunities (×8 statistics for hadronic modes)

- Known hadrons in different final states
- Many unobserved hadrons come within reach, in particular in the beauty and baryon sector

- **U2: ×5 larger statistics** than Upgrade I
➔ fruitful spectroscopy



Thank you for your attention!