



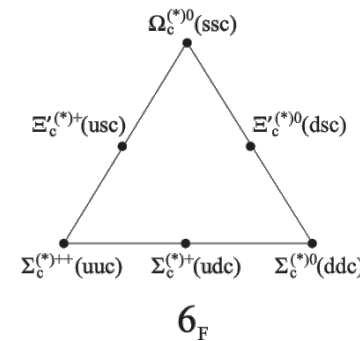
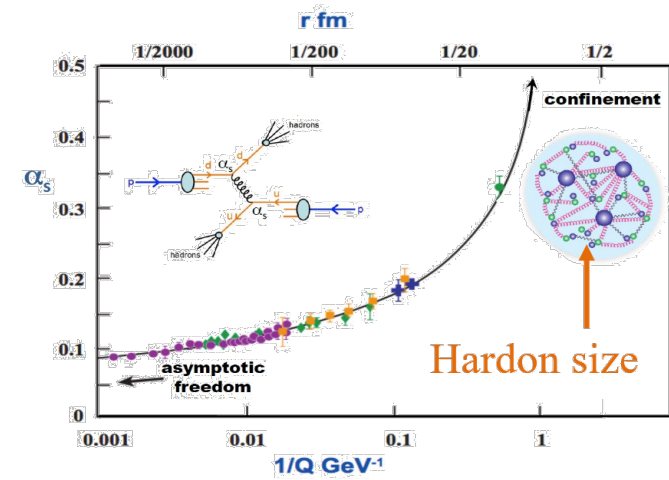
LHCb 粲强子激发态的实验测量

张辰佳

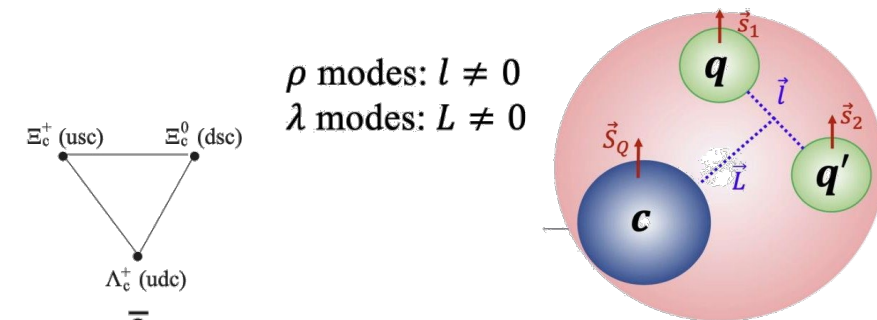
北京大学

Conventional charmed baryons

- Charmed baryons are ideal laboratories for non-perturbative QCD
- Together with thorough theory, provide lots of knowledge for QCD
- Rich spectrum:
 - Rich Ground states
 - $S/P/D$ -wave excitations, angular excitation



ρ modes: $l \neq 0$
 λ modes: $L \neq 0$



Conventional charmed baryons

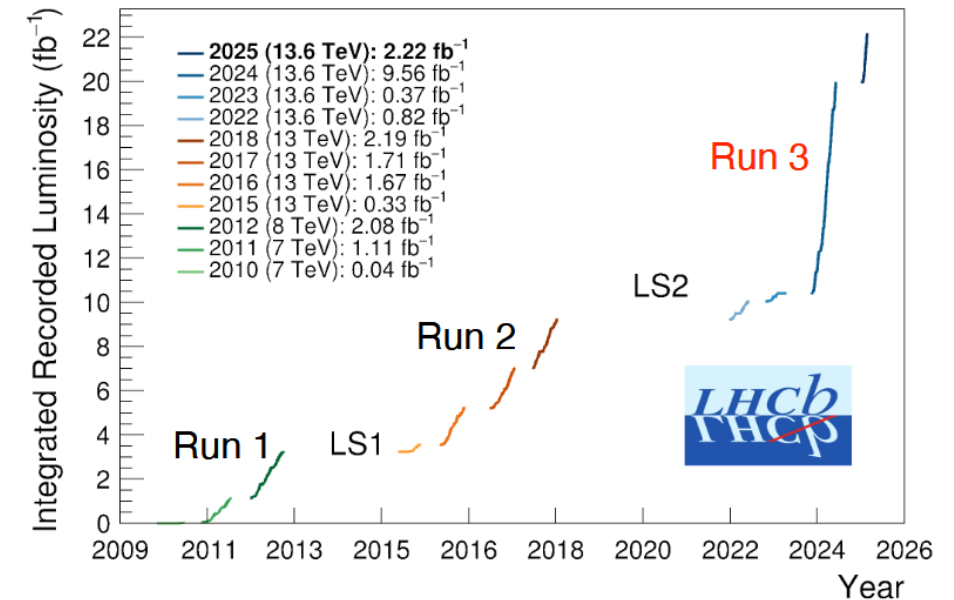
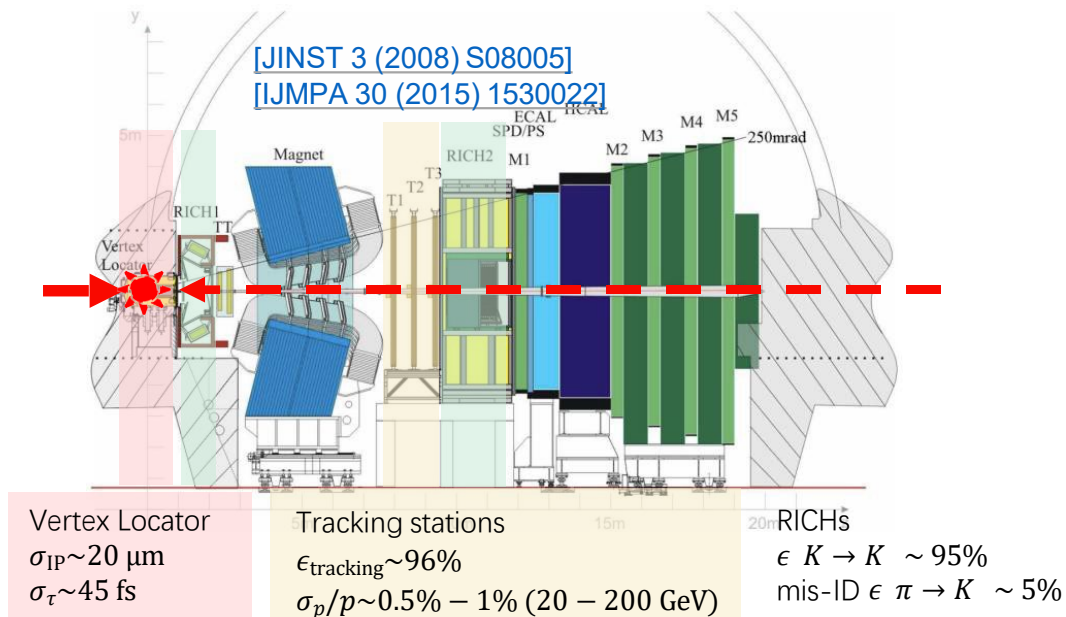
- Charmed baryons are ideal laboratories for non-perturbative QCD
- Rich spectrum:
 - Rich Ground states
 - $S/P/D$ -wave excitations, angular excitation
- Together with thorough theory, provide lots of knowledge for QCD
- Lots of states to be **found**
- Quantum number, mass width to be measured

	J^P (nL)	Exp. Mass [3]
Λ_c	$1/2^+$ ($1S$)	2286.46 ± 0.14
Ξ_c	$1/2^+$ ($1S$)	$2467.94^{+0.17}_{-0.20}$
Σ_c	$1/2^+$ ($1S$)	2452.9 ± 0.4
Σ_c^*	$3/2^+$ ($1S$)	2517.5 ± 2.3
Ξ_c'	$1/2^+$ ($1S$)	2578.4 ± 0.5
Ξ_c^*	$3/2^+$ ($1S$)	$2645.56^{+0.24}_{-0.30}$
Ω_c	$1/2^+$ ($1S$)	2695.2 ± 1.7
Ω_c^*	$3/2^+$ ($1S$)	2765.9 ± 2.0
Λ_c	$1/2^-$ ($1P$)	$\Lambda_c(2595) : 2592.25 \pm 0.28$
Λ_c	$3/2^-$ ($1P$)	$\Lambda_c(2625) : 2628.11 \pm 0.19$
Ξ_c	$1/2^-$ ($1P$)	$\Xi_c(2590) : 2590.4 \pm 0.5$
Ξ_c	$3/2^-$ ($1P$)	$\Xi_c(2815) : 2816.74^{+0.20}_{-0.23}$
Σ_c	$1/2^-$ ($1P$)	—
Σ_c	$1/2^-$ ($1P$)	—
Σ_c	$3/2^-$ ($1P$)	$\Sigma_c(2800) : 2792^{+14}_{-5}$
Σ_c	$3/2^-$ ($1P$)	—
Σ_c	$5/2^-$ ($1P$)	—
Ξ_c'	$1/2^-$ ($1P$)	—
Ξ_c'	$1/2^-$ ($1P$)	$\Xi_c(2923) : 2923.04 \pm 0.35$ [304]
Ξ_c'	$3/2^-$ ($1P$)	$\Xi_c(2939) : 2938.55 \pm 0.30$ [304]
Ξ_c'	$3/2^-$ ($1P$)	$\Xi_c(2965) : 2964.88 \pm 0.33$ [304]
Ξ_c'	$5/2^-$ ($1P$)	—
Ω_c	$1/2^-$ ($1P$)	—
Ω_c	$1/2^-$ ($1P$)	$\Omega_c(3000) : 3000.41 \pm 0.22$
Ω_c	$3/2^-$ ($1P$)	$\Omega_c(3050) : 3050.20 \pm 0.13$
Ω_c	$3/2^-$ ($1P$)	$\Omega_c(3066) : 3065.46 \pm 0.28$
Ω_c	$5/2^-$ ($1P$)	$\Omega_c(3090) : 3090.0 \pm 0.5$
Λ_c	$1/2^+$ ($2S$)	$\Lambda_c(2765) : 2766.6 \pm 2.4$
Ξ_c	$1/2^+$ ($2S$)	$\Xi_c(2970) : 2966.34^{+0.17}_{-1.00}$
Σ_c	$1/2^+$ ($2S$)	—
Σ_c	$3/2^+$ ($2S$)	—
Ξ_c'	$1/2^+$ ($2S$)	—
Ξ_c'	$3/2^+$ ($2S$)	—
Ω_c	$1/2^+$ ($2S$)	$\Omega_c(3119) : 3119.1 \pm 1.0$
Ω_c	$3/2^+$ ($2S$)	—
Λ_c	$3/2^+$ ($1D$)	$\Lambda_c(2860) : 2856.1^{+2.3}_{-5.9}$
Λ_c	$5/2^+$ ($1D$)	$\Lambda_c(2880) : 2881.63 \pm 0.24$
Ξ_c	$3/2^+$ ($1D$)	$\Xi_c(3055) : 3055.9 \pm 0.4$
Ξ_c	$5/2^+$ ($1D$)	$\Xi_c(3080) : 3077.2 \pm 0.4$
Σ_c	$1/2^+$ ($1D$)	—
Σ_c	$3/2^+$ ($1D$)	—
Σ_c	$3/2^+$ ($1D$)	—
Σ_c	$5/2^+$ ($1D$)	—
Σ_c	$5/2^+$ ($1D$)	—
Σ_c	$7/2^+$ ($1D$)	—
Ξ_c'	$1/2^+$ ($1D$)	—
Ξ_c'	$3/2^+$ ($1D$)	—
Ξ_c'	$3/2^+$ ($1D$)	—
Ξ_c'	$5/2^+$ ($1D$)	—
Ξ_c'	$5/2^+$ ($1D$)	—
Ξ_c'	$7/2^+$ ($1D$)	—
Ω_c	$1/2^+$ ($1D$)	—
Ω_c	$3/2^+$ ($1D$)	—
Ω_c	$3/2^+$ ($1D$)	—
Ω_c	$5/2^+$ ($1D$)	—
Ω_c	$5/2^+$ ($1D$)	—
Ω_c	$7/2^+$ ($1D$)	—

[Rep. Prog. Phys. 80 (2017) 076201]

LHCb detector

- LHCb is a dedicated flavor (specialize in charm and beauty) physics experiment at the LHC
 - Single-arm forward spectrometer covering $2 < \eta < 5$
- Charmed baryons:
 - Prompt: Prompt production from pp collisions, large cross section, higher background
 - B decay: Lower yield and lower background



Some of recent LHCb results

- Ξ_c^{**} states

- Prompt $\Xi_c(2923)^0$, $\Xi_c(2939)^0$ and $\Xi_c(2965)^0$ observed in $\Lambda_c^+ K^-$ decays [\[PhysRevLett. 124 \(2020\) 222001\]](#)
- $\Xi_c(2923)^0$, $\Xi_c(2939)^0$ confirmed in $B^- \rightarrow \Lambda_c^+ \bar{\Lambda}_c^- K^-$ [\[PhysRevD. 108 \(2023\) 012020\]](#)
- $\Xi_c(2923)^+$ observed in prompt data, $\Xi_c(2645)^0 \pi^+$ final state **New!** [\[2502.18987\]](#)
- First spin-parity determination of $\Xi_c(3055)^{+(0)}$ **New!** [\[PhysRevLett. 134 \(2025\) 081901\]](#)

- Ω_c^{**} states

- Seven new Ω_c^{**0} states observed in prompt $\Xi_c^+ K^-$ decays [\[PhysRevLett. 118 \(2017\) 182001\]](#), [\[PhysRevLett. 131 \(2023\) 131902\]](#)
- Confirming Ω_c^{**0} states in $\Omega_b^- \rightarrow \Xi_c^+ K^- \pi^+$ channel and spin tests [\[PhysRevD. 104. \(2021\) L091102\]](#)
- First observation of SCS decays $\Omega_c^0 \rightarrow \Xi^- \pi^+$, $\Omega_c^0 \rightarrow \Omega^- K^+$ **New!** [\[Phys. Rev. Lett. 132 \(2024\) 081802\]](#)

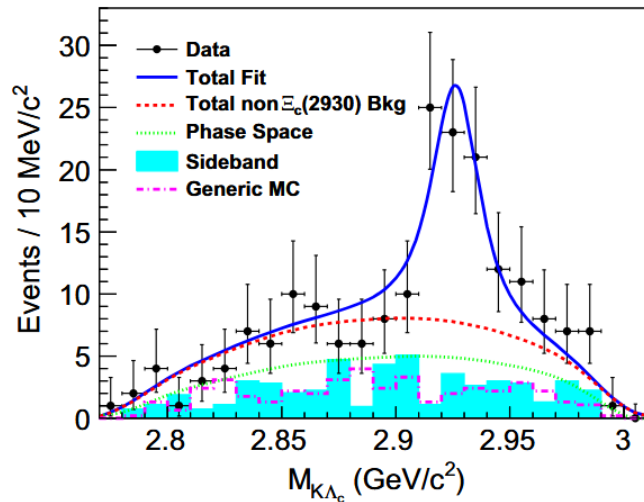
- Doubly charmed baryons

- Search for doubly charmed baryons Ξ_{cc}^+ and Ω_{cc}^+ [\[Sci.China-Phys.Mech.Astron. 64 \(2021\) 101062\]](#), [\[Sci.China Phys.Mech.Astron. 63 \(2020\) 221062\]](#), [\[JHEP12 \(2021\) 107\]](#), [\[JHEP05 \(2022\) 038\]](#)
- Observation of $\Xi_{cc}^{++} \rightarrow \Xi_c^0 \pi^+ \pi^+$ **New!** [\[2504.05063\]](#)

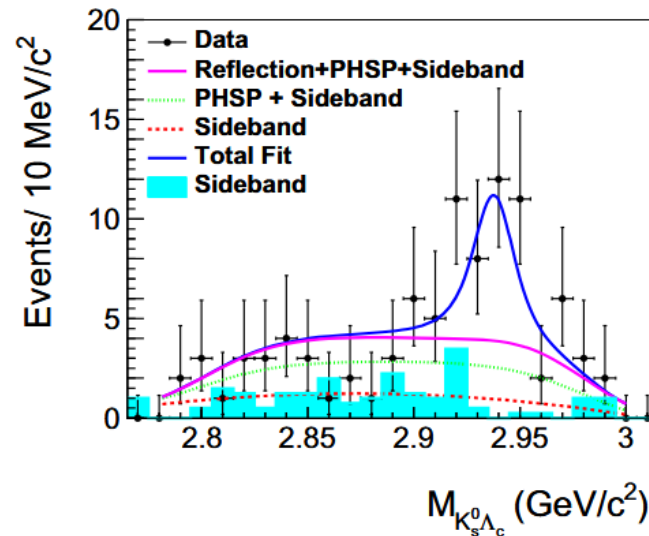
E_c^{**} states

Prompt $\Xi_c(2923)^0$, $\Xi_c(2939)^0$ and $\Xi_c(2965)^0$ observed in $\Lambda_c^+ K^-$ decays

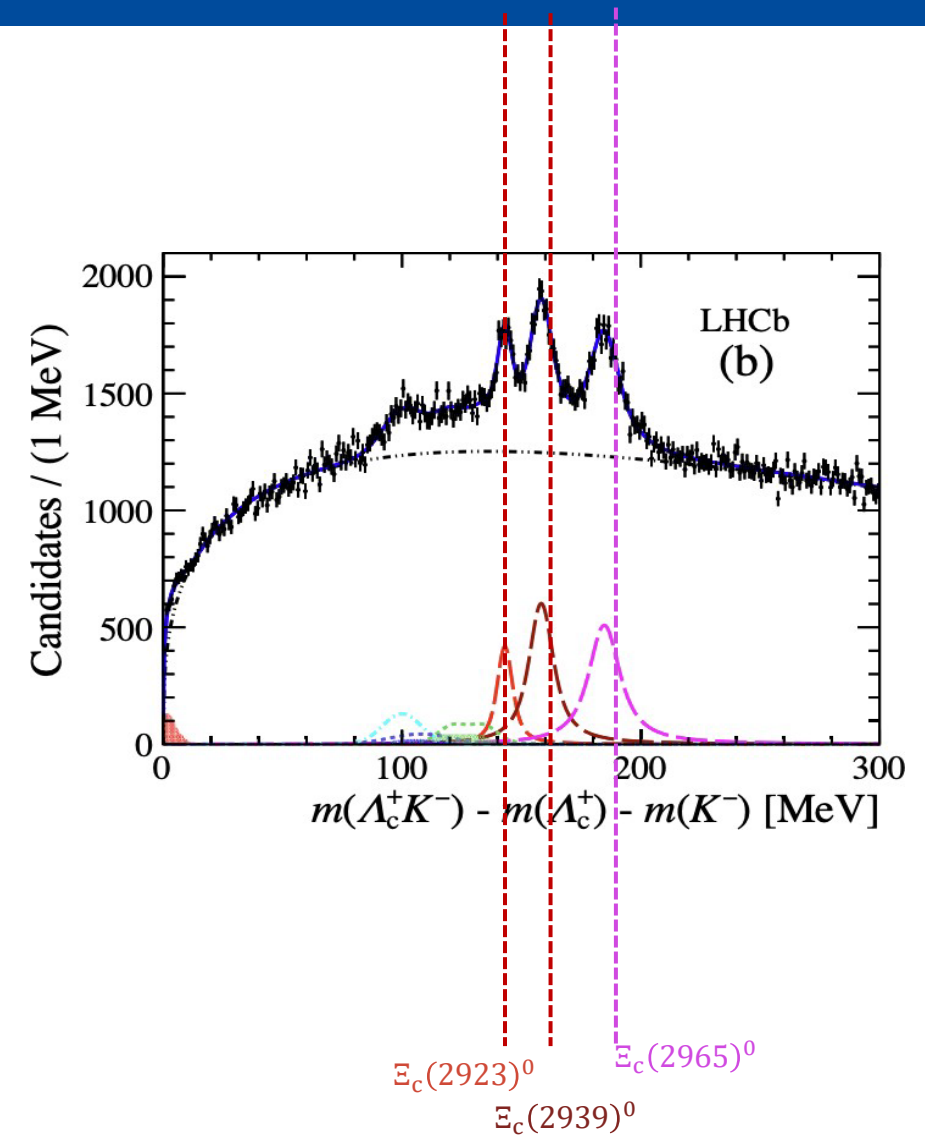
- With prompt Ξ_c^{*0} decaying into $\Lambda_c^+ K^-$
 - New states $\Xi_c(2923)^0$, $\Xi_c(2939)^0$ observed
 - Replace previous bump at 2930 MeV



[Eur. Phys. J. C \(2018\) 78:252](#)



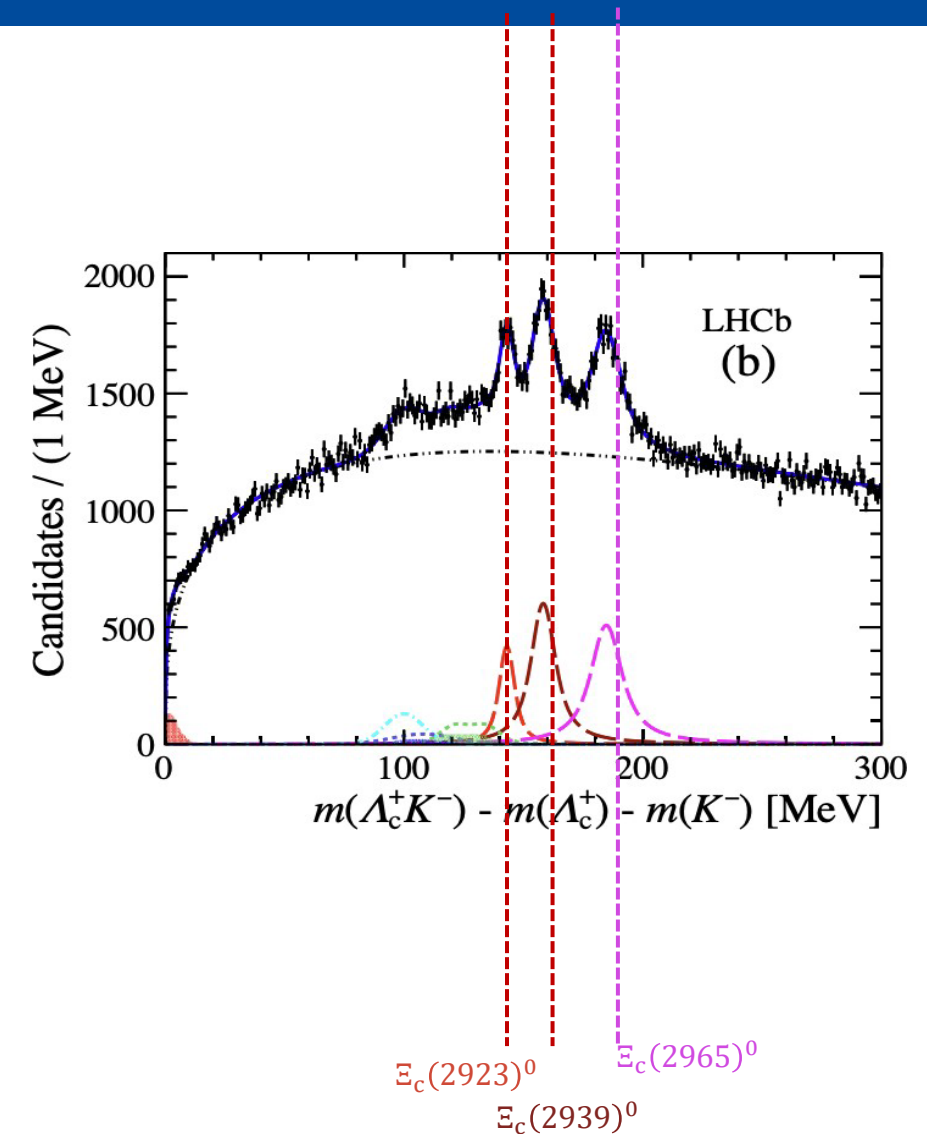
[Eur. Phys. J. C \(2018\) 78:928](#)



[\[PhysRevLett. 124 \(2020\) 222001\]](#)

Prompt $\Xi_c(2923)^0$, $\Xi_c(2939)^0$ and $\Xi_c(2965)^0$ observed in $\Lambda_c^+ K^-$ decays

- With prompt Ξ_c^{**0} decaying into $\Lambda_c^+ K^-$
 - New states $\Xi_c(2923)^0$, $\Xi_c(2939)^0$ observed
 - ▣ Replace previous bump at 2930 MeV
 - New state $\Xi_c(2965)^0$ observed
 - ▣ In the vicinity of previous state $\Xi_c(2970)^0$, but only half of the width



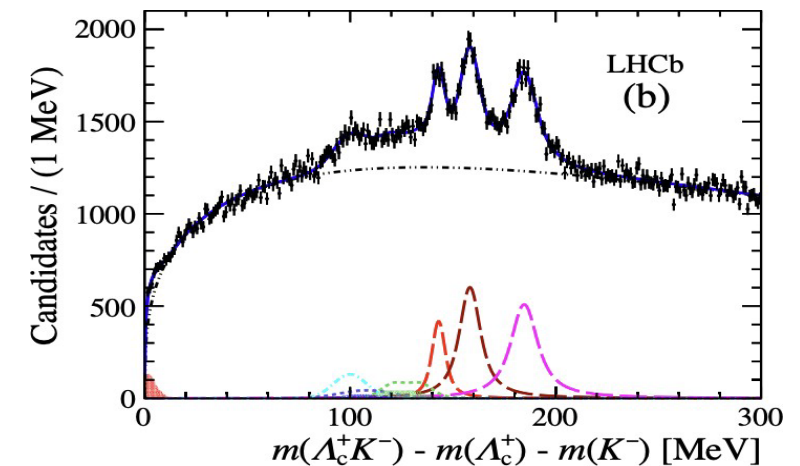
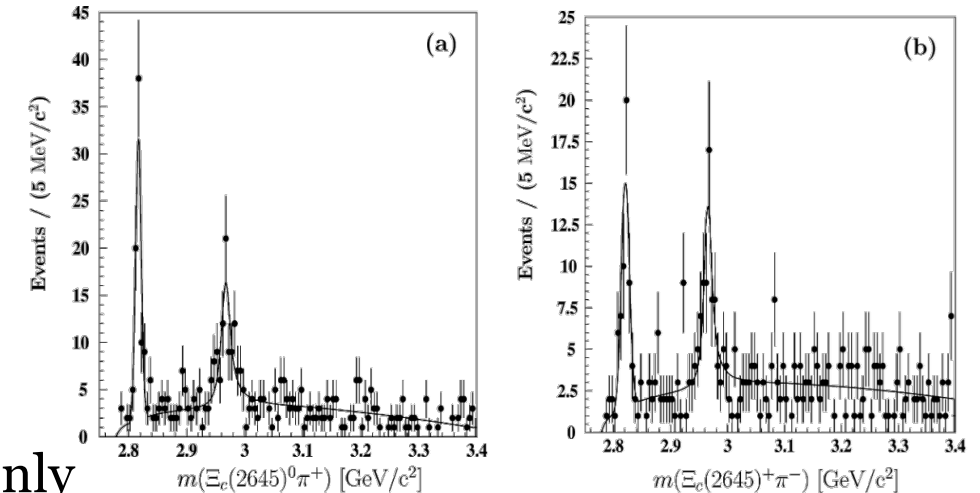
[PhysRevLett. 124 (2020) 222001]

Prompt $\Xi_c(2923)^0$, $\Xi_c(2939)^0$ and $\Xi_c(2965)^0$ observed in $\Lambda_c^+ K^-$ decays

- With prompt Ξ_c^{**0} decaying into $\Lambda_c^+ K^-$
 - New states $\Xi_c(2923)^0$, $\Xi_c(2939)^0$ observed
 - ▣ Replace previous bump at 2930 MeV
 - New state $\Xi_c(2965)^0$ observed
 - ▣ In the vicinity of previous state $\Xi_c(2970)^0$, but only half of the width

	Mass/MeV	Width/MeV
$\Xi_c(2965)^0$	$2964.88 \pm 0.26 \pm 0.14 \pm 0.14$	$14.1 \pm 0.9 \pm 1.3$
$\Xi_c(2970)^0$	$2967.8^{+0.9}_{-0.7}$	$28.1^{+3.4}_{-4.0}$

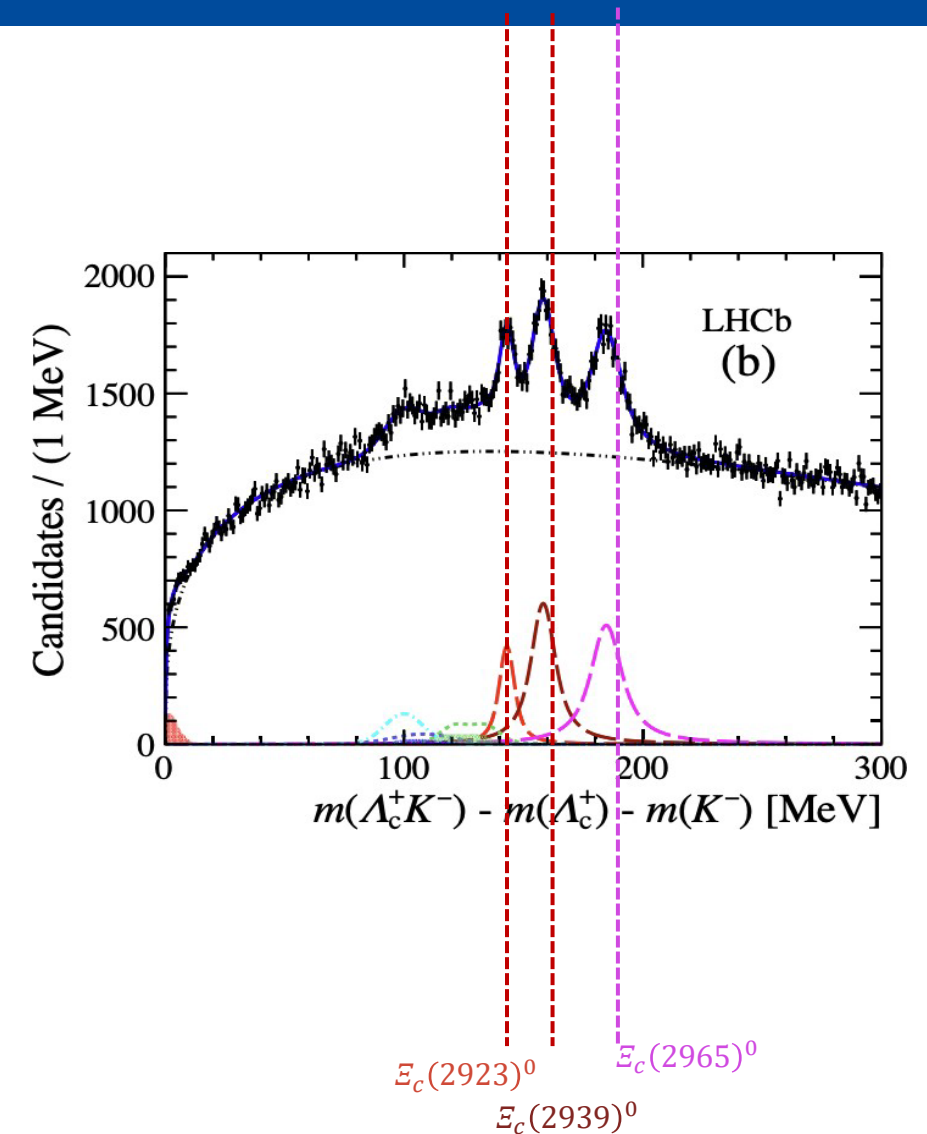
[Physics Letters B 665 \(2008\) 9–15](#)



[\[PhysRevLett. 124 \(2020\) 222001\]](#)

Prompt $\Xi_c(2923)^0$, $\Xi_c(2939)^0$ and $\Xi_c(2965)^0$ observed in $\Lambda_c^+ K^-$ decays

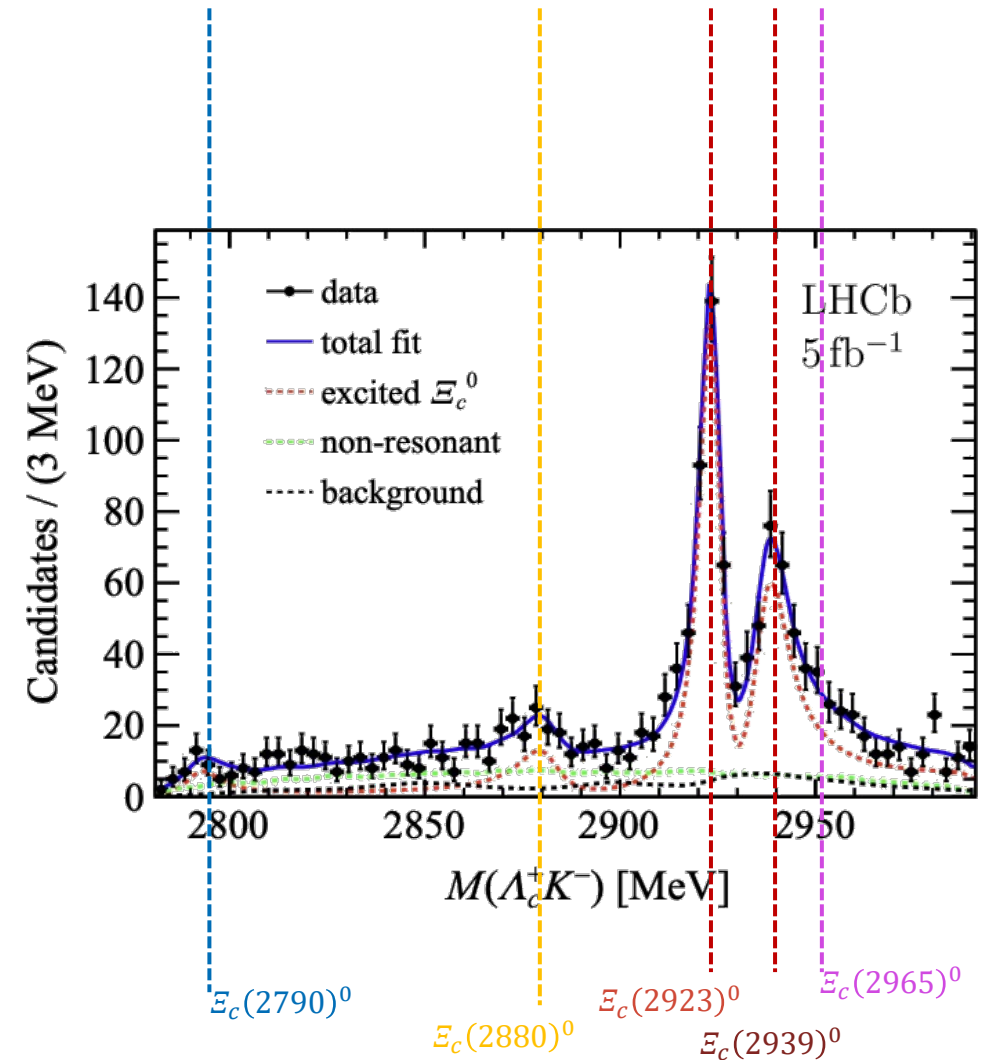
- With prompt Ξ_c^{**0} decaying into $\Lambda_c^+ K^-$
 - New states $\Xi_c(2923)^0$, $\Xi_c(2939)^0$ observed
 - ▣ Replace previous bump at 2930 MeV
 - New state $\Xi_c(2965)^0$ observed
 - ▣ In the vicinity of previous state $\Xi_c(2970)^0$, but only half of the width
 - Hint of $\Xi_c(2880)^0$ with alternative model
 - ▣ Can be also described by feed-down components



[PhysRevLett. 124 (2020) 222001]

$\Xi_c(2923)^0, \Xi_c(2939)^0$ confirmed in $B^- \rightarrow \Lambda_c^+ \bar{\Lambda}_c^- K^-$

- In $B^- \rightarrow \Lambda_c^+ \bar{\Lambda}_c^- K^-$ decays
 - $\Xi_c(2923)^0, \Xi_c(2939)^0$ confirmed
 - Evidence of $\Xi_c(2880)^0$, significance 3.8σ
 - New $\Xi_c(2790)^0$ decay with significance 3.4σ
 - No evidence for $\Xi_c(2970)^0$???

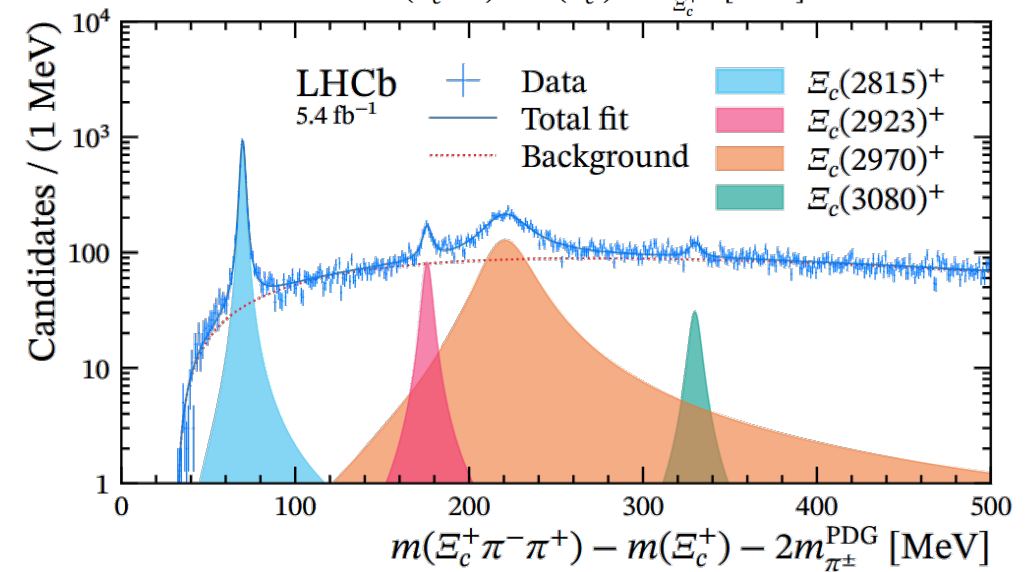
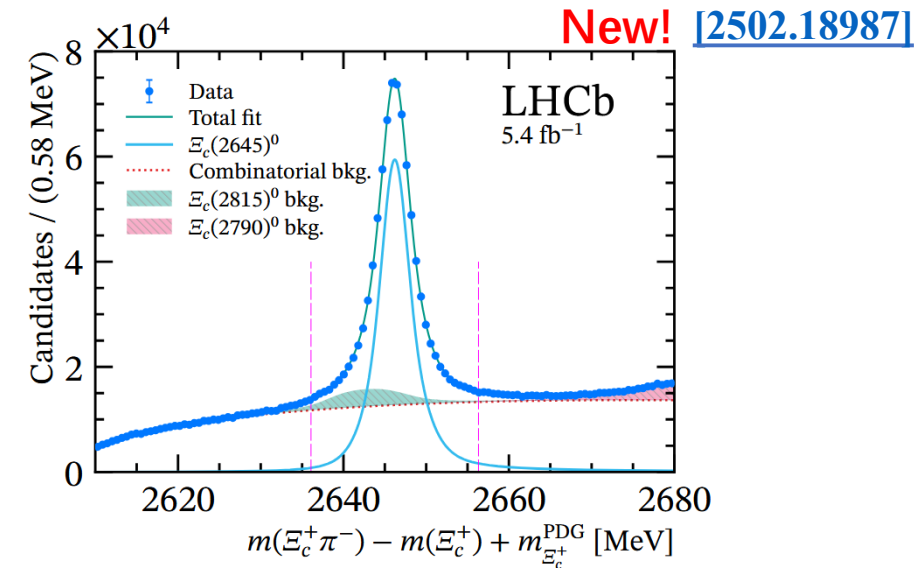


[PhysRevD. 108 (2023) 012020]

$\Xi_c(2923)^+$ observed in prompt data $\Xi_c(2645)^0\pi^+$ final state

- Exploring prompt Ξ_c^{**} decaying to $\Xi_c(2645)^0\pi^+$
- New state $\Xi_c(2923)^+$ found ($\Xi_c(2923)^0$ isospin partner)
- Four states observed $\Xi_c(2815)^+$, $\Xi_c(2923)^+$, $\Xi_c(2970)^+$, $\Xi_c(3080)^+$
 - $\Xi_c(3080)^+$ first time in this final state, with 5.4σ
 - Precise measurement of masses & widths (than current averages)
- $\Xi_c(2970)^+$ observed, width twice as $\Xi_c(2965)^0$

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



$\Xi_c(2923)^+$ observed in prompt data $\Xi_c(2645)^0\pi^+$ final state

New! [\[2502.18987\]](#)

- Exploring prompt Ξ_c^{**} decaying to $\Xi_c(2645)^0\pi^+$
 - $\Xi_c^+(\rightarrow pK^-\pi^+)\pi^-$
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 - Precise measurement of masses & widths (than current averages)
- $\Xi_c(2970)^+$ observed, width twice as $\Xi_c(2965)^0$

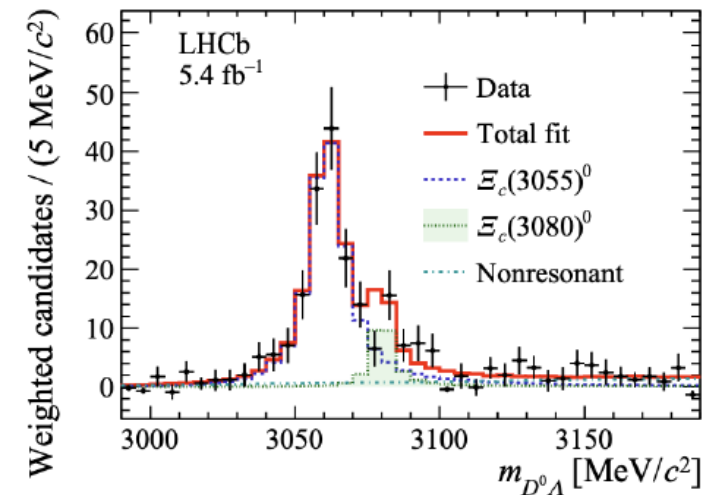
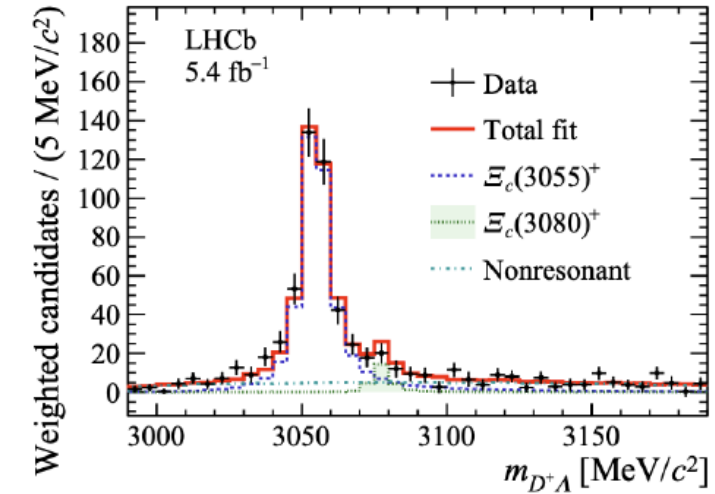
$$\begin{aligned}
 N[\Xi_c(2815)^+] &= 4072 \pm 77, \\
 m[\Xi_c(2815)^+] &= 2816.65 \pm 0.03 \pm 0.03 \pm 0.23 \text{ MeV}, \\
 \Gamma[\Xi_c(2815)^+] &= 2.07 \pm 0.08 \pm 0.12 \text{ MeV}, \\
 N[\Xi_c(2923)^+] &= 738 \pm 76, \\
 m[\Xi_c(2923)^+] &= 2922.8 \pm 0.3 \pm 0.5 \pm 0.2 \text{ MeV}, \\
 \Gamma[\Xi_c(2923)^+] &= 5.3 \pm 0.9 \pm 1.4 \text{ MeV}, \\
 N[\Xi_c(2970)^+] &= 6105 \pm 255, \\
 m[\Xi_c(2970)^+] &= 2968.6 \pm 0.5 \pm 0.5 \pm 0.2 \text{ MeV}, \\
 \Gamma[\Xi_c(2970)^+] &= 31.7 \pm 1.7 \pm 1.9 \text{ MeV}, \\
 N[\Xi_c(3080)^+] &= 344 \pm 77, \\
 m[\Xi_c(3080)^+] &= 3076.8 \pm 0.7 \pm 1.3 \pm 0.2 \text{ MeV}, \\
 \Gamma[\Xi_c(3080)^+] &= 6.8 \pm 2.3 \pm 0.9 \text{ MeV},
 \end{aligned}$$

	Mass/MeV	Width/MeV
$\Xi_c(2965)^0$	$2964.88 \pm 0.26 \pm 0.14 \pm 0.14$	$14.1 \pm 0.9 \pm 1.3$
$\Xi_c(2970)^0$	$2967.8^{+0.9}_{-0.7}$	$28.1^{+3.4}_{-4.0}$

First spin-parity determination of $\Xi_c(3055)^{+ (0)}$

- $\Xi_c^{**+ (0)}$ in $\Xi_b^{0 (-)} \rightarrow D^{+ (0)} \Lambda \pi^+$ process
- $\Xi_c(3055)^+$ and $\Xi_c(3055)^0$ observed first time in Ξ_b decays
- Evidence of $\Xi_c(3080)^{+ (0)}$, significance $4.4(3.6)\sigma$
 - Mass width $\Xi_c(3080)^{+ (0)} / \Xi_c(3055)^{+ (0)}$ relative branching fraction measured

Quantity	$\Xi_c(3055)^+$	$\Xi_c(3055)^0$
$m [\text{MeV}/c^2]$	$3054.52 \pm 0.36 \pm 0.17$	$3061.00 \pm 0.80 \pm 0.23$
$\Gamma [\text{MeV}/c^2]$	$8.01 \pm 0.76 \pm 0.34$	$12.4 \pm 2.0 \pm 1.1$
R_B	$0.045 \pm 0.023 \pm 0.006$	$0.14 \pm 0.06 \pm 0.04$

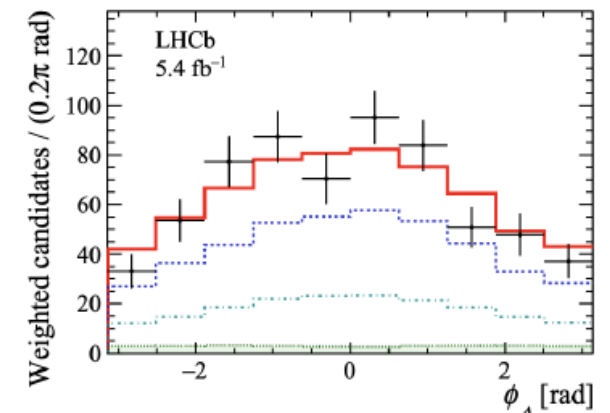
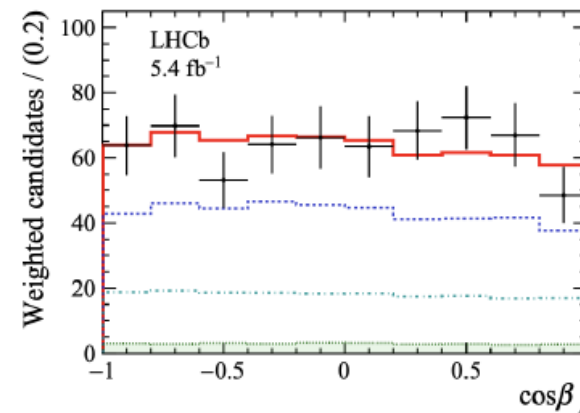
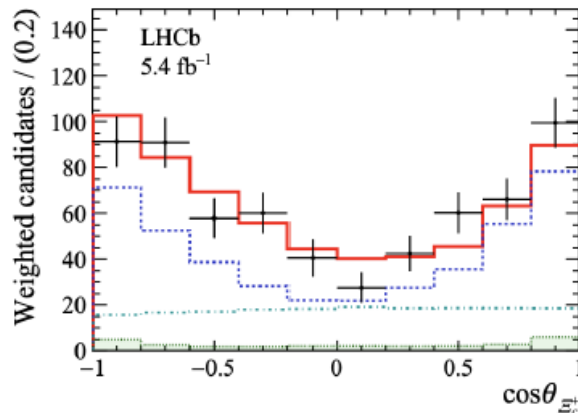
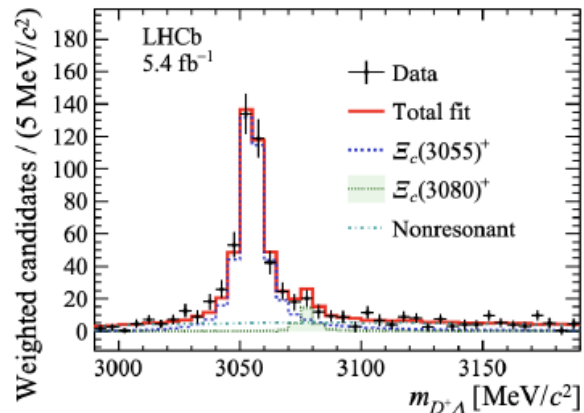


New! [\[PhysRevLett. 134 \(2025\) 081901\]](#)

First spin-parity determination of $\Xi_c(3055)^{+(0)}$

New! [\[PhysRevLett. 134 \(2025\) 081901\]](#)

- $\Xi_c^{**+(0)}$ in $\Xi_b^{0(-)} \rightarrow D^{+(0)} \Lambda \pi^+$ process
 $\Xi_c^{**+(0)} \rightarrow D^{+(0)} \Lambda \pi^+$
- $\Xi_c(3055)^+$ and $\Xi_c(3055)^0$ observed first time in Ξ_b decays
- Evidence of $\Xi_c(3080)^{+(0)}$, significance $4.4(3.6)\sigma$
 - Mass width $\Xi_c(3080)^{+(0)} / \Xi_c(3055)^{+(0)}$ relative branching fraction measured
- Full chain amplitude analysis done for spin-parity
 - $\Xi_c(3055)^{+(0)}$ as $(3/2^+$ with $6.5(3.5)\sigma$) D wave λ mode excitation of 3_F



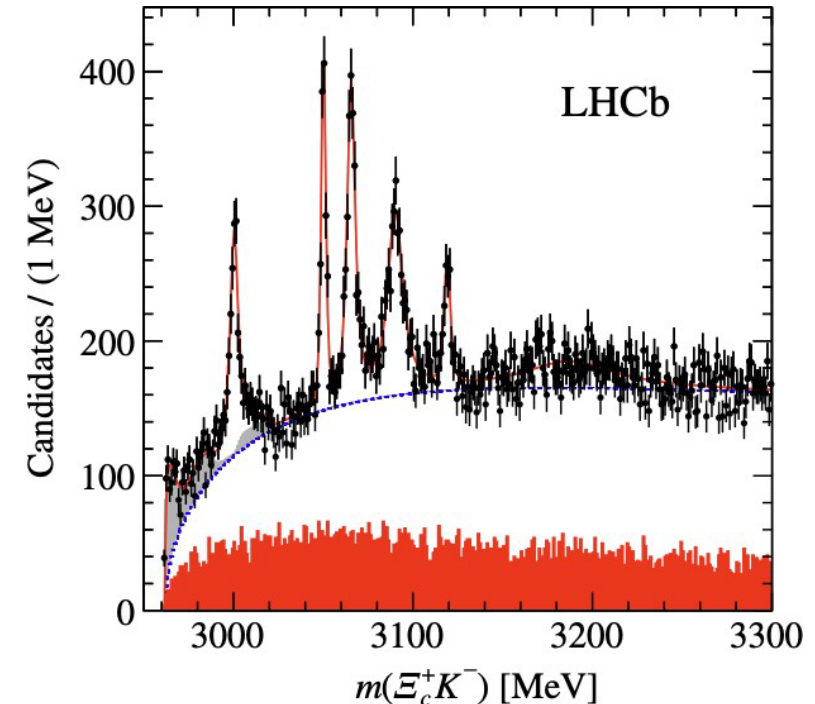
Ω_c^{**} states

Seven new Ω_c^{*0} states observed in prompt $\Xi_c^+ K^-$ decays

[\[PhysRevLett. 118 \(2017\) 182001\]](#)

[\[PhysRevLett. 131 \(2023\) 131902\]](#)

- Ω_c^{*0} from **prompt** $pp \rightarrow \Xi_c^+ (pK^- \pi^+) K^- X$ processes, where $\Omega_c^* \rightarrow \Xi_c^+ K^-$
- **5 new states (in 2017)** $\Omega_c(3000)^0$, $\Omega_c(3050)^0$, $\Omega_c(3065)^0$, $\Omega_c(3090)^0$, $\Omega_c(3119)^0$ firstly observed
(With LHCb 3.3 fb⁻¹ Run 1 + (partly) 2 dataset)



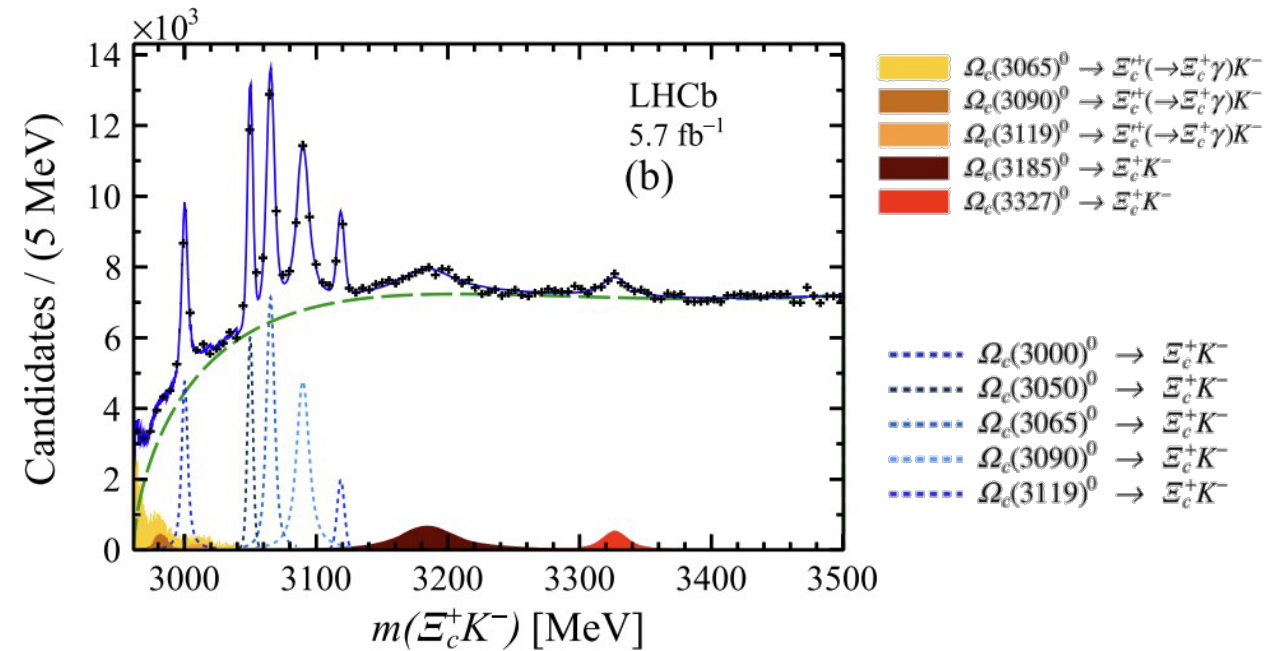
Seven new Ω_c^{*0} states observed in prompt $\Xi_c^+ K^-$ decays

[PhysRevLett. 118 (2017) 182001],

[PhysRevLett. 131 (2023) 131902]

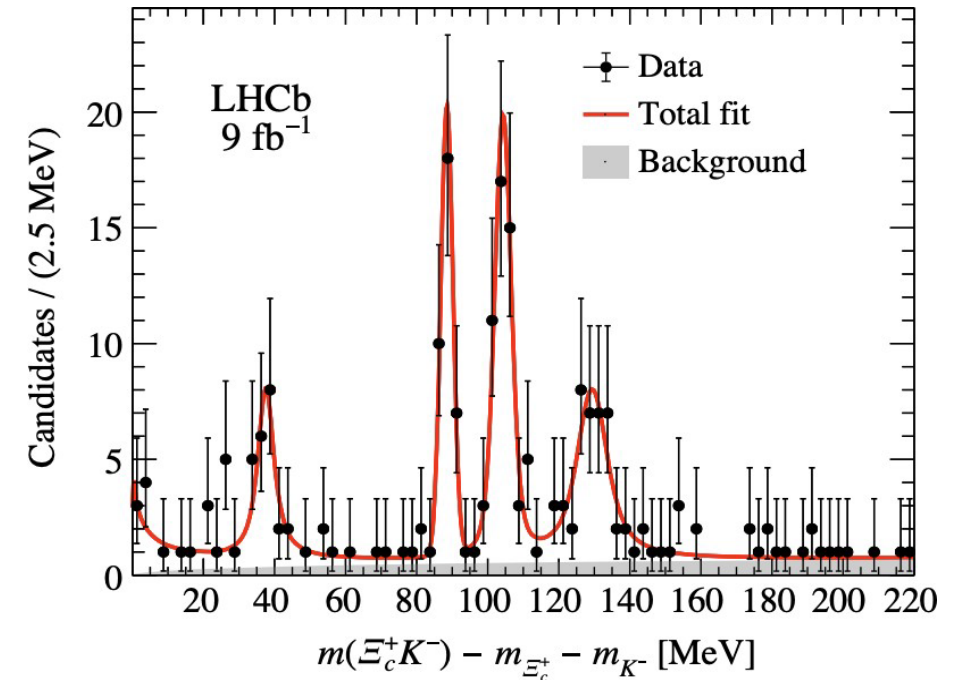
- Ω_c^{*0} from **prompt** $pp \rightarrow \Xi_c^+ (pK^- \pi^+) K^- X$ processes, where $\Omega_c^* \rightarrow \Xi_c^+ K^-$
- **5 new states (in 2017)** $\Omega_c(3000)^0$, $\Omega_c(3050)^0$, $\Omega_c(3065)^0$, $\Omega_c(3090)^0$, $\Omega_c(3119)^0$ firstly observed
(With LHCb 3.3 fb⁻¹ Run 1 + (partly) 2 dataset)
- **2 new states** $\Omega_c(3185)^0$ (12 σ), $\Omega_c(3327)^0$ (10 σ) later observed (With updated 9fb⁻¹ Run 1+2 dataset)

Resonance	m (MeV)	Γ (MeV)
$\Omega_c(3000)^0$	$3000.44 \pm 0.07^{+0.07}_{-0.13} \pm 0.23$	$3.83 \pm 0.23^{+1.59}_{-0.29}$
$\Omega_c(3050)^0$	$3050.18 \pm 0.04^{+0.06}_{-0.07} \pm 0.23$	$0.67 \pm 0.17^{+0.64}_{-0.72}$
< 1.8 MeV, 95% CL		
$\Omega_c(3065)^0$	$3065.63 \pm 0.06^{+0.06}_{-0.06} \pm 0.23$	$3.79 \pm 0.20^{+0.38}_{-0.47}$
$\Omega_c(3090)^0$	$3090.16 \pm 0.11^{+0.06}_{-0.10} \pm 0.23$	$8.48 \pm 0.44^{+0.61}_{-1.62}$
$\Omega_c(3119)^0$	$3118.98 \pm 0.12^{+0.09}_{-0.23} \pm 0.23$	$0.60 \pm 0.63^{+0.90}_{-1.05}$
< 2.5 MeV, 95% CL		
$\Omega_c(3185)^0$	$3185.1 \pm 1.7^{+7.4}_{-0.9} \pm 0.2$	$50 \pm 7^{+10}_{-20}$
$\Omega_c(3327)^0$	$3327.1 \pm 1.2^{+0.1}_{-1.3} \pm 0.2$	$20 \pm 5^{+13}_{-1}$



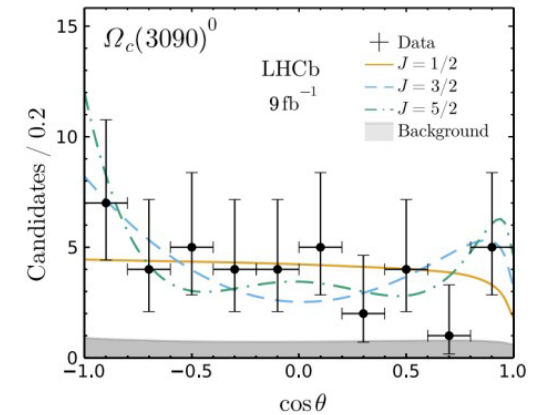
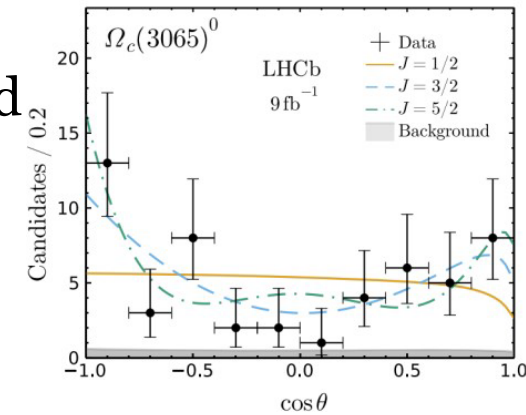
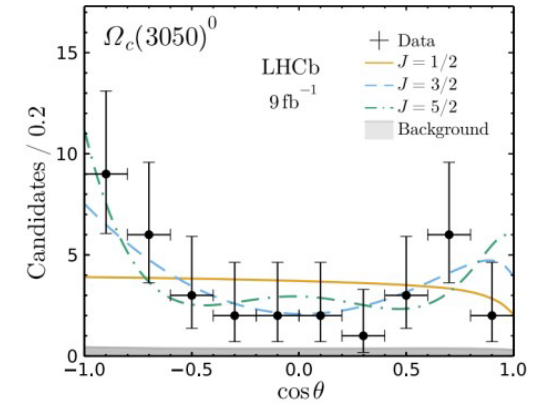
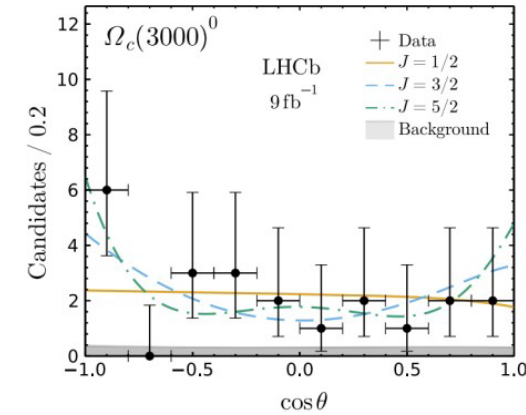
Confirming Ω_c^{**0} states in $\Omega_b^- \rightarrow \Xi_c^+ K^- \pi^+$ channel and spin tests

- Ω_c^{**0} from $\Omega_b^- \rightarrow \Omega_c^{**0}(\rightarrow \Xi_c^+ K^-)\pi^+$
- Four states observed
 - $\Omega_c(3000)^0, \Omega_c(3050)^0, \Omega_c(3065)^0, \Omega_c(3090)^0$
 - Absence of $\Omega_c(3120)^0$
- Angular analysis for spin:
 - Reject $J=1/2$ for $\Omega_c(3050)^0, \Omega_c(3065)^0$ with 2.2σ and 3.6σ
 - Theory proposed spin order $J=1/2, 3/2, 3/2, 3/2$ rejected 3.5σ



Confirming Ω_c^{**0} states in $\Omega_b^- \rightarrow \Xi_c^+ K^- \pi^+$ channel and spin tests

- Ω_c^{**0} from $\Omega_b^- \rightarrow \Omega_c^{**0}(\rightarrow \Xi_c^+ K^-)\pi^+$
- Four states observed
 - $\Omega_c(3000)^0, \Omega_c(3050)^0, \Omega_c(3065)^0, \Omega_c(3090)^0$
 - Absence of $\Omega_c(3120)^0$
- Angular analysis for spin:
 - Reject $J=1/2$ for $\Omega_c(3050)^0, \Omega_c(3065)^0$ with 2.2σ and 3.6σ
 - Theory proposed spin order $J=1/2, 3/2, 3/2, 3/2$ rejected 3.5σ



First observation of SCS decays $\Omega_c^0 \rightarrow \Xi^- \pi^+$, $\Omega_c^0 \rightarrow \Omega^- K^+$

- First observation of the Cabibbo-suppressed decays $\Omega_c^0 \rightarrow \Xi^- \pi^+$, $\Omega_c^0 \rightarrow \Omega^- K^+$

$$\triangleright \frac{B(\Omega_c^0 \rightarrow \Xi^- \pi^+)}{B(\Omega_c^0 \rightarrow \Omega^- \pi^+)} = 0.1581 \pm 0.0087(stat.) \pm 0.0041(syst.) \pm 0.0016(ext.)$$

$$\triangleright \frac{B(\Omega_c^0 \rightarrow \Omega^- K^+)}{B(\Omega_c^0 \rightarrow \Omega^- \pi^+)} = 0.0608 \pm 0.0051(stat.) \pm 0.0039(syst.)$$

$$\frac{B(\Omega_c^0 \rightarrow \Omega^- K^+)}{B(\Omega_c^0 \rightarrow \Omega^- \pi^+)} = \frac{r_N}{r_e},$$

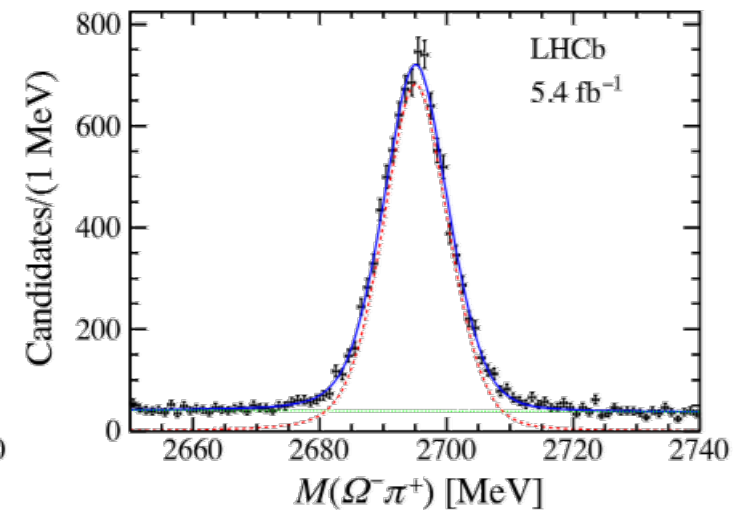
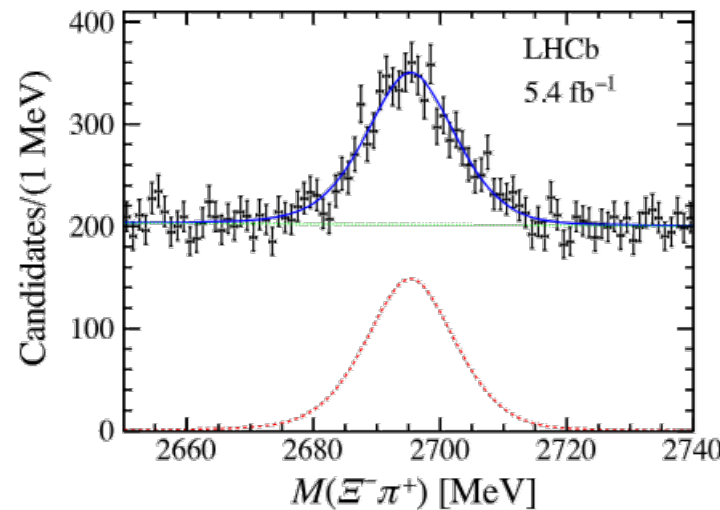
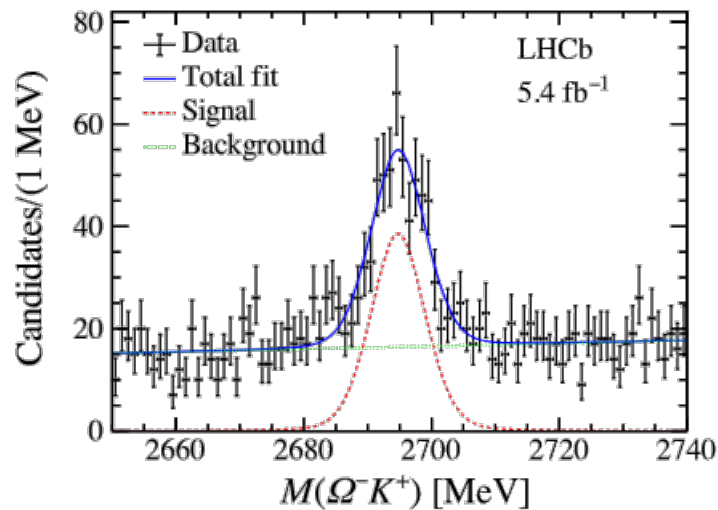
$$\frac{B(\Omega_c^0 \rightarrow \Xi^- \pi^+)}{B(\Omega_c^0 \rightarrow \Omega^- \pi^+)} = \frac{r'_N}{r'_e} \cdot \frac{B(\Omega^- \rightarrow \Lambda K^-)}{B(\Xi^- \rightarrow \Lambda \pi^-)},$$



- Ω_c^0 mass measured with better precision **Previous: 2695 ± 1.7 MeV**

New! [\[Phys. Rev. Lett. 132 \(2024\) 081802\]](#)

$$\triangleright m(\Omega_c^0) = 2695.28 \pm 0.07(stat.) \pm 0.27(syst.) \pm 0.30(ext.) [MeV]$$

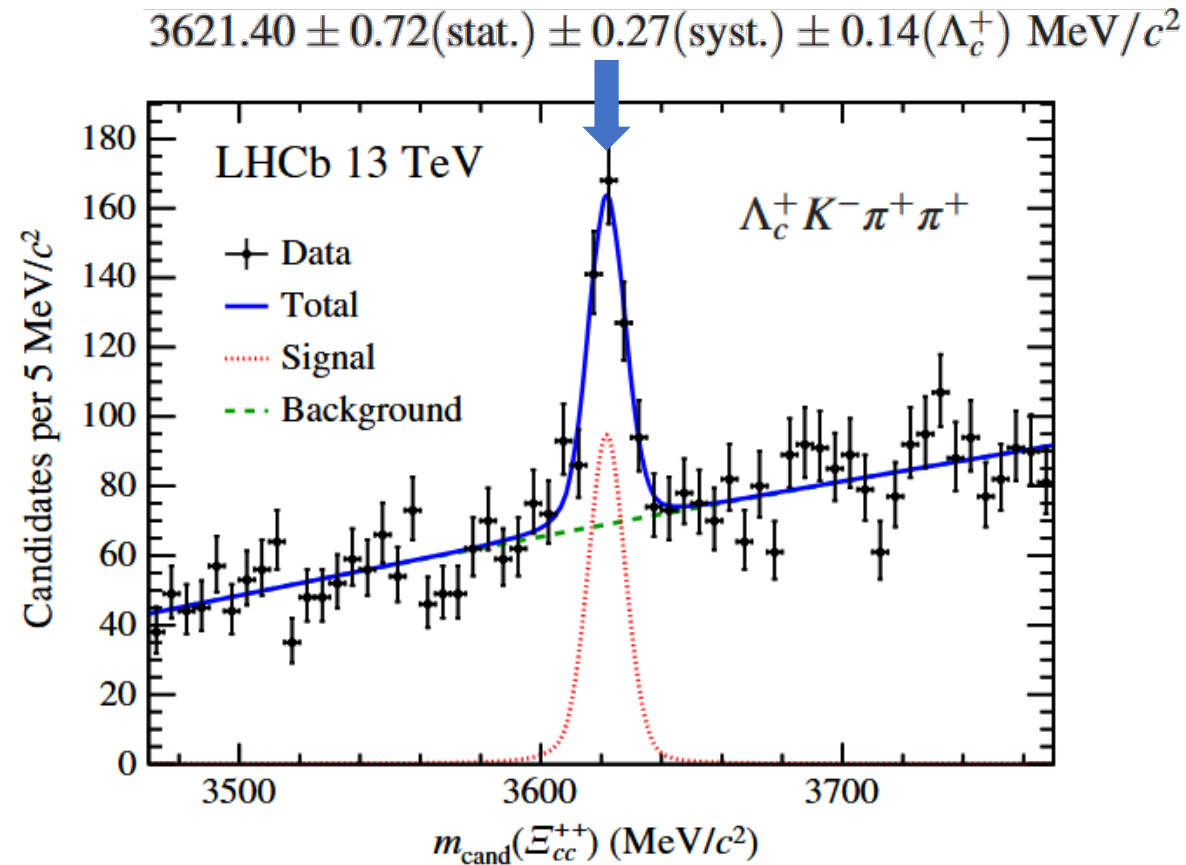


Doubly charmed baryons

Doubly charmed baryons

[Phys.Rev.Lett. 119 (2017) 11, 112001]

- Ξ_{cc}^{++} has been observed in three modes previously
- $\Xi_{cc}^{++} \rightarrow \Lambda_c^+ K^- \pi^+ \pi^+$



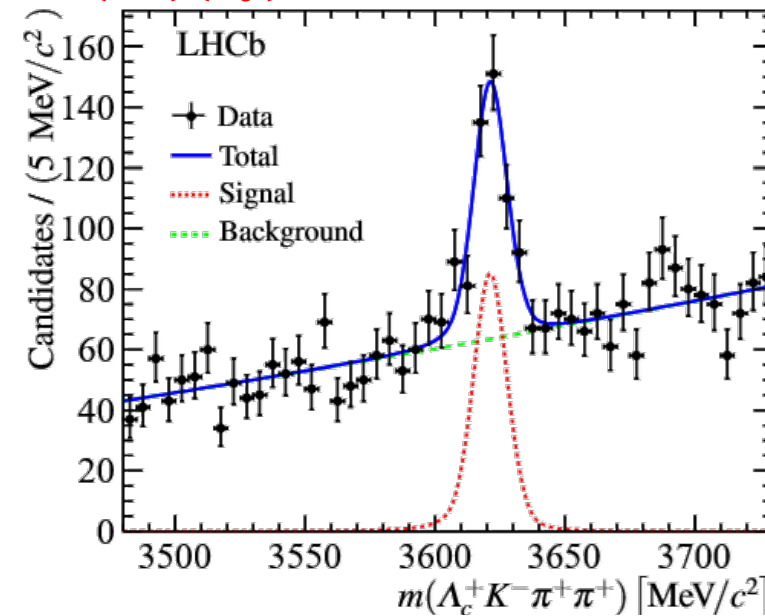
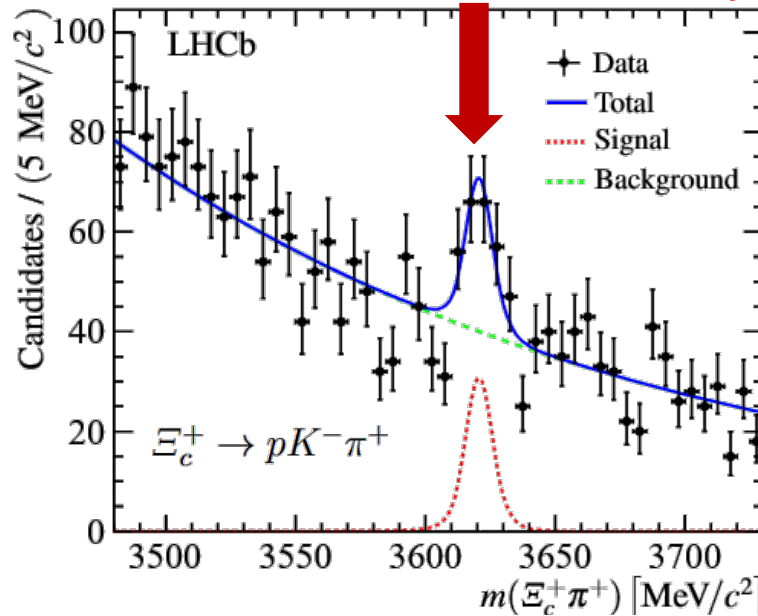
Doubly charmed baryons

- Ξ_{cc}^{++} has been observed in three modes previously

[Phys.Rev.Lett. 121 (2018) 16, 162002]

- $\Xi_{cc}^{++} \rightarrow \Xi_c^+(\rightarrow pK^-\pi^+)\pi^+$

$$3620.6 \pm 1.5(\text{stat.}) \pm 0.4(\text{syst.}) \pm (0.3)(\Xi_c^+)$$

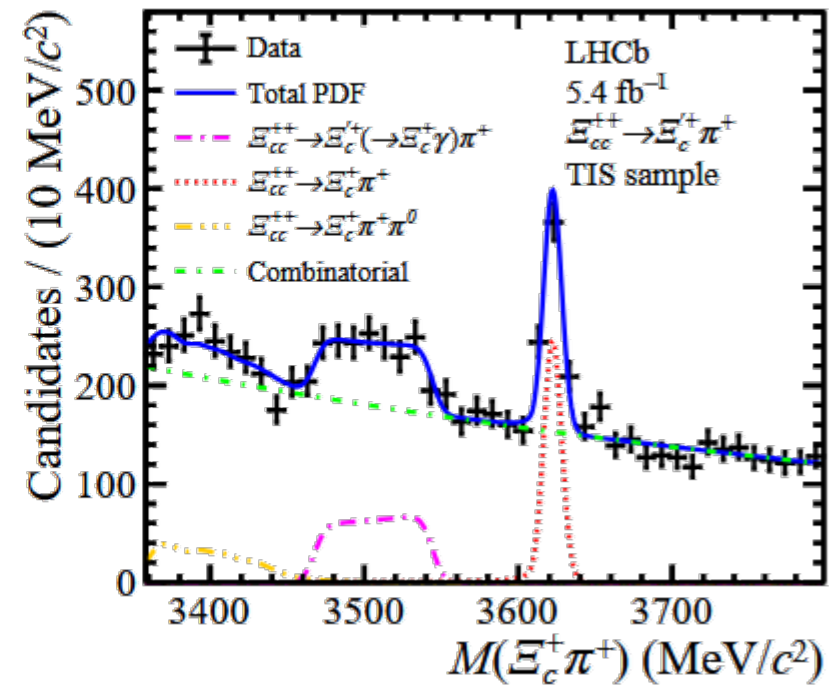
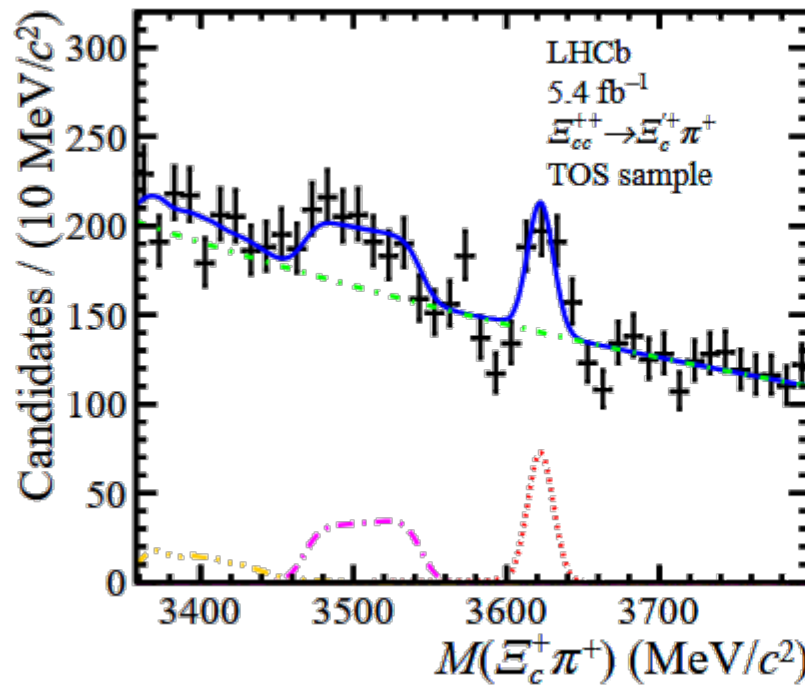


$$\frac{\mathcal{B}(\Xi_{cc}^{++} \rightarrow \Xi_c^+ \pi^+) \times \mathcal{B}(\Xi_c^+ \rightarrow pK^-\pi^+)}{\mathcal{B}(\Xi_{cc}^{++} \rightarrow \Lambda_c^+ K^-\pi^+\pi^+) \times \mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+)} = 0.035 \pm 0.009 (\text{stat}) \pm 0.003 (\text{syst})$$

Doubly charmed baryons

- Ξ_{cc}^{++} has been observed in three modes previously
- $\Xi_{cc}^{++} \rightarrow \Xi_c'^+ (\rightarrow \Xi_c^+ (\rightarrow p K^- \pi^+) \gamma) \pi^+$

[JHEP05 (2022) 038]



$$\frac{\mathcal{B}(\Xi_{cc}^{++} \rightarrow \Xi_c'^+ \pi^+)}{\mathcal{B}(\Xi_{cc}^{++} \rightarrow \Xi_c^+ \pi^+)} = 1.41 \pm 0.17 \pm 0.10$$

Doubly charmed baryons

- Ξ_{cc}^{++} has been observed in three modes previously

[\[Phys.Rev.Lett. 119 \(2017\) 11, 112001\]](#)

[\[Phys.Rev.Lett. 121 \(2018\) 5, 052002\]](#)

[\[Phys.Rev.Lett. 121 \(2018\) 16, 162002\]](#)

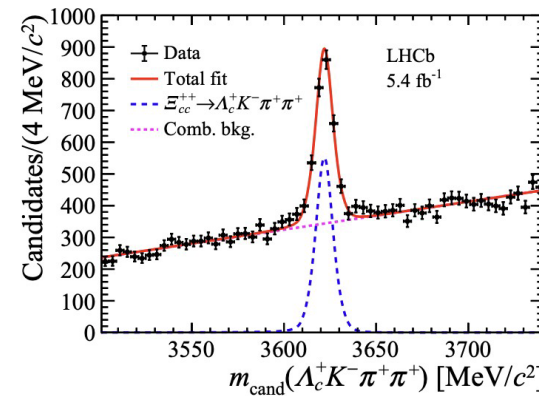
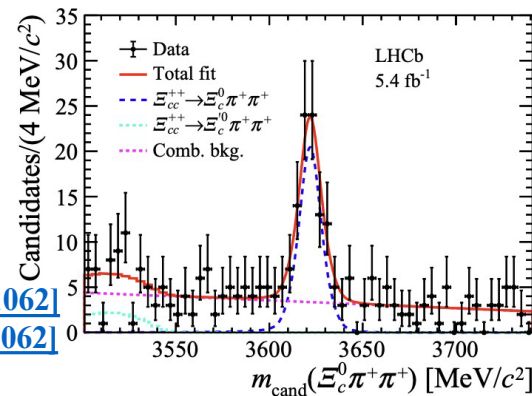
[\[JHEP05 \(2022\) 038\]](#)

- A new LHCb analysis has observed $\Xi_{cc}^{++} \rightarrow \Xi_c^0 \pi^+ \pi^+$

New! [\[2504.05063\]](#)

➤ Relative branching fraction measured

$$\frac{\mathcal{B}(\Xi_{cc}^{++} \rightarrow \Xi_c^0 \pi^+ \pi^+)}{\mathcal{B}(\Xi_{cc}^{++} \rightarrow \Lambda_c^+ K^- \pi^+ \pi^+)} = 1.37 \pm 0.18(\text{stat}) \pm 0.09(\text{syst}) \pm 0.35(\text{ext}),$$



- Ξ_{cc}^+ and Ω_{cc}^+ not observed yet

➤ More challenging due to longer (predicted) lifetime

[\[Eur.Phys.J.C 9 \(1999\) 213-219\]](#)

[\[Phys.Rev.D 98 \(2018\) 11, 113005\]](#)

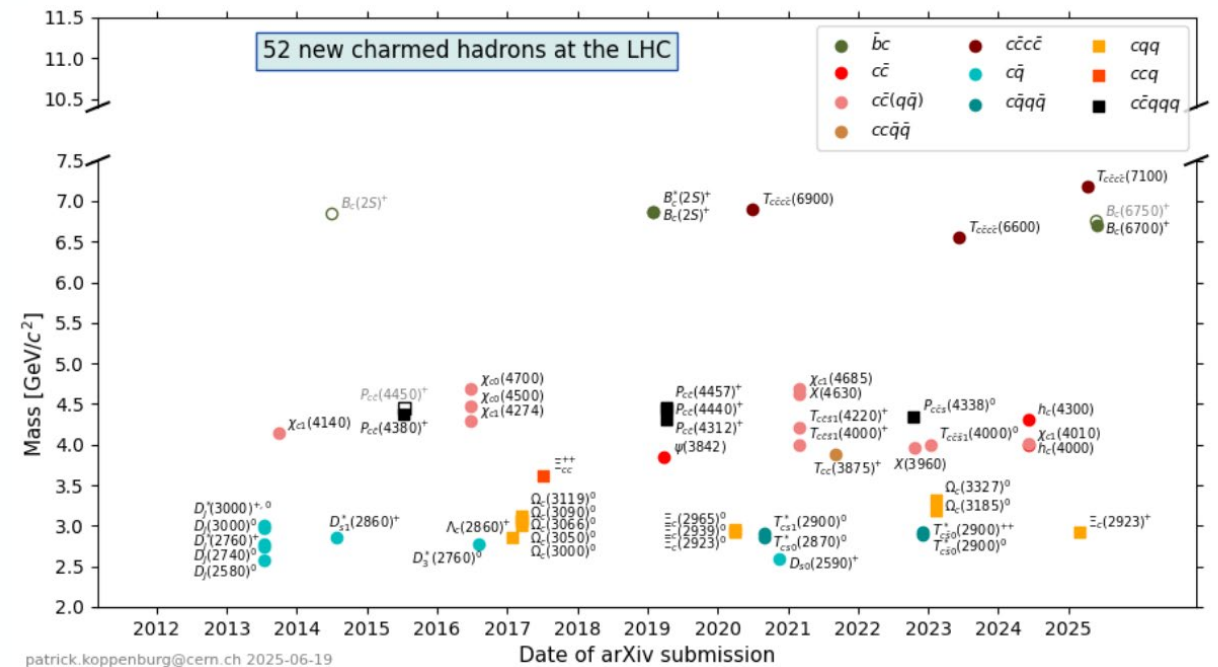
[\[Commun.Theor.Phys. 49 \(2008\) 993-1000...\]](#)

Summary

Summary

- A summary of recent study of conventional charmed baryons from LHCb
 - LHCb playing important roles in the region
 - Emerging connections between results from the same experiment
- More results from Run1&2 data
- Stay tuned with Run3 data!

<https://www.nikhef.nl/~pkoppenb/particles.html>



谢谢大家

Backup

First observation of SCS decays $\Omega_c^0 \rightarrow \Xi^- \pi^+$, $\Omega_c^0 \rightarrow \Omega^- K^+$

