



MENU 2026

The 17th International Conference on Meson-Nucleon Physics and the Structure of the Nucleon

Update on Hadron Spectroscopy in LHCb

Hangyi Wu (Syracuse University)

On behalf of the LHCb Collaboration

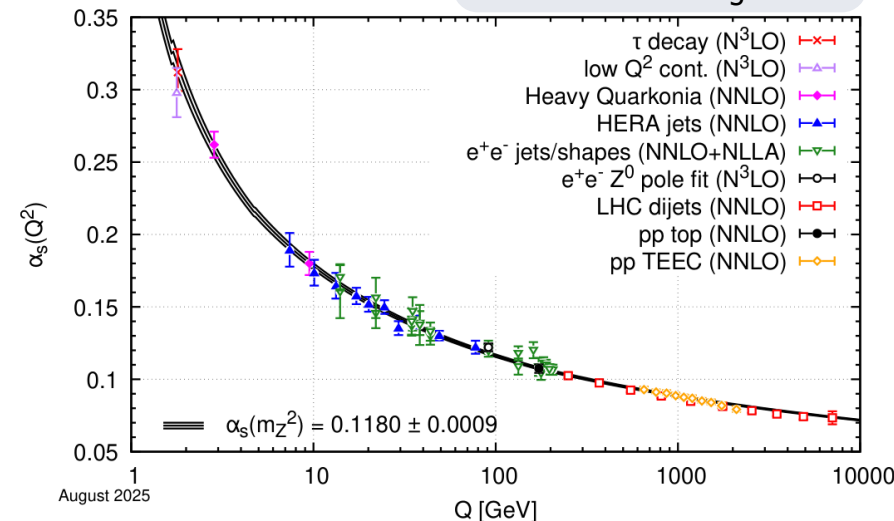
MENU 2026 | Stony Brook University | 19–23 October 2026

October 19, 2026

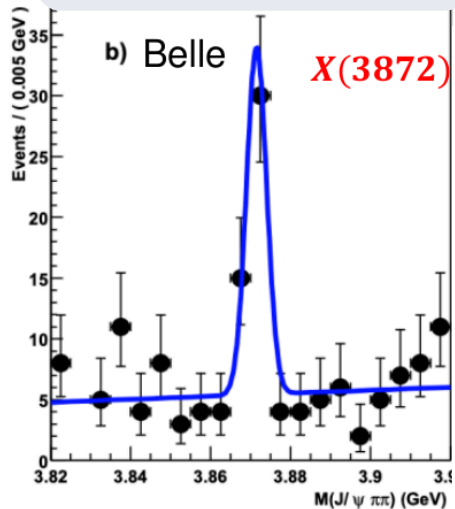
Introduction

- **Hadron spectroscopy:**
a probe of non-perturbative QCD
- **Masses, widths, quantum numbers:**
tests of the strong interaction
- **Conventional and exotic hadrons:**
a growing spectrum

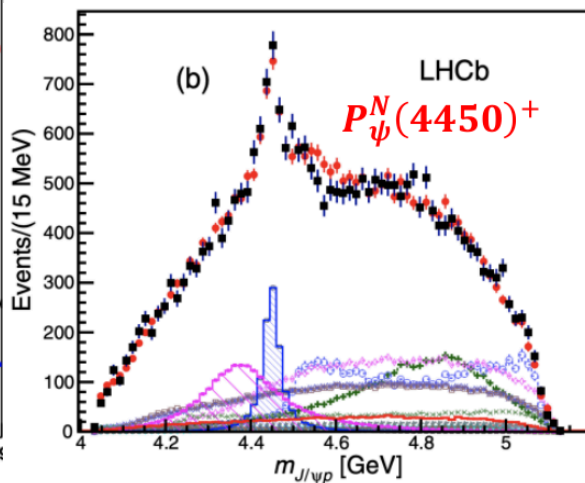
PDG 2025 • Fig. 9.4



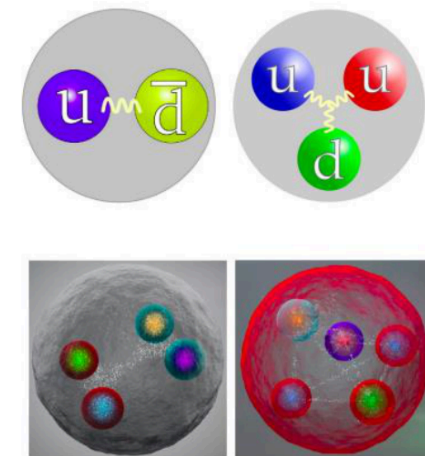
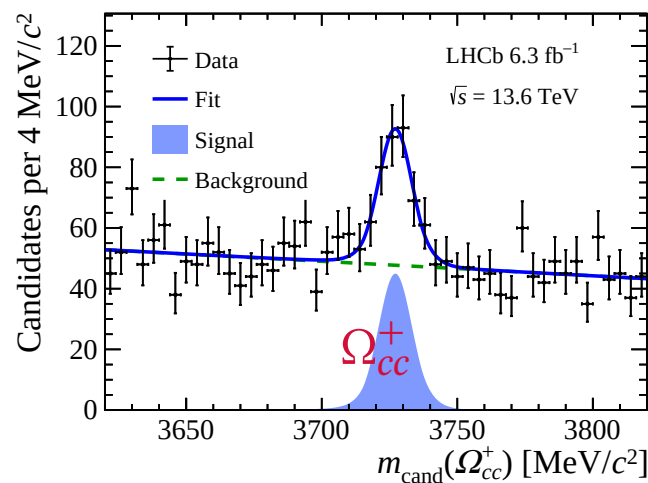
PRL 91 (2003) 262001



PRL 115 (2015) 072001



arXiv:2609.21921



LHCb detector

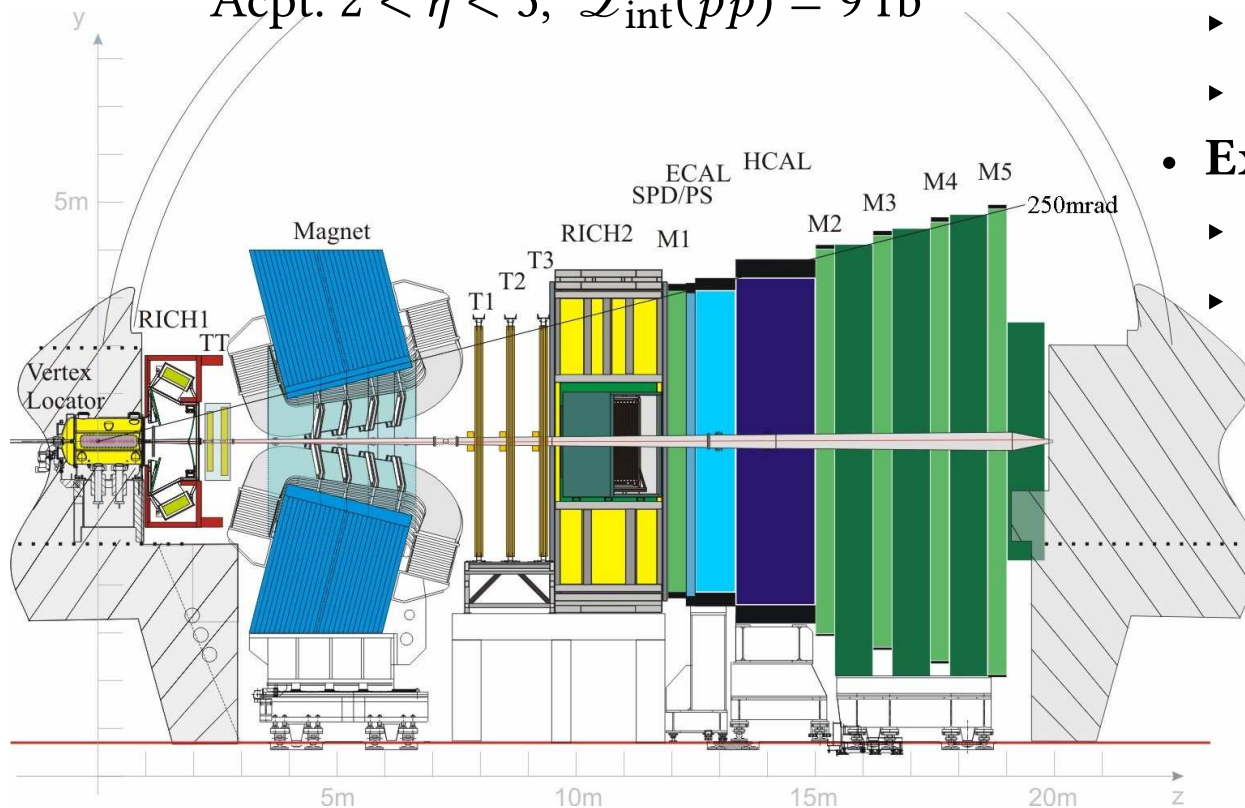
JINST 3 (2008) S08005

IJMPA 30 (2015) 1530022

Single-arm, forward spectrometer designed for heavy-flavour physics.

LHCb Run 1&2 detector

Acpt. $2 < \eta < 5$, $\mathcal{L}_{\text{int}}(pp) = 9 \text{ fb}^{-1}$

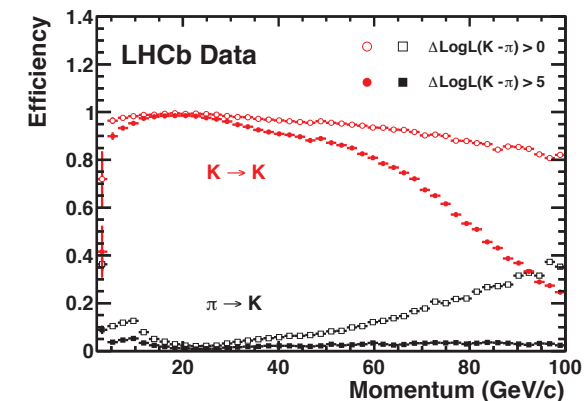


- **Excellent tracking and vertexing**

- $\sigma(p)/p < 1\% @ \epsilon_{\text{track}} > 96\%$
- $\sigma(\text{IP}) = (15 + 29/p_T)\mu\text{m}$

- **Excellent particle identification**

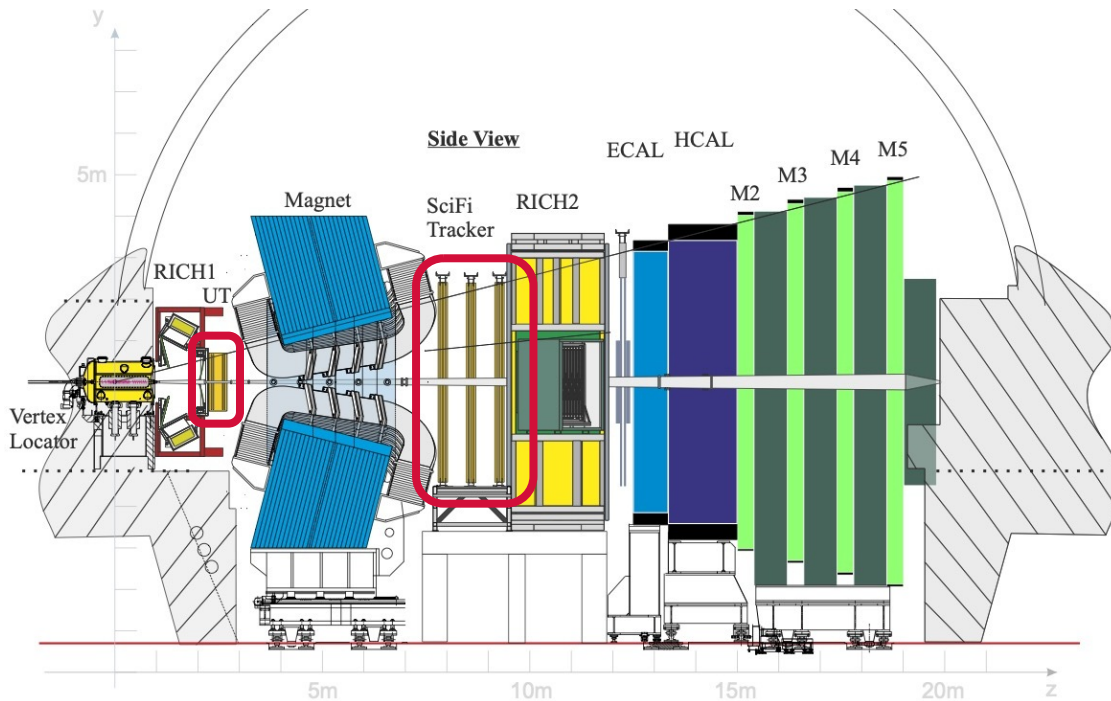
- $\epsilon_{\text{PID}}(K) \approx 95\% @ \text{MisID}(\pi \rightarrow K) \approx 5\%$
- $\epsilon_{\text{PID}}(\mu) \approx 97\% @ \text{MisID}(\pi \rightarrow \mu) \approx 3\%$



LHCb Upgrade detector

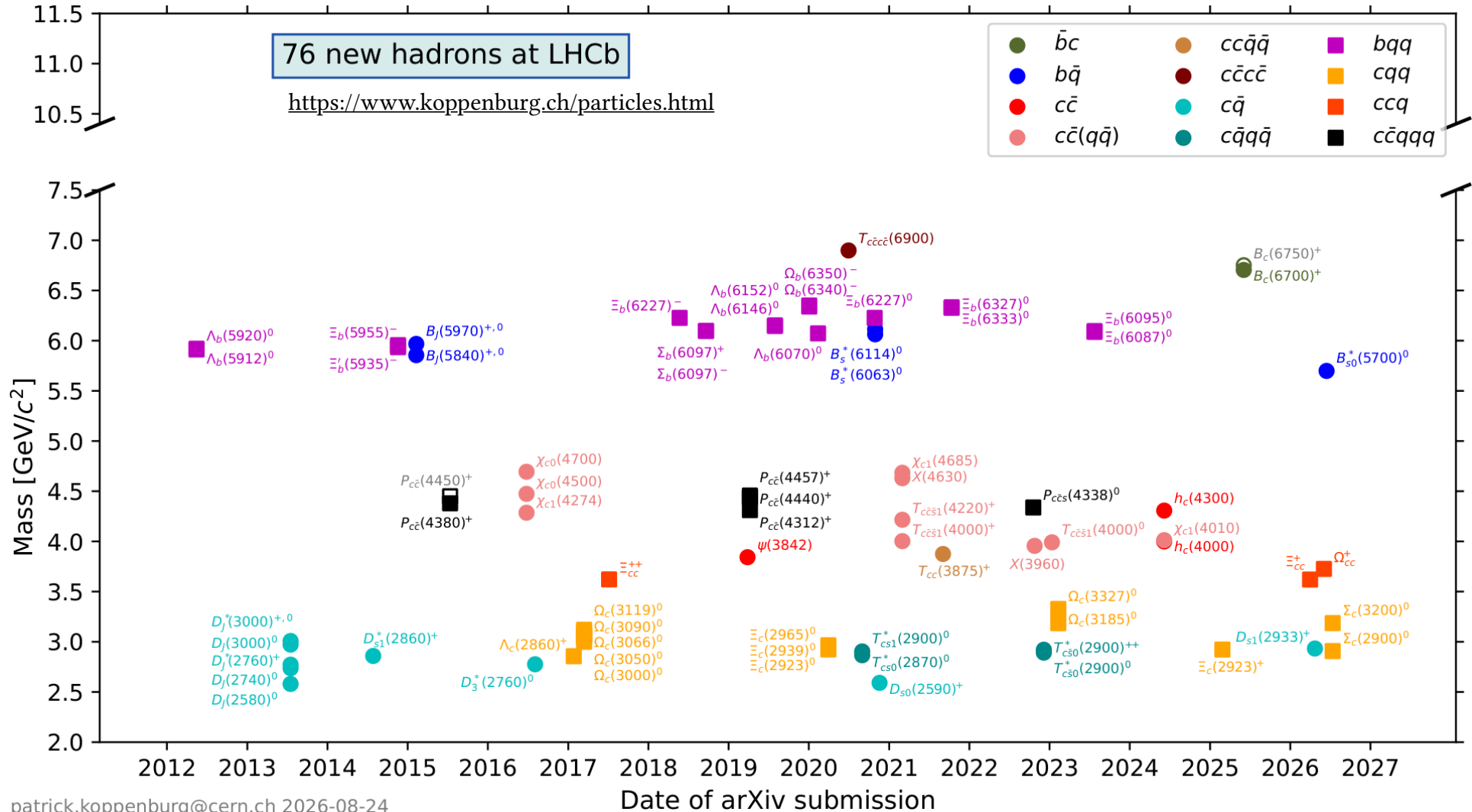
JINST 19 (2024) P05065

LHCb Run 3 detector

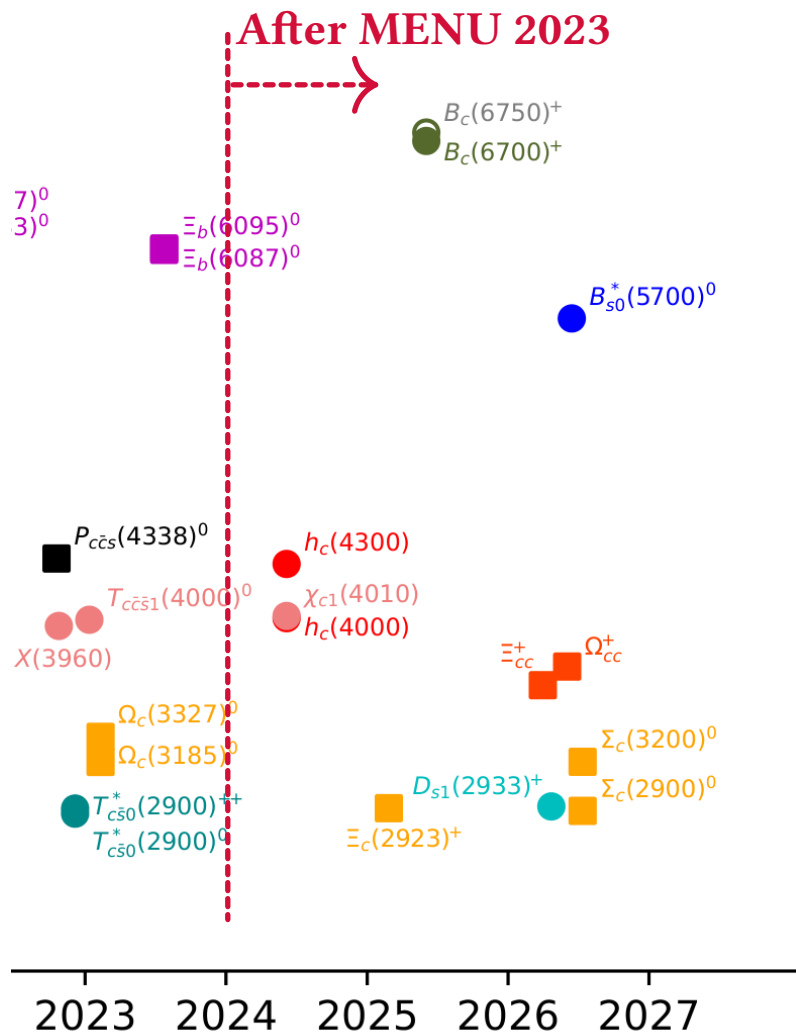


- All subdetectors have **readout rate** at the full **40 MHz** collision rate.
- A **fully software-based trigger** ditching the hardware Level-0 trigger.
- The VELO switched from strip to pixel, to improves primary-vertex and impact-parameter measurements.
- The upstream tracker (UT) and SciFi tracker provide fast, precise tracking at higher instantaneous luminosity.

Hadrons discovered by LHCb



Meson results shown in this talk



• New meson states

► New charmonium states:
 $h_c(4000)$, $\chi_{c1}(4010)$, $h_c(4300)$

PRL 133 (2024) 131902

► New orbitally excited states:
 $B_c^+(1P)$

PRL 135 (2025) 231902

► New charm-strange state:
 $D_{s1}(2933)^+$, $J^P = 1^+$

arXiv:2604.21257

► New beauty-strange state:
 $B_{s0}^*(5700)^0$

arXiv:2609.25178

• Exotic-structure tests

► Updated radiative-decay study:
 $X(3872)$

JHEP 11 (2024) 121

► The $T_{c\bar{c}1}(4430)^-$ state in hidden and open charm channels:

PRD 113 (2026) L071101

LHCb-PAPER-2026-033 (prelim.)

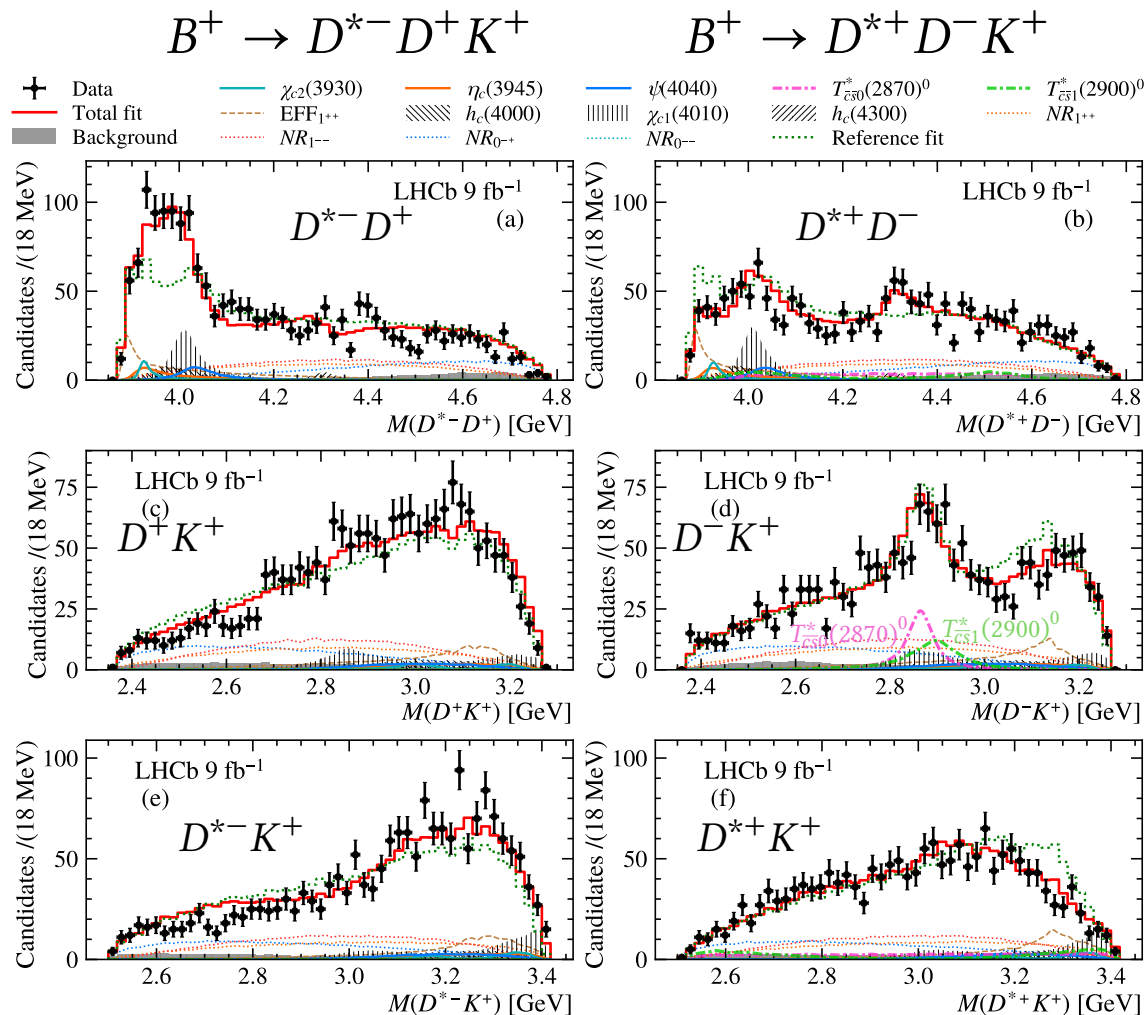
Simultaneous fit to $B^+ \rightarrow D^{*\mp} D^\pm K^+$ channels

PRL 133 (2024) 131902

Open-charm tetraquarks confirmed in a new channel

- Most obvious in $D^- K^+$ spectrum:
 - $T_{\bar{c}s0}^*(2870)^0$: 11σ significance
 - $T_{\bar{c}s1}^*(2900)^0$: 9.2σ significance
- **Explicitly exotic:** $[\bar{c}sud]$
- First observed in $B^+ \rightarrow D^+ D^- K^+$

PRL 125 (2020) 242001



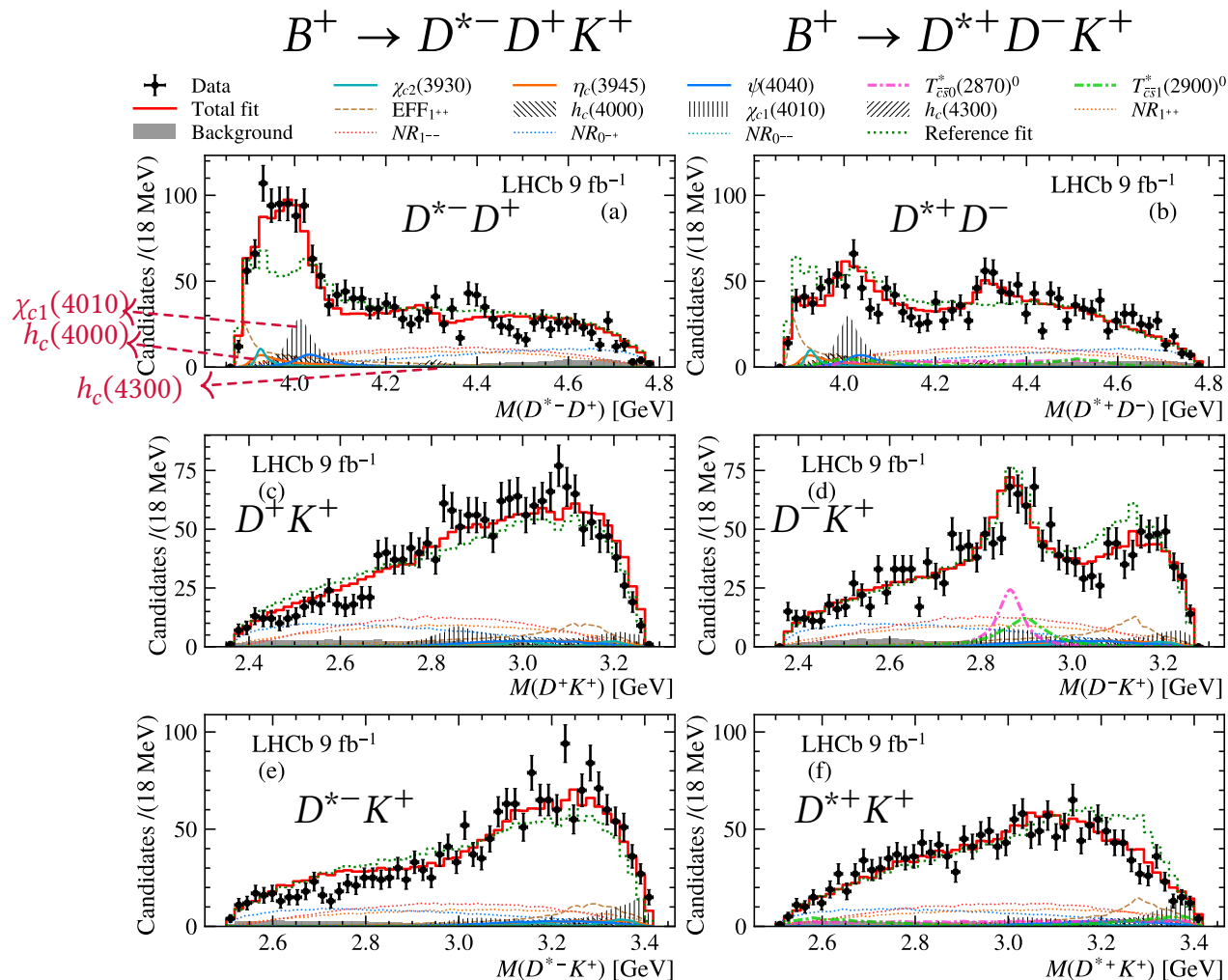
Three new charmonium-like states

PRL 133 (2024) 131902

- Simultaneous fit: **three new contributions**

State	J^{PC}	m_0 (MeV)	Γ_0 (MeV)	Sig.
$h_c(4000)$	1^{+-}	4000^{+17+29}_{-14-22}	184^{+71+97}_{-45-61}	9.1σ
$\chi_{c1}(4010)$	1^{++}	$4012.5^{+3.6+4.1}_{-3.9-3.7}$	$62.7^{+7.0+6.4}_{-6.4-6.6}$	16σ
$h_c(4300)$	1^{+-}	$4307.3^{+6.4+3.3}_{-6.6-4.1}$	58^{+28+28}_{-16-25}	6.4σ

- Possible/tentative level assignments
 - $h_c(4000), h_c(4300)$:
→ $h_c(2P) / h_c(3P)$ candidates
 - $\chi_{c1}(4010)$:
→ possible $\chi_{c1}(2P)$ with potential exotic admixture



Orbitally excited B_c^+ mesons

- Previously: 2S excitations

- ATLAS: first candidate PRL 113 (2014) 212004

- CMS / LHCb: two resolved peaks

PRL 122 (2019) 132001

PRL 122 (2019) 232001

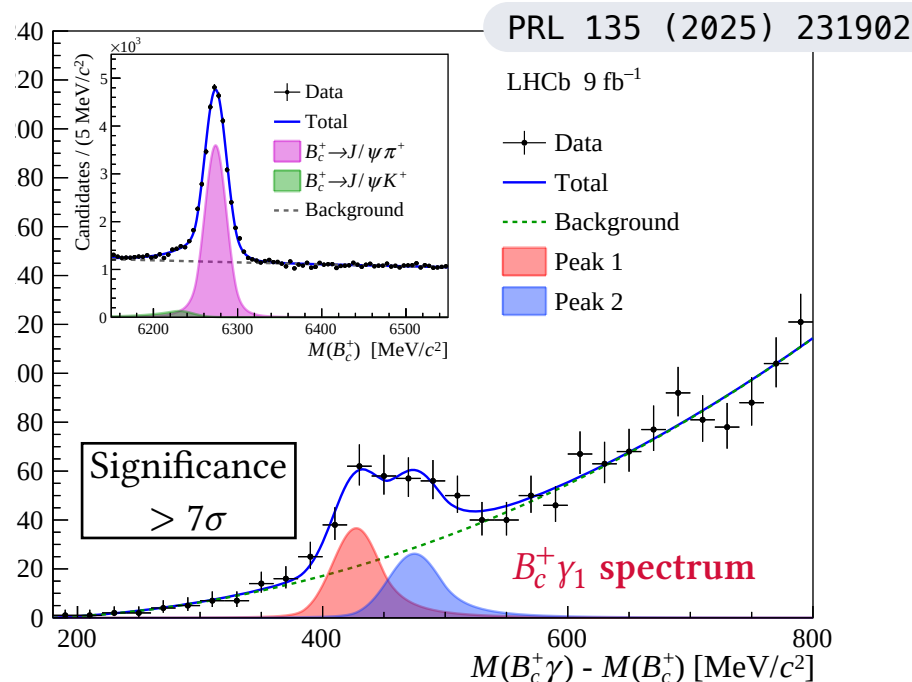
- This work: first orbitally excited 1P signal**

- Cascade decay:

$$B_c(1P)^+ \rightarrow B_c^{*+} \gamma_1 \rightarrow B_c^+ \gamma_2 \rightarrow J/\psi \pi$$

- Soft γ_2 undetected

→ shifted reconstructed $B_c^+ \gamma_1$ mass



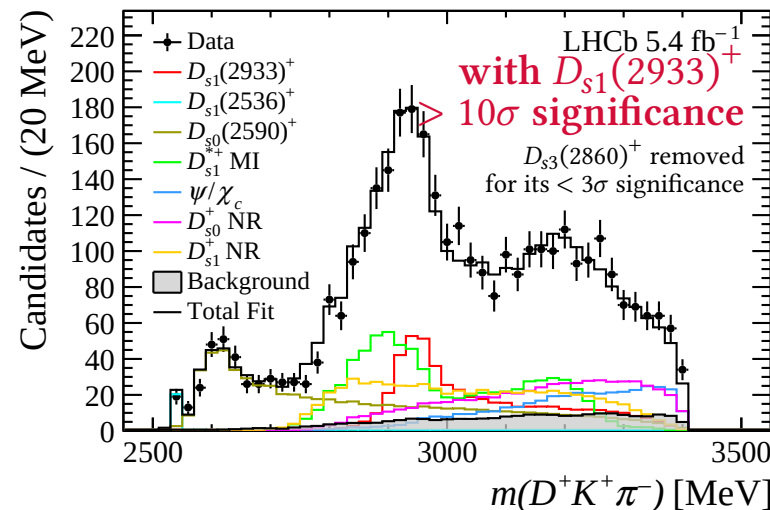
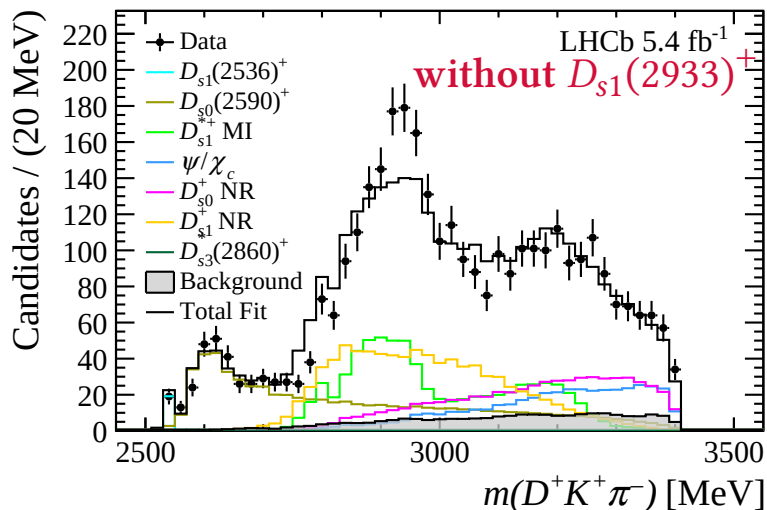
- Two effective peaks in $B_c^+ \gamma_1$

	stat.	syst.	external $m_{B_c^+}$ uncer.	
M_1	6704.8 ± 5.5	± 2.8	± 0.3	MeV/ c^2
M_2	6752.4 ± 9.5	± 3.1	± 0.3	MeV/ c^2

- Four 1P levels unresolved

A new charm–strange state: $D_{s1}(2933)^+$

arXiv:2604.21257



- Full phase-space 5D amplitude analysis on the decay channel: $B^0 \rightarrow D^+ D^- K^+ \pi^-$ using LHCb Run2 data, totally 5.4fb^{-1} at 13 TeV
- Discovered a new charm strange state at

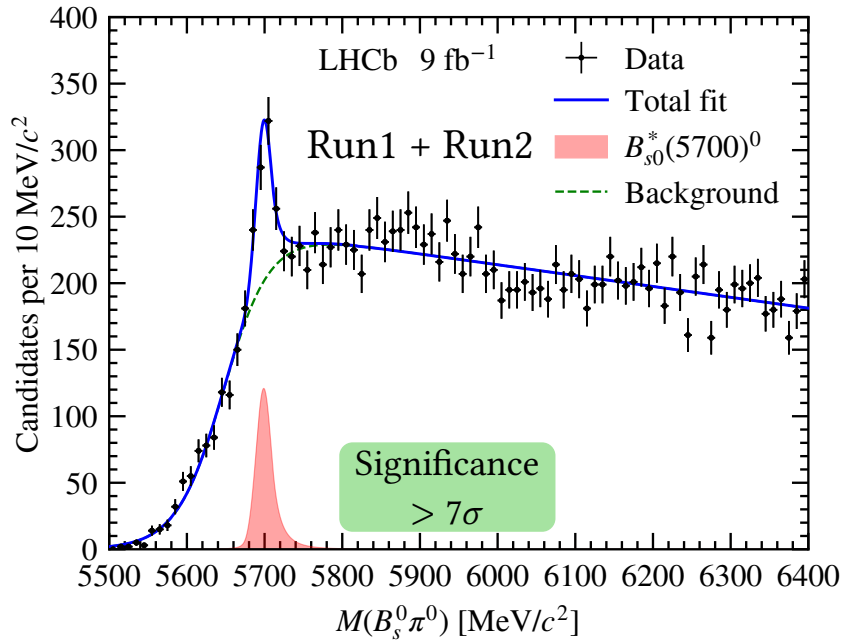
	stat.	syst.
$m_0=2933$	$^{+6}_{-5}$	$^{+4}_{-3}$
$\Gamma_0=$	72	$^{+18}_{-12}$

MeV

- Angular dependence determines $J^P = 1^+$, not only a mass-spectrum excess.
- Compatible with a conventional $D_s(2P_1')^+$ state, the first radial excitation of the P -wave D_s system.

A new beauty-strange state: $B_{s0}^*(5700)^0$

arXiv:2609.25178



- B_s^0 reconstructed via three decay modes

- $B_s^0 \rightarrow D_s^- \pi^+$
- $B_s^0 \rightarrow J/\psi \varphi$
- $B_s^0 \rightarrow D_s^- \pi^+ \pi^+ \pi^-$

where $D_s^- \rightarrow K^+ K^- \pi^-$, $J/\psi \rightarrow \mu^+ \mu^-$ and $\varphi \rightarrow K^+ K^-$

- **Narrow peak in $B_s^0 \pi^0$**

$$m = 5698.9 \pm 1.5^{\text{stat.}} \pm 0.6^{\text{syst.}} \text{ MeV}/c^2$$

$$\Gamma < 9.8 \text{ MeV at 90\% CL}$$

- Below both $B^+ K^-$ and $B^0 \bar{K}^0$ thresholds, and much lighter than conventional quark-model expectations
- Interpretations:
 - 0^+ analogue of the $D_{s0}^*(2317)^+$ state, or
 - 1^+ state which decays through $B_s^{*0} \pi^0$, with the photon undetected

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LATEST POSTS

PHYSICS RESULTS

Discovery of a beauty-strange particle with unexpected properties

01/08/2026

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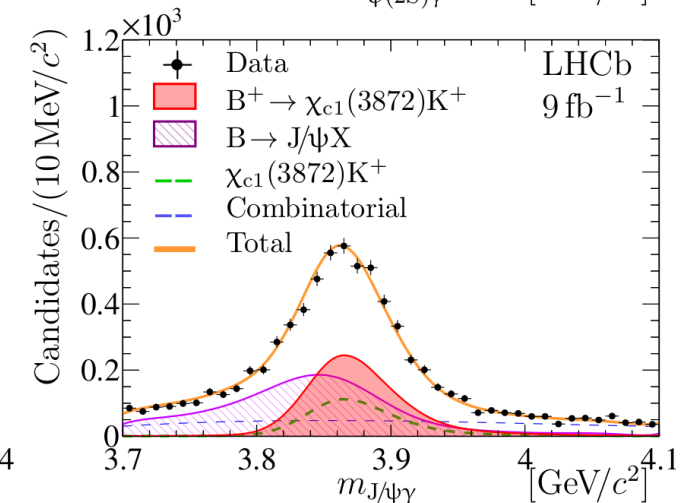
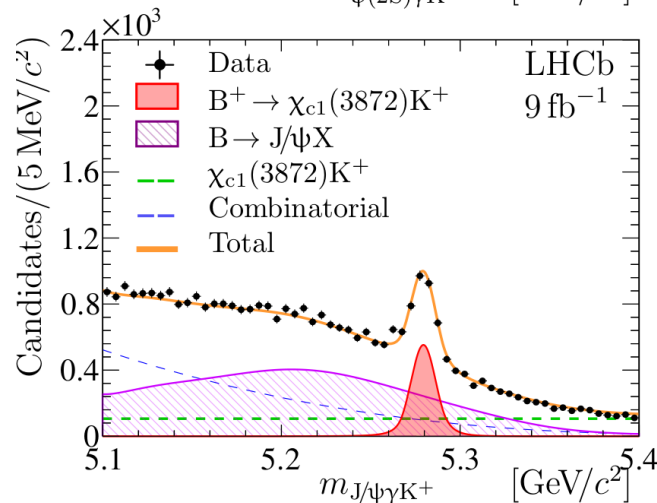
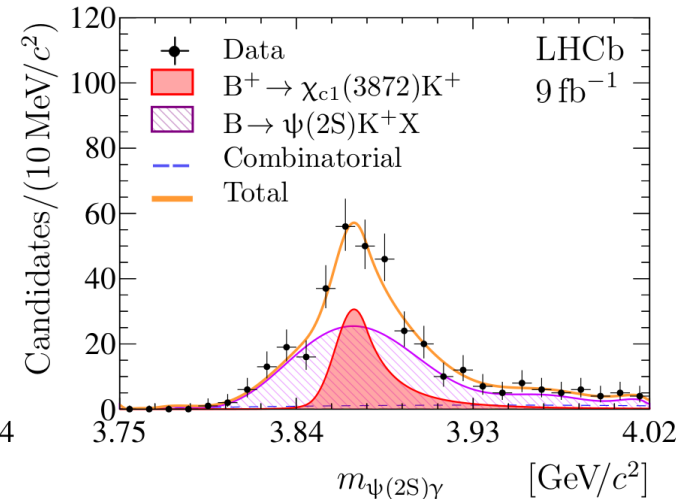
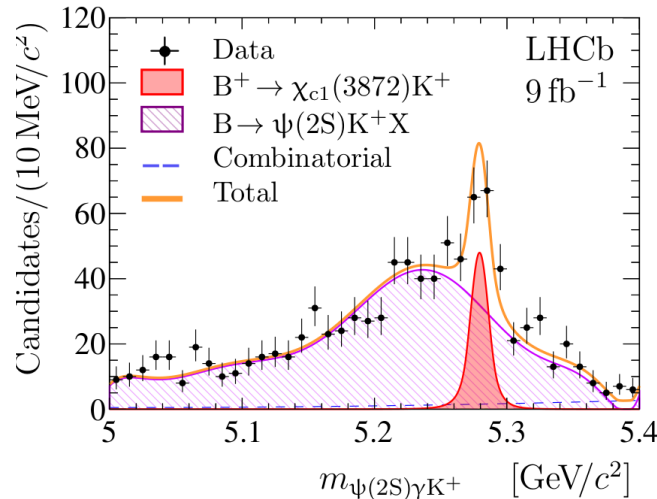
$X(3872)$: radiative decays constrain structure

JHEP 11 (2024) 121

- Analyzed decay channels:
 - $B^+ \rightarrow \chi_{c1}(3872)(\rightarrow \psi(2S)\gamma)K^+$
 - $B^+ \rightarrow \chi_{c1}(3872)(\rightarrow J/\psi\gamma)K^+$
- First observation of $\chi_{c1}(3872) \rightarrow \psi(2S)\gamma$:**
 - 4.8σ with Run 1 data,
 - and 6.0σ with Run 2 data, both including systematic uncertainty.
- The $\mathcal{R}_{\psi\gamma}$ ratio turns out to be substantial:

$$\mathcal{R}_{\psi\gamma} = \frac{\Gamma_{\chi_{c1}(3872) \rightarrow \psi(2S)\gamma}}{\Gamma_{\chi_{c1}(3872) \rightarrow J/\psi\gamma}}$$

$$= 1.67 \pm 0.21^{\text{stat.}} \pm 0.12^{\text{syst.}} \pm 0.04^{\text{external BF}}$$

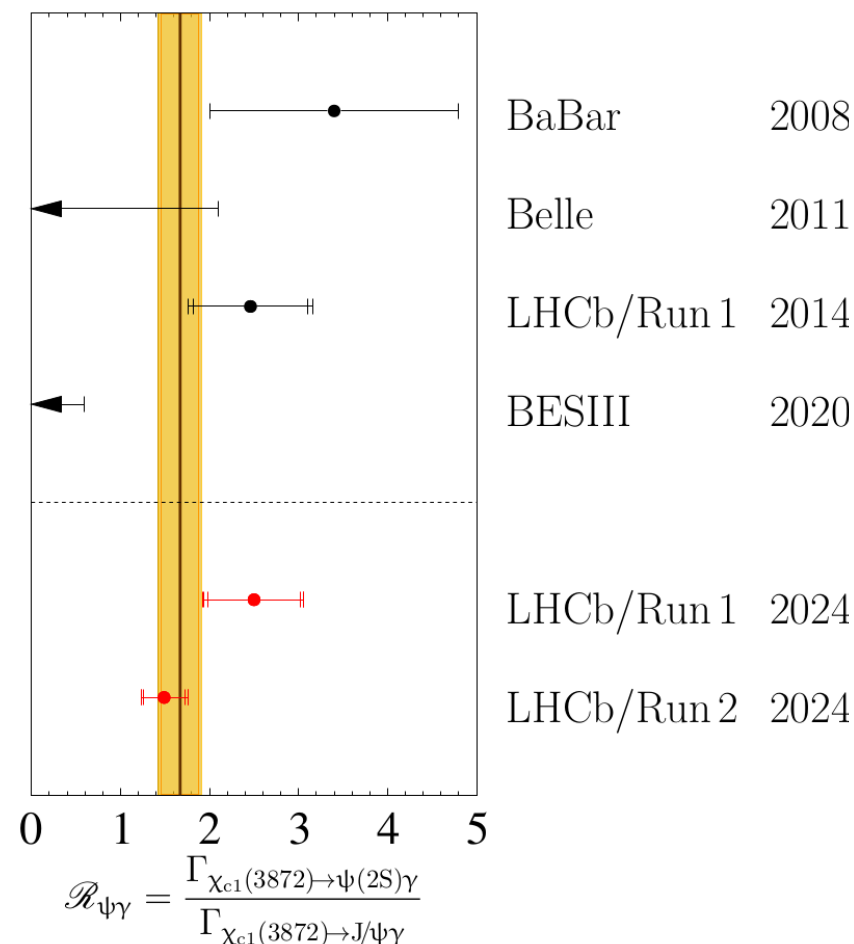


$X(3872)$: interpreting the radiative ratio

JHEP 11 (2024) 121

- Previous measurements are confusing
- **Updated Run 1 + Run 2**; improved systematics
- **Large $\mathcal{R}_{\psi\gamma}$** despite smaller $\psi(2S)\gamma$ phase space
- Pure-molecule predictions disfavoured **in the models tested**

A sizeable compact component is favoured, though the precise composition remains model-dependent



Reinvestigation of $T_{c\bar{c}1}(4430)^+$

PRD 113 (2026) L071101

- 4D amplitude fit:

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

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

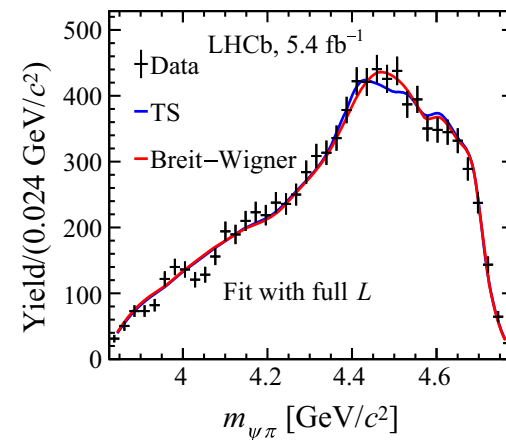
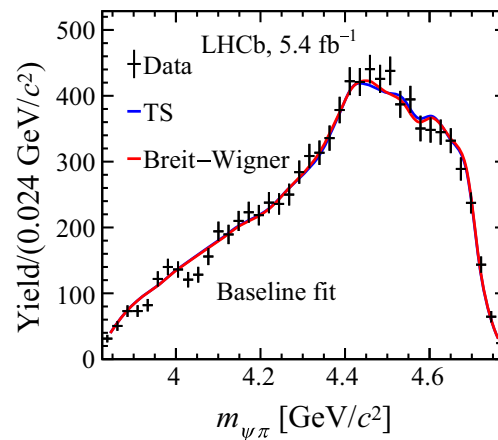
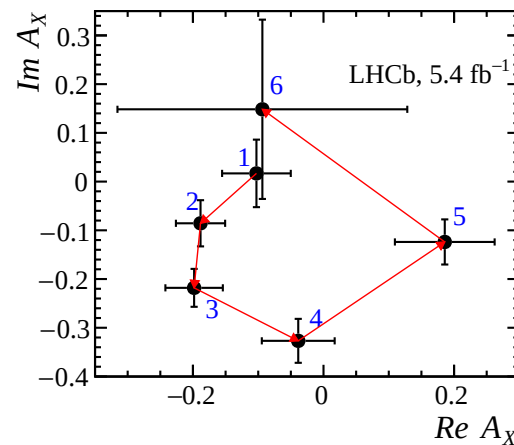
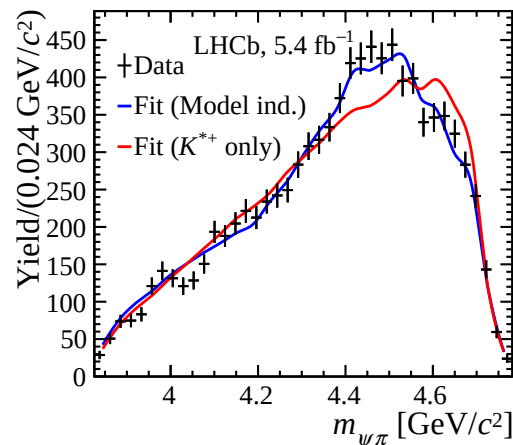
$> 16\sigma$ statistical; $> 9\sigma$ incl. systematics

- supported by Argand motion

- Multiple models tested:

- Baseline: Relativistic Breit–Wigner
- Triangle-singularity model also describes the data but within a large statistical error
- Flatté parameterization: constrains the coupling to a near by open-charm coupling.

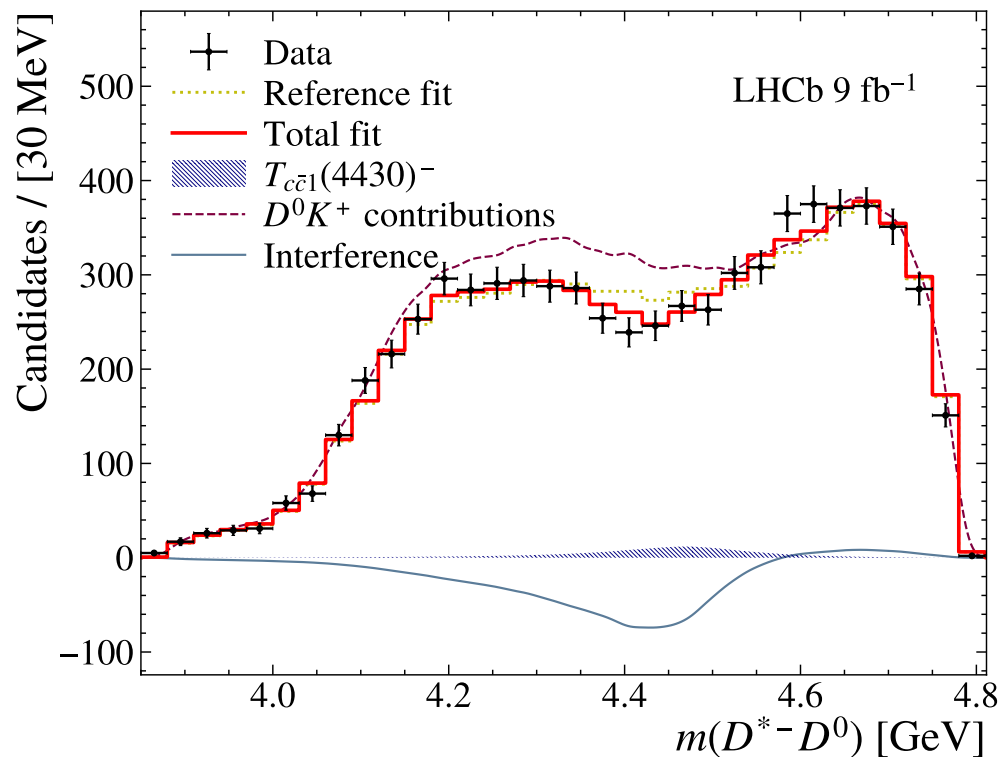
Argand motion consistent with resonant phase variation



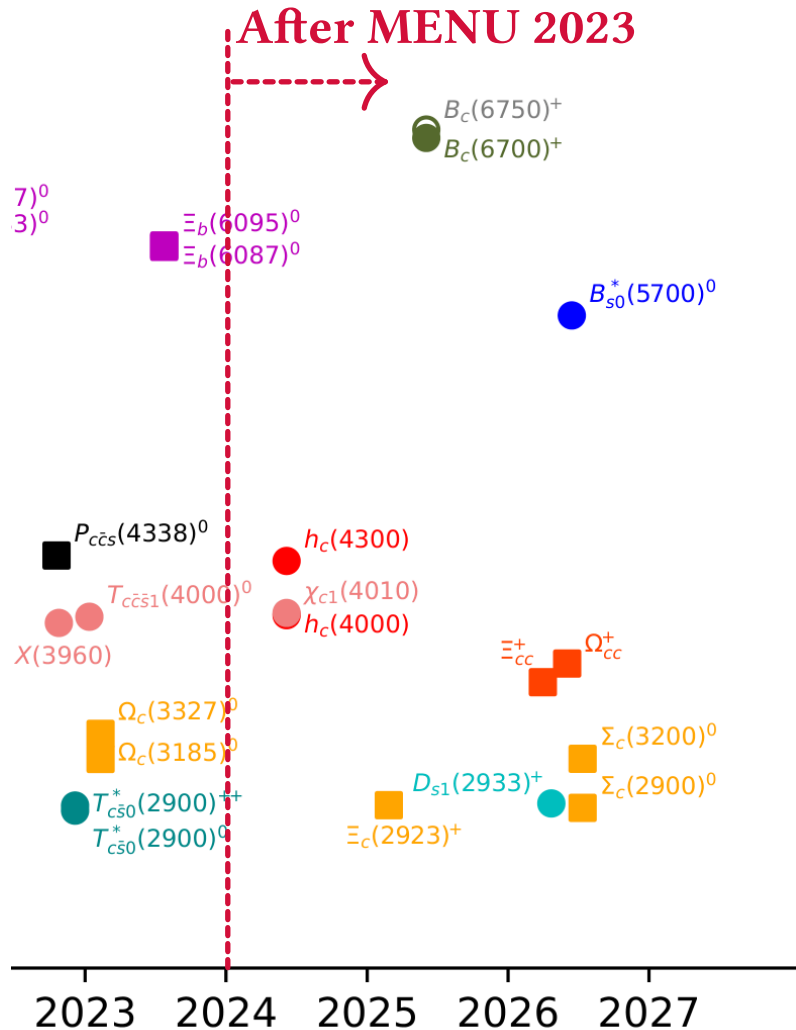
$T_{c\bar{c}1}(4430)^-$ in open charm

LHCb-PAPER-2026-033 (preliminary)

- **First open-charm observation**:
 $T_{c\bar{c}1}(4430)^- \rightarrow D^{*-} D^0$ in $B^0 \rightarrow D^{*-} D^0 K^+$.
 - Reference fit: known D_s^+ contributions alone miss the dip near 4.4 GeV
 - Adding $T(4430)^-$ gives a 5.3σ significance including systematics.
- **Preferred $J^P = 1^+$** fitted mass and width are consistent with the $\psi(2S)\pi^-$ measurement.
- The open/hidden partial-width ratio is near unity, but its uncertainties are large. This ratio offers a test of molecular versus compact models.



Baryon results shown in this talk



Beyond the meson sector, these baryon results complement LHCb's broader hadron-spectroscopy programme:

- New charmed baryon:

$$\Xi_c(2923)^+ \rightarrow \Xi_c^+ \pi^- \pi^+$$

PRL 135 (2025) 161901

- New excited charmed baryons

$$\Sigma_c(2900)^0 \text{ and } \Sigma_c(3200)^0$$

arXiv:2607.10595

- New doubly charmed baryons with Run 3 data:

$$\Omega_{cc}^+ \rightarrow \Omega_c^0 \pi^+$$

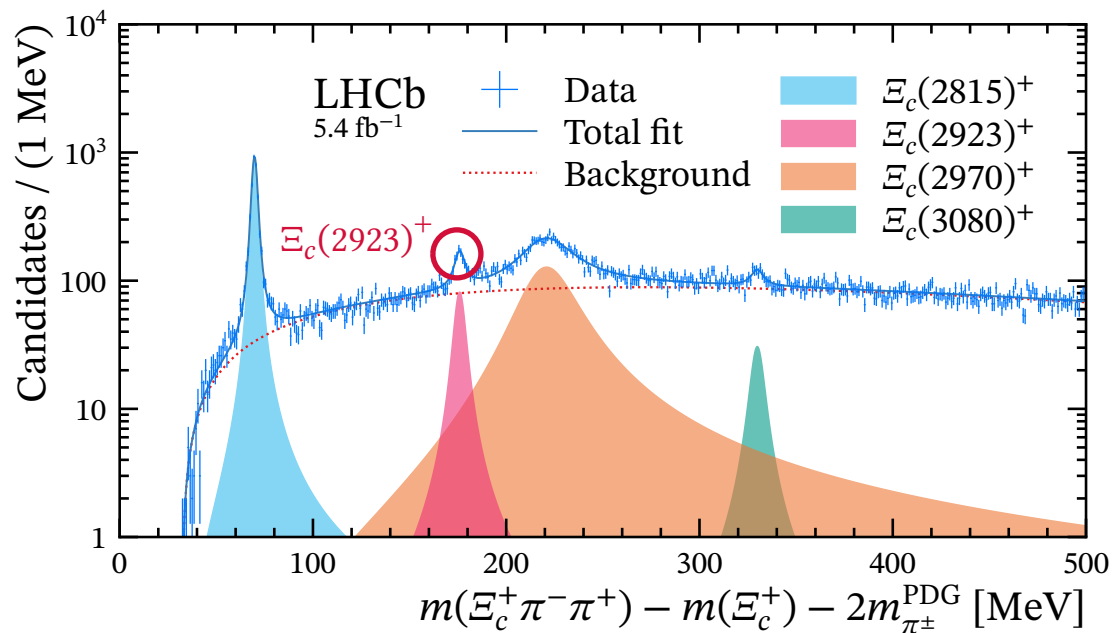
arXiv:2609.21921

$$\Xi_{cc}^+ \rightarrow \Lambda_c^+ K^- \pi^+$$

PRL 137 (2026) 021902

New charmed baryon: $\Xi_c(2923)^+$

PRL 135 (2025) 161901



- **First observation** of the charged $\Xi_c(2923)^+$ in the $\Xi_c^+ \pi^- \pi^+$ spectrum.

- Measured mass/width:

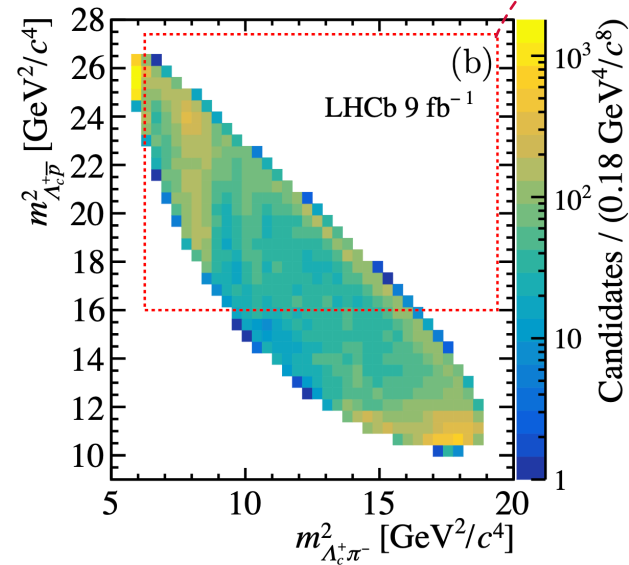
$$m = 2922.8 \pm 0.3^{\text{stat}} \pm 0.5^{\text{syst}} \pm 0.2^{\Xi_c^+ \text{ mass}} \text{ MeV}$$
$$\Gamma = 5.3 \pm 0.9 \pm 1.4 \text{ MeV}$$

- Consistent with the isospin partner of the previously observed $\Xi_c(2923)^0$.

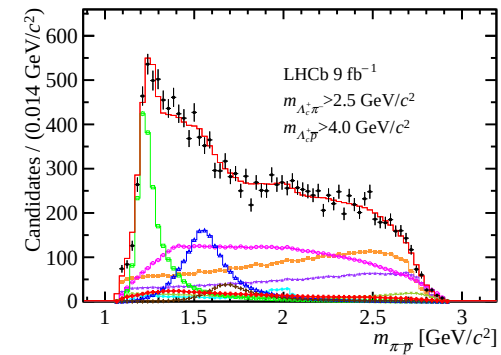
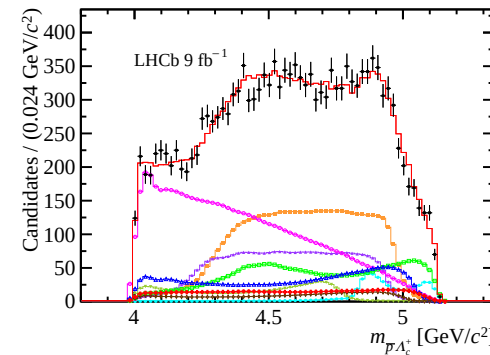
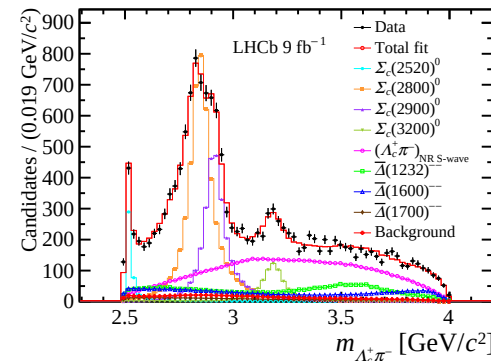
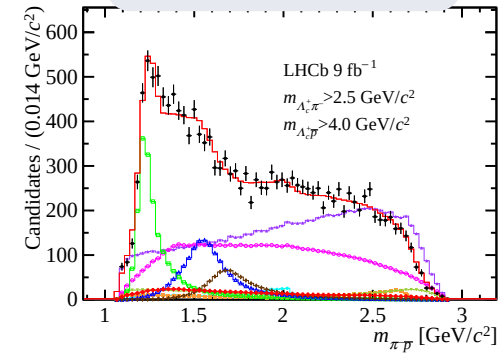
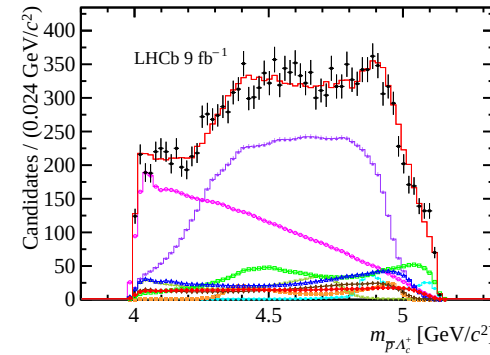
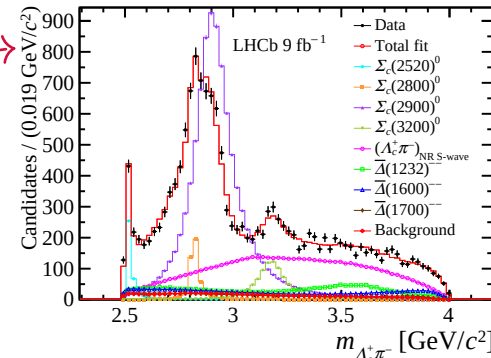
New excited charmed baryons: $\Sigma_c(2900)^0$ and $\Sigma_c(3200)^0$

arXiv:2607.10595

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



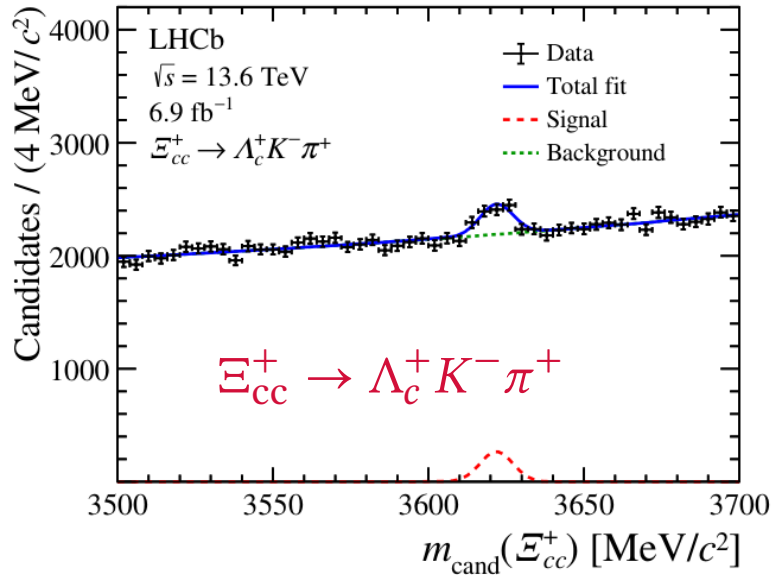
- Candidates within the red box are considered for the amplitude fit



- 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.

First Run 3 baryon observation: Ξ_{cc}^+

PRL 137 (2026) 021902



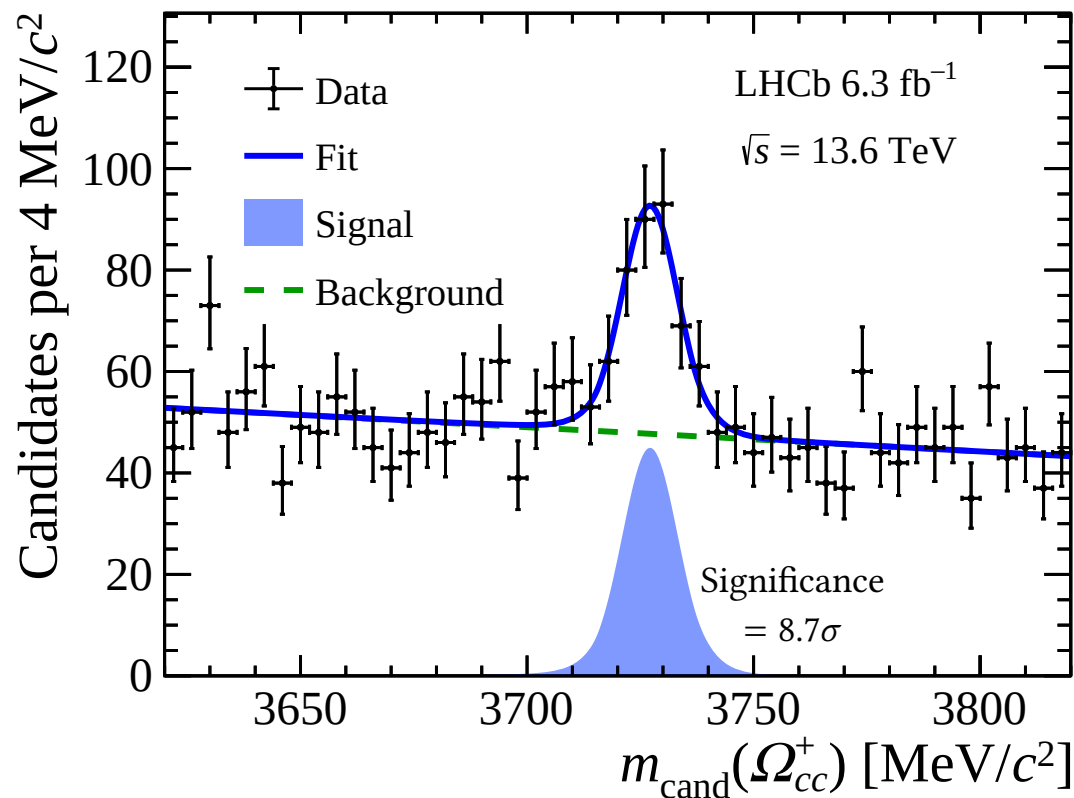
- Decay channel: $\Xi_{cc}^+ \rightarrow \Lambda_c^+ K^- \pi^+$, using 6.9 fb^{-1} at 13.6 TeV collected in 2024 (Run 3).
- First new particle observed with the LHCb Run 3 detector; significance exceeds 7σ .
- Mass and isospin splitting ($\Delta m = m(\Xi_{cc}^+) - m(\Xi_{cc}^{++})$):

	stat.	syst.	$\tau(\Xi_{cc}^+)$
m	3619.97 ± 0.83	± 0.26	$^{+1.90}_{-1.30} \text{ MeV}/c^2$
Δm	-1.77 ± 0.84	± 0.15	$^{+1.90}_{-1.30} \text{ MeV}/c^2$
- Nearly equal masses: consistent with the predicted balance of strong and electromagnetic effects.

PRD 91 (2015) 094502

New doubly charmed baryon: $\Omega_{cc}^+(ccs)$

arXiv:2609.21921



- Decay chain:

$$\Omega_{cc}^+ \rightarrow \Omega_c^0 \pi^+ \rightarrow p K^- K^- \pi^+$$

- using 6.3fb⁻¹ at 13.6 TeV collected in 2024 (Run 3)

- Mass:**

	stat.	syst.	lifetime	external masses	
	± 1.0	± 0.2	± 0.4	± 0.6	MeV/ c^2

3725.9

- Width measurement is consistent with detector resolution.

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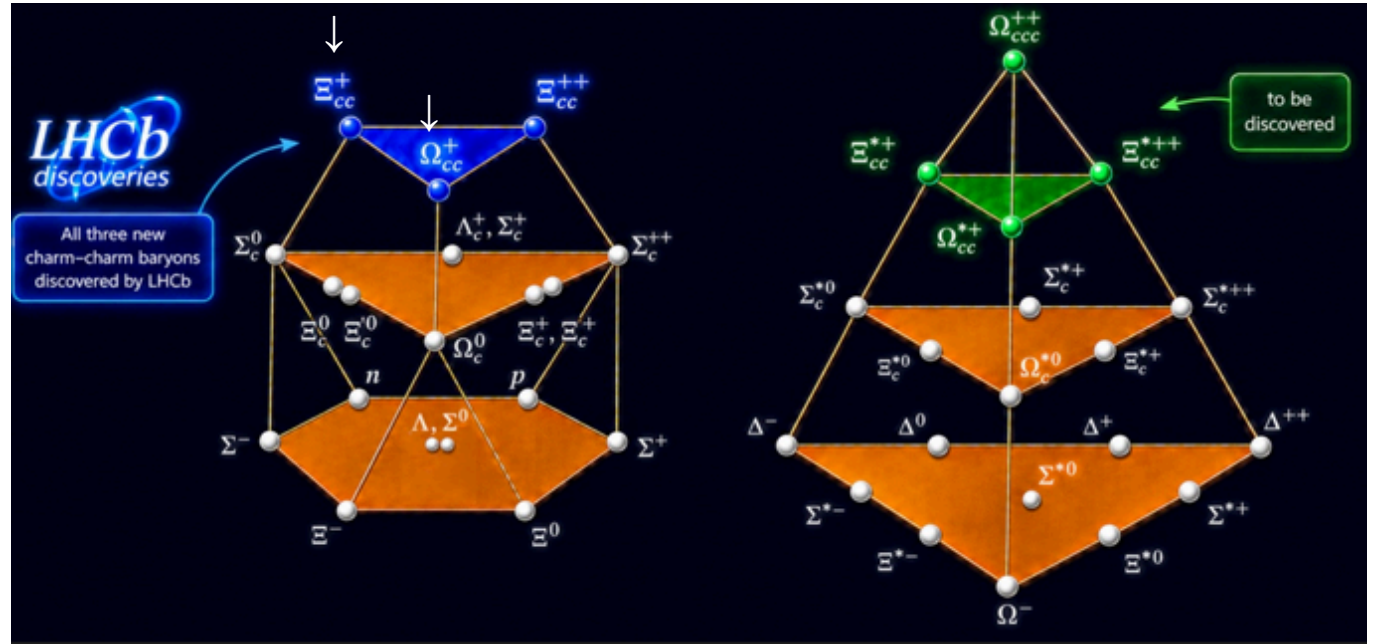
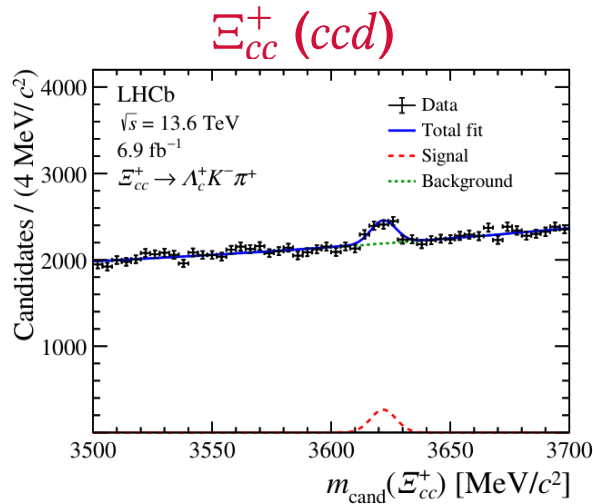
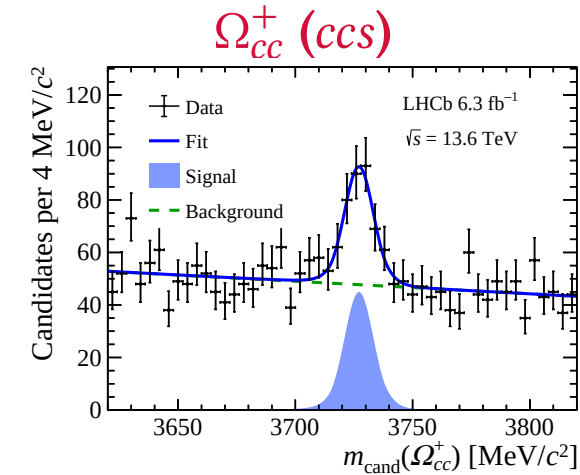
PHYSICS RESULTS

Observation of the doubly charmed baryon Ω_{cc}^+

03/06/2026

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Completing the spin-1/2 baryon multiplet



- Together with Ξ_{cc}^{++} (ccu), discovered in 2017: **the ground-state spin-1/2 multiplet is complete.**
- Spin-3/2 partners remain to be discovered.

Summary and outlook

- **New results since MENU 2023:**
 - **Meson spectroscopy:**
 - Three charmonium-like states, $h_c(4000)$, $\chi_{c1}(4010)$, $h_c(4300)$, with measured J^{PC}
 - First orbitally excited B_c^+ signal, with four $1P$ levels still unresolved
 - New $D_{s1}(2933)^+$ state with $J^P = 1^+$, and tentative spectroscopic assignment
 - Unexpectedly light and narrow $B_{s0}^*(5700)^0$
 - **Exotic-structure tests:**
 - Confirmed $T_{cs0}^*(2870)^0$ and $T_{cs1}^*(2900)^0$
 - $X(3872)$ radiative decays challenge a purely molecular interpretation in the models tested
 - $Z(4430)$ in hidden and open charm: revisited in $\psi(2S)\pi$ and first observed in D^*D
 - **Baryon spectroscopy:**
 - New Ξ_c^+ and Σ_c^0 states; Run 3 observations of Ω_{cc}^+ and Ξ_{cc}^+
- **Outlook with Run 3:** a much larger dataset and many ongoing analyses promise more spectroscopy results in the near future.