Spectroscopy studies with B $\longrightarrow$ DDX decays at LHCb

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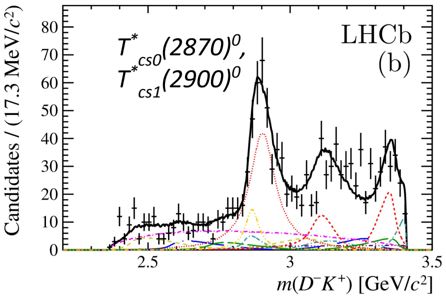
On behalf of the LHCb collaboration

$B \to DDX$ decays

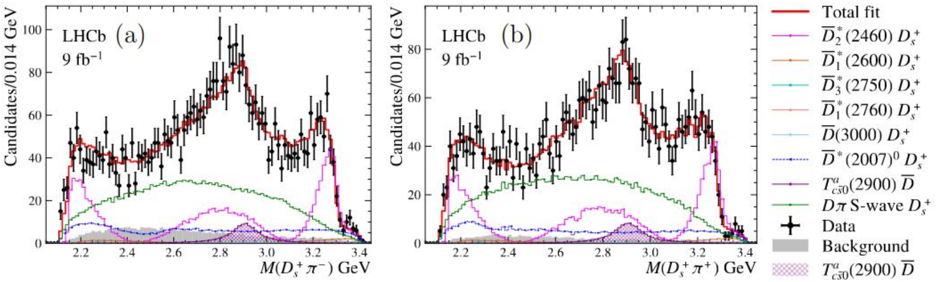
- Big family of topologically similar decays.
  - Final states containing two charmed hadrons
- Important for spectroscopy studies:
  - Excited charm (strange) mesons,
  - Charmonium spectrum,
  - Exotic states (tetraquarks, pentaquarks).
- Relevant results on mesonic exotic states:
  - $B^+ \to D^+D^-K^+$
    - Observation of two open-charmed structures in the D^-K^+ channel:
  - $B^0 \to D^0D_s^+\pi^-$, $B^+ \to D^-D_s^+\pi^+$
    - Observation of a pair of open-charmed states decaying to $D_s^+\pi^-$ and $D_s^+\pi^+$.



PRL 131, 041902
PRD 108, 012017

PRL 125, 242001
PRD 102, 112003

$T^*_{cs0}(2900)^0$ $T^*_{cs0}(2900)^{++}$



CONTENT

- Amplitude analysis and branching fraction measurement of $B^+ \to D^{*-} D_s^+ \pi^+$ decays.
  arXiv: 2405.0098 submitted to JHEP.

- Observation of new charmonium (-like) states in $B^+ \to D^{*\pm} D^\mp K^+$ decays.
  arXiv: 2406.03156 submitted to PRL.

- First observation of the $\Lambda_b \to D^+ D^- \Lambda$ decay.
  arXiv: 2403.03586 submitted to JHEP.

Amplitude analysis and branching fraction measurement of $B^+ \to D^{*-} D_s^+ \pi^+$ decays

arXiv: 2405.0098
submitted to JHEP

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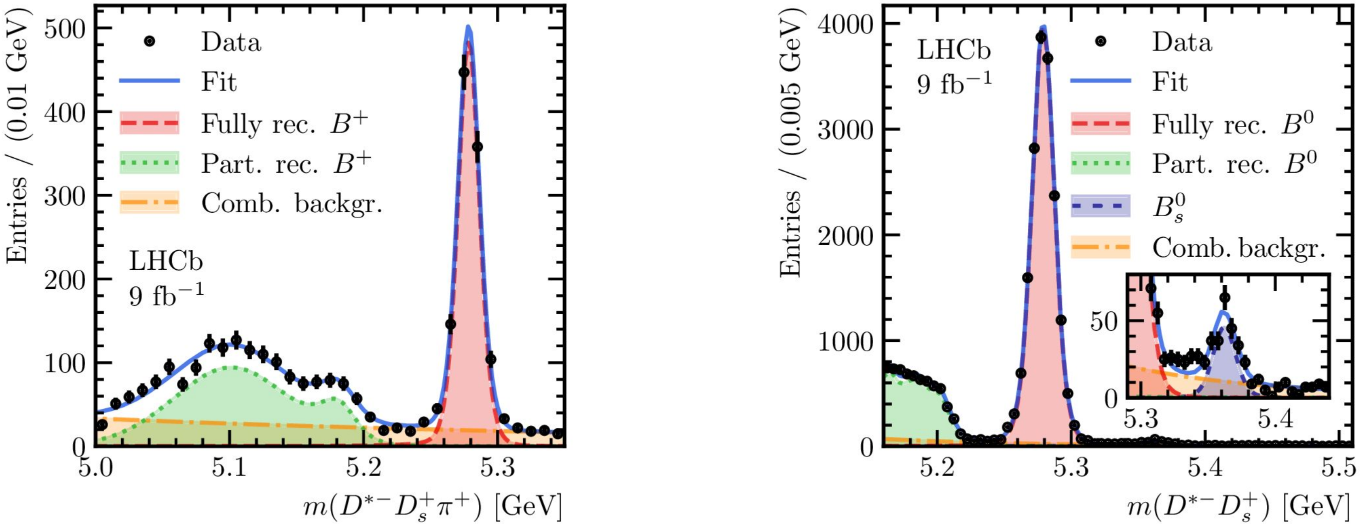
- Measured ratio of branching fractions:
  - with respect to $B^0 \to D^{*-} D_s^+$.

$$\mathcal{R} = \frac{\mathcal{B}(B^+ \to D^{*-} D_s^+ \pi^+)}{\mathcal{B}(B^0 \to D^{*-} D_s^+)} = 0.173 \pm 0.006 \pm 0.010,$$

- Observation of the $B^+ \to D^{*-} D_s^{*+} \pi^+$ decay
  - Using partially reconstructed $D_s^{*+} \to D_s^+ \gamma$ and $D_s^+ \pi^0$ decays

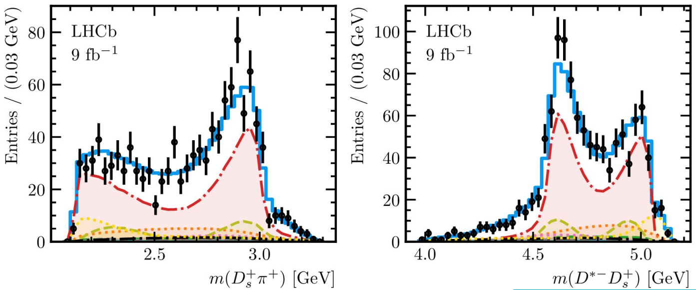
$$\mathcal{R}^* = \frac{\mathcal{B}(B^+ \to D^{*-} D_s^{*+} \pi^+)}{\mathcal{B}(B^+ \to D^{*-} D_s^+ \pi^+)} = 1.32 \pm 0.07 \pm 0.14.$$

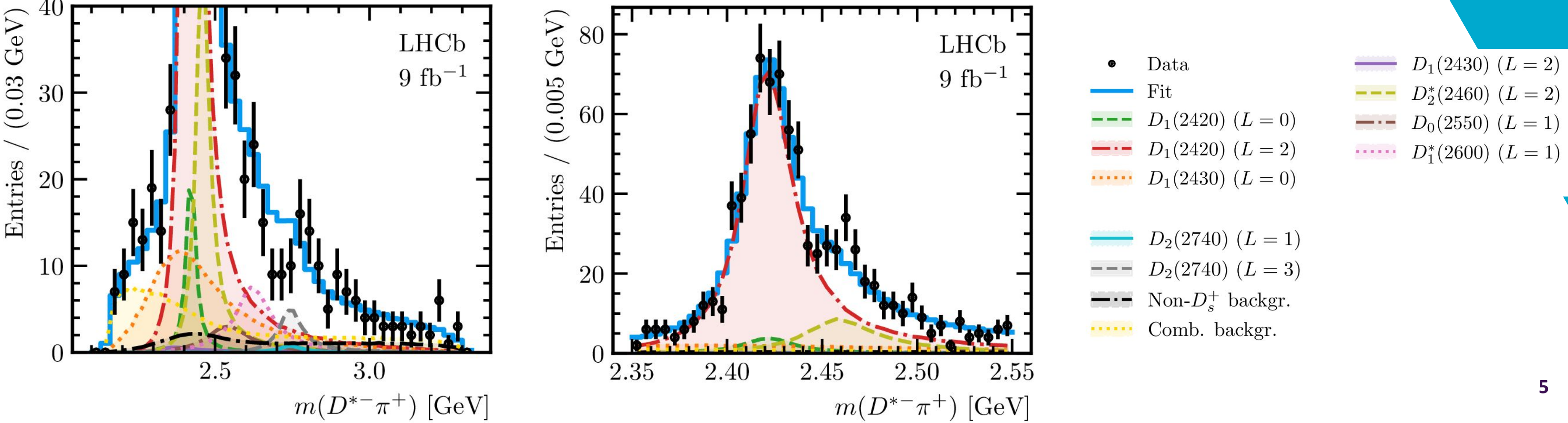


Amplitude analysis and branching fraction measurement of $B^+ \to D^{*-} D_s^+ \pi^+$ decays

arXiv: 2405.0098
submitted to JHEP

- First amplitude analysis of $B^+ \to D^{*-} D_s^+ \pi^+$ decays.
- Baseline fit exclusively incorporates activity in the $D^{*-}\pi^+$ channel.
- Amplitude dominated by
  - D$_1$(2420), D$_1$(2430), D$_2^*$(2460), D$_0$(2550), D$_1^*$(2600), D$_2$(2740).





Amplitude analysis and branching fraction measurement of $B^+ \to D^{*-} D_s^+ \pi^+$ decays

arXiv: 2405.0098
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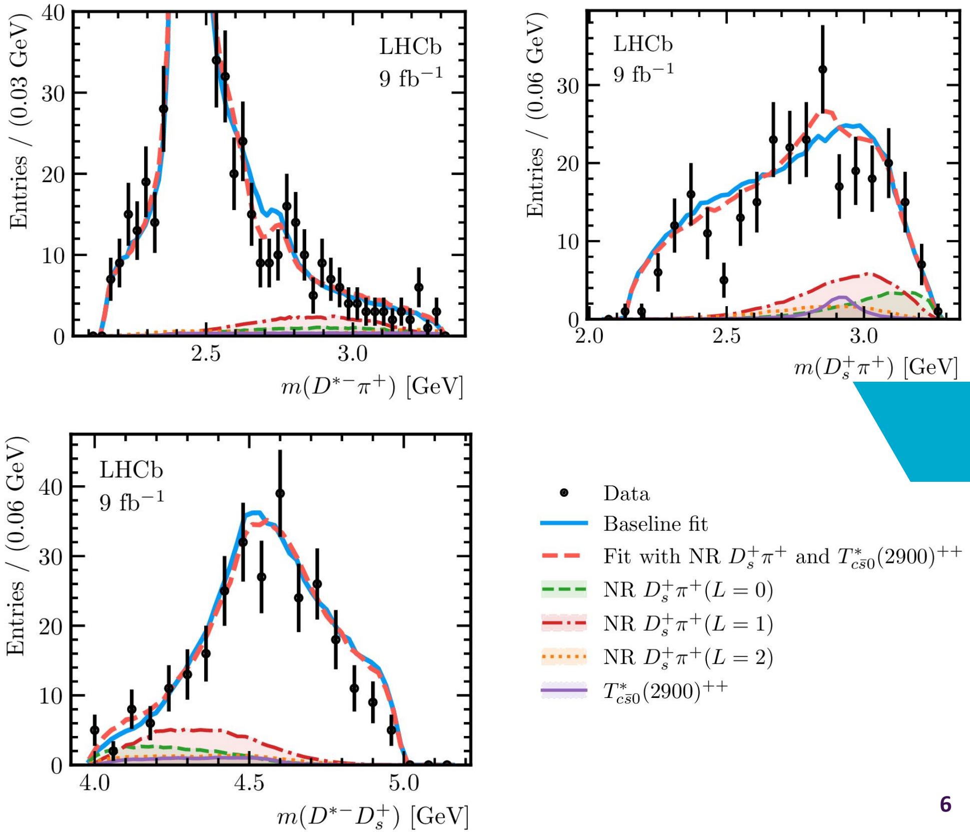
- Examined **alternative** fits incorporating $\boldsymbol{D_s^+\pi^+}$ amplitudes.
- Motivated by the discovery of $T^*_{c\bar{s}0}(2900)^{++}$ in $B^+ \to D^- D_s^+ \pi^+$.
- No evidence of a scalar $D_s^+ \pi^+$ state with parameters fixed to those of $T^*_{c\bar{s}0}(2900)^{++}$,
- Upper limit on its fit fraction:

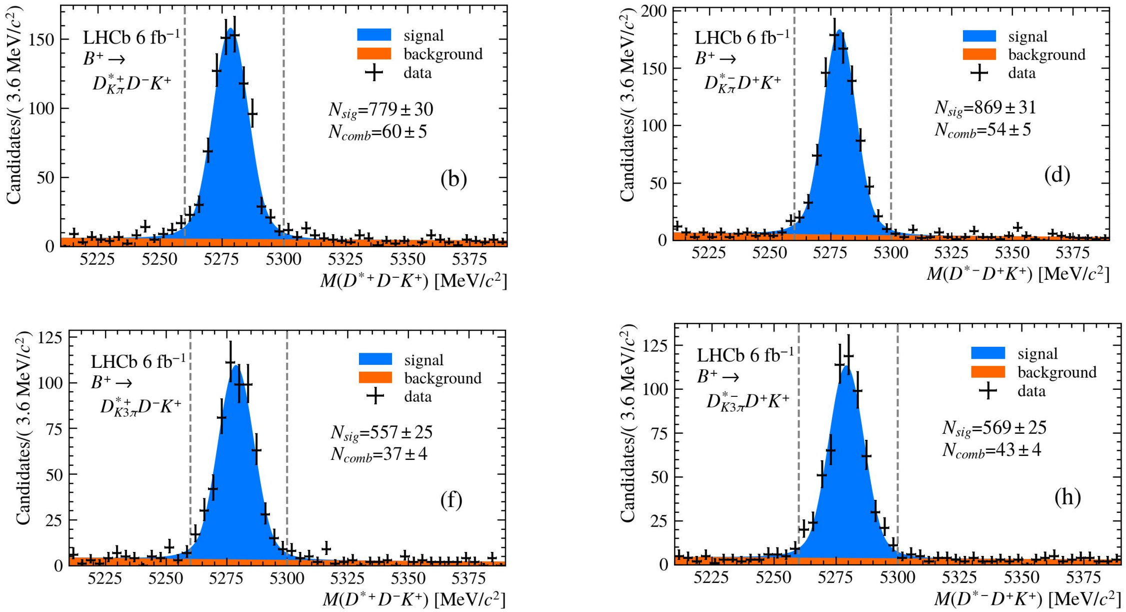
  < 2.3% at 90% CL



Observation of new charmonium(-like) states in $B^+ \to D^{*\pm} D^{\mp} K^+$ decays

arXiv: 2406.03156
submitted to PRL

- Simultaneous analysis of the $B^+ \to D^{*+} D^- K^+$ and $B^+ \to D^{*-} D^+ K^+$ decays.
- Decay amplitudes for $B^+ \to R(D^{*+} D^-) K^+$ and $B^+ \to R(D^{*-} D^+) K^+$ linked by *C*-parity.
  - Allows determination of the C-parities of the *R* resonances.



Observation of new charmonium(-like) states in $B^+ \to D^{*\pm} D^{\mp} K^+$ decays

arXiv: 2406.03156
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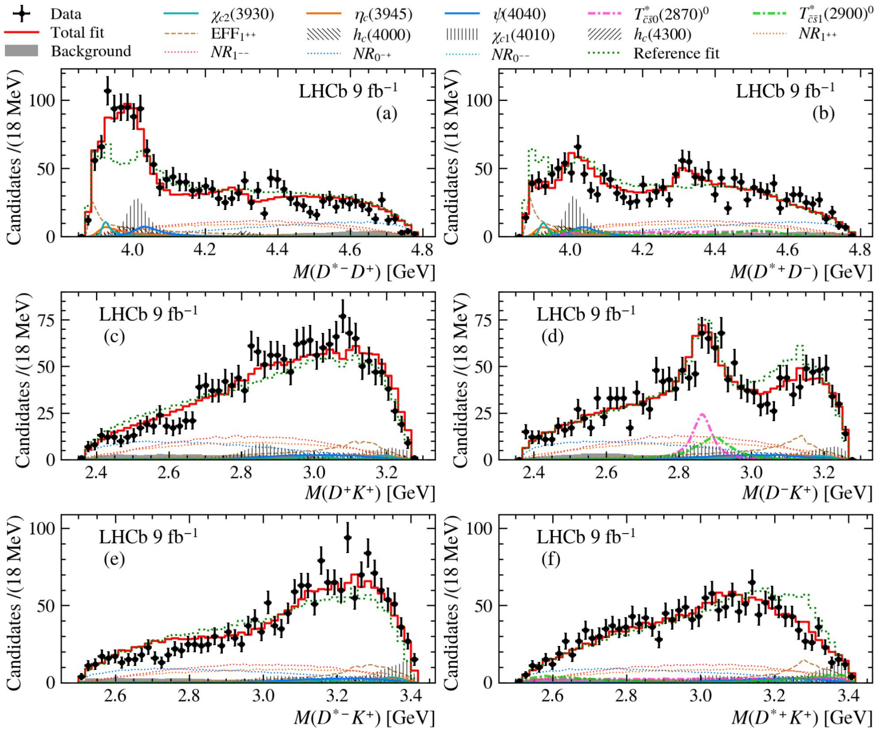
- Multiple contributions needed in the $\boldsymbol{D^{*\pm} D^{\mp}}$ spectrum to describe the data:
  - Four non-resonant: 1^{--}, 0^{--}, 1^{--}, 0^{--},
  - $\chi_{c2}(3930)$, $\psi(4040)$ with fixed parameters.
  - $\eta_c(3945)$, $\boldsymbol{h_c(4000)}$, $\boldsymbol{\chi_c(4010)}$ **and** $\boldsymbol{h_c(4300)}$, with statistical significances of 10σ, 9.1σ, 16σ and 6.4σ.
- Fit includes the $\boldsymbol{T^*_{cs0}(2870)^0}$, $\boldsymbol{T^*_{cs1}(2900)^0}$ states, first found in $\boldsymbol{B^+ \to D^+ D^- K^+}$ decays
  - Statistical significances of 11σ, 9.2σ, respectively,
  - confirming their existence in a new decay.



Observation of new charmonium(-like) states in $B^+ \to D^{*\pm} D^{\mp} K^+$ decays

arXiv: 2406.03156
submitted to PRL

- $J^P = 1^+$ states are the main contribution in the $D^{*\pm} D^{\mp}$ mass spectrum.
- Interferences due to different C-parities results in different patterns in M($D^{*+} D^-$) and M($D^{*-} D^+$).
- J^{PC} values for $\eta_c(3945)$, $h_c(4000)$, $\chi_c(4010)$ and $h_c(4300)$
  - 0^{-+}, 1^{+-}, 1^{++}, 1^{+-},

This work		Known states [6]		$c\bar{c}$ prediction [34]	
$\eta_c(3945)$	$J^{PC} = 0^{-+}$	$X(3940)$ [9,10]	$J^{PC} = ?^{??}$	$\eta_c(3S)$	$J^{PC} = 0^{-+}$
$m_0 = 3945\,^{+28}_{-17}\,^{+37}_{-28}$	$\Gamma_0 = 130\,^{+92}_{-49}\,^{+101}_{-70}$	$m_0 = 3942 \pm 9$	$\Gamma_0 = 37\,^{+27}_{-17}$	$m_0 = 4064$	$\Gamma_0 = 80$
$h_c(4000)$	$J^{PC} = 1^{+-}$	$T_{c\bar{c}}(4020)^0$ [35]	$J^{PC} = ?^{?-}$	$h_c(2P)$	$J^{PC} = 1^{+-}$
$m_0 = 4000\,^{+17}_{-14}\,^{+29}_{-22}$	$\Gamma_0 = 184\,^{+71}_{-45}\,^{+97}_{-61}$	$m_0 = 4025.5\,^{+2.0}_{-4.7} \pm 3.1$	$\Gamma_0 = 23.0 \pm 6.0 \pm 1.0$	$m_0 = 3956$	$\Gamma_0 = 87$
$\chi_{c1}(4010)$	$J^{PC} = 1^{++}$			$\chi_{c1}(2P)$	$J^{PC} = 1^{++}$
$m_0 = 4012.5\,^{+3.6}_{-3.9}\,^{+4.1}_{-3.7}$	$\Gamma_0 = 62.7\,^{+7.0}_{-6.4}\,^{+6.4}_{-6.6}$			$m_0 = 3953$	$\Gamma_0 = 165$
$h_c(4300)$	$J^{PC} = 1^{+-}$			$h_c(3P)$	$J^{PC} = 1^{+-}$
$m_0 = 4307.3\,^{+6.4}_{-6.6}\,^{+3.3}_{-4.1}$	$\Gamma_0 = 58\,^{+28}_{-16}\,^{+28}_{-25}$			$m_0 = 4318$	$\Gamma_0 = 75$
		$\chi_c(4274)$ [36]	$J^{PC} = 1^{++}$	$\chi_{c1}(3P)$	$J^{PC} = 1^{++}$
		$m_0 = 4294 \pm 4\,^{+6}_{-3}$	$\Gamma_0 = 53 \pm 5 \pm 5$	$m_0 = 4317$	$\Gamma_0 = 39$

[9] PRL 98, 082001
[10] PRL 100, 202001
[34] PRD 72, 054026
[35] PRL 115, 182002
[36] PRL 127, 082001

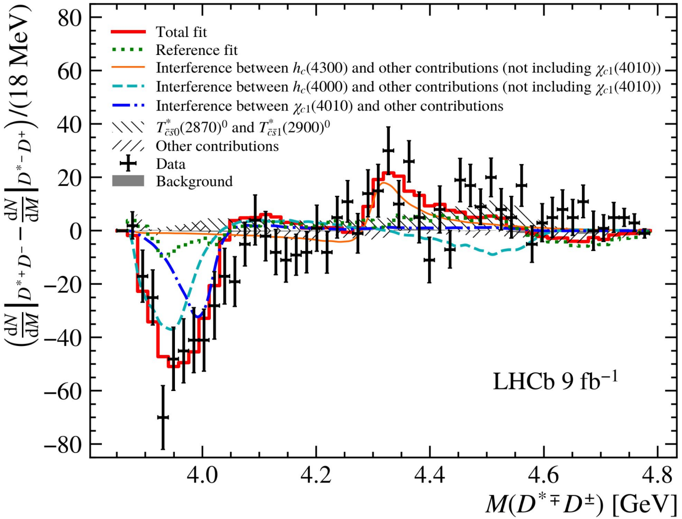


Figure 3: Difference between the $M(D^*D)$ distributions of the $B^+ \to D^{*+}D^-K^+$ and $B^+ \to D^{*-}D^+K^+$ decays. Only interference between states with the same J^P but different C-parities, and reflections from $T^{*0}_{c\bar{s}0,1}$ resonances, have significant contributions. The reference fit where $h_c(4000)$, $\chi_{c1}(4010)$ and $h_c(4300)$ are not included is shown as green-dotted line.

Observation of the $\Lambda_b \to D^+ D^- \Lambda$ decay

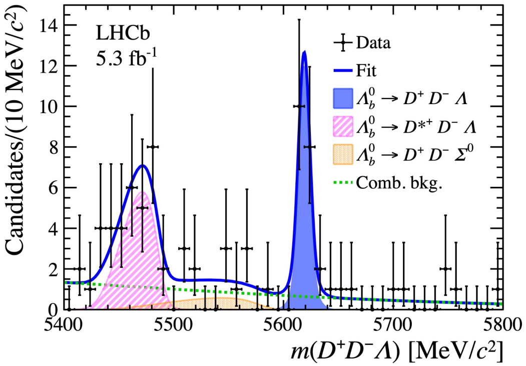
arXiv: 2403.03586
submitted to JHEP

- Branching fraction measured relative to $B^0 \to D^+ D^- K_s^0$.
- $\Lambda_b \to D^{*+} D^- \Lambda$ decay also observed as a partially reconstructed component.
- Indications of various intermediate resonances in $\Lambda_b \to D^+ D^- \Lambda$
  - Future exploration with larger statistics,
  - or similar decay channels like $\Lambda_b \to D^{\bar{0}} D^0 \Lambda$

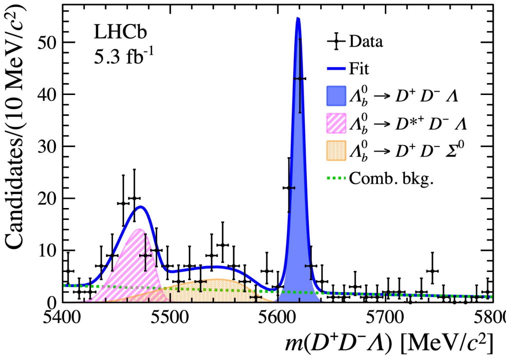
$$\mathcal{R} = \frac{\sigma_{\Lambda_b^0}}{\sigma_{B^0}} \times \frac{\mathcal{B}(\Lambda_b^0 \to D^+ D^- \Lambda)}{\mathcal{B}(B^0 \to D^+ D^- K_S^0)} = 0.179 \pm 0.022 \pm 0.014,$$

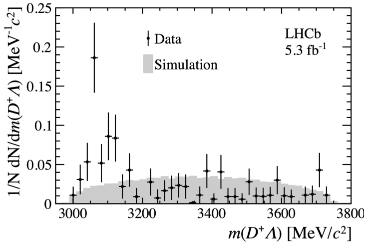
$$\mathcal{B}(\Lambda_b^0 \to D^+ D^- \Lambda) = (1.24 \pm 0.15 \pm 0.10 \pm 0.28 \pm 0.11) \times 10^{-4},$$

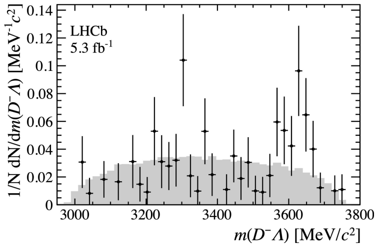
Λ decays inside velo

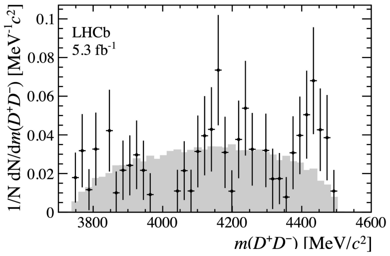


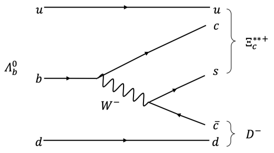
Λ decays outside velo

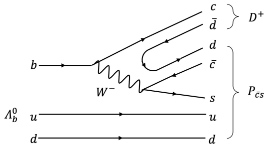


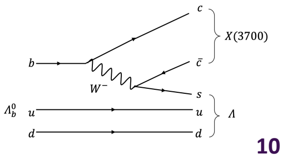












Summary

- Presented latest spectroscopy results from ***B*** $\longrightarrow$ ***DDX*** decays at LHCb.
  - First amplitude analysis of $B^+ \longrightarrow D^{*-} D_s^{*+} \pi^+$.
  - New charmonium(-like) states observed in $B^+ \longrightarrow D^{*\pm} D^{\mp} K^+$.
  - Confirmation of $T^*_{cs0}(2870)^0$, $T^*_{cs1}(2900)^0$ states, previously observed in $B^+ \longrightarrow D^+ D^- K^+$.
- Results presented based on Run 1 and Run 2 datasets.
  - Still more to come.
- Currently collecting Run 3 datasets.
  - Full software trigger will increase efficiency by about a factor 2.
  - Expecting high statistics and unprecedented production of heavy hadrons.

BACKUP SLIDES

Amplitude analysis of $B^+ \to D^{*-} D_s^+ \pi^+$ decays

arXiv: 2405.0098
submitted to JHEP

- 4D phase space: $\mathcal{A}(m^2(D^{*-}\pi^+), m^2(D_s^+\pi^+), \theta_D, \phi_D)$

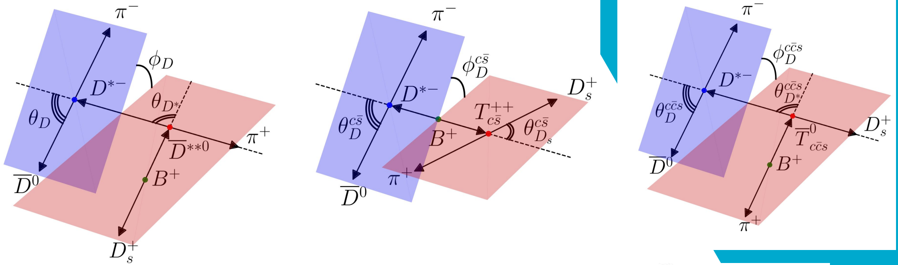
$$\mathcal{A} = \mathcal{A}^{(D^*\pi)} + \mathcal{A}^{(D_s\pi)} + \mathcal{A}^{(D^*D_s)}.$$

$$\mathcal{A}^{(\mathrm{ch})} = \sum_n \mathcal{A}_n^{(\mathrm{ch})} = \sum_n \mathcal{R}_n^{(\mathrm{ch})}\mathcal{H}_n^{(\mathrm{ch})}.$$

$$\mathcal{H}_n^{(D^*\pi)} = \sum_{\lambda=0,\pm1} h_{n,\lambda}^{(D^*\pi)}\, d_{0,\lambda}^{J_n}(\theta_{D^*})\; d_{\lambda,0}^{1}(\theta_D)\; \exp(i\lambda\phi_D),$$

$$\mathcal{H}_n^{(D_s\pi)} = \sum_{\lambda=0,\pm1} h_{n,\lambda}^{(D_s\pi)}\, d_{\lambda,0}^{J_n}(\theta_{D_s}^{c\bar{s}})\; d_{\lambda,0}^{1}(\theta_D^{c\bar{s}})\; \exp(i\lambda\phi_D^{c\bar{s}}),$$

$$\mathcal{H}_n^{(D^*D_s)} = \sum_{\lambda=0,\pm1} h_{n,\lambda}^{(D^*D_s)}\, d_{0,\lambda}^{J_n}(\theta_{D^*}^{c\bar{c}s})\; d_{\lambda,0}^{1}(\theta_D^{c\bar{c}s})\; \exp(i\lambda\phi_D^{c\bar{c}s}).$$



$B^+ \to \overline{D}^{**0}(\to D^{*-}\pi^+)D_s^+$

J^P	L_R	Angular term
0^-	1	$-\cos\theta_D$
1^-	1	$\frac{i}{\sqrt{2}}\sin\theta_{D^*}\sin\theta_D\sin\phi_D$
1^+	0	$\frac{1}{\sqrt{3}}(\cos\theta_{D^*}\cos\theta_D - \sin\theta_{D^*}\sin\theta_D\cos\phi_D)$
	2	$-\frac{1}{\sqrt{6}}(2\cos\theta_{D^*}\cos\theta_D + \sin\theta_{D^*}\sin\theta_D\cos\phi_D)$
2^-	1	$\frac{1}{\sqrt{10}}(-3\sin\theta_{D^*}\cos\theta_{D^*}\sin\theta_D\cos\phi_D - 3\sin^2\theta_{D^*}\cos\theta_D + 2\cos\theta_D)$
	3	$\frac{\sqrt{15}}{10}(-2\sin\theta_{D^*}\cos\theta_{D^*}\sin\theta_D\cos\phi_D + 3\sin^2\theta_{D^*}\cos\theta_D - 2\cos\theta_D)$
2^+	2	$\frac{i\sqrt{6}}{2}\sin\theta_{D^*}\cos\theta_{D^*}\sin\theta_D\sin\phi_D$

$B^+ \to D^{*-}T_{c\bar{s}}^{++}(\to D_s^+\pi^+)$

J^P	L_B	Angular term
0^+	1	$-\cos\theta_D^{c\bar{s}}$
1^-	0	$-\frac{1}{\sqrt{3}}(\cos\theta_{D_s}^{c\bar{s}}\cos\theta_D^{c\bar{s}} - \sin\theta_{D_s}^{c\bar{s}}\sin\theta_D^{c\bar{s}}\cos\phi_D^{c\bar{s}})$
	1	$-\frac{i}{\sqrt{2}}\sin\theta_{D_s}^{c\bar{s}}\sin\theta_D^{c\bar{s}}\sin\phi_D^{c\bar{s}}$
	2	$\frac{1}{\sqrt{6}}(2\cos\theta_{D_s}^{c\bar{s}}\cos\theta_D^{c\bar{s}} + \sin\theta_{D_s}^{c\bar{s}}\sin\theta_D^{c\bar{s}}\cos\phi_D^{c\bar{s}})$
2^+	1	$\frac{1}{\sqrt{10}}(-3\sin\theta_{D_s}^{c\bar{s}}\cos\theta_{D_s}^{c\bar{s}}\sin\theta_D^{c\bar{s}}\cos\phi_D^{c\bar{s}} - 3\sin^2\theta_{D_s}^{c\bar{s}}\cos\theta_D^{c\bar{s}} + 2\cos\theta_D^{c\bar{s}})$
	2	$\frac{i\sqrt{6}}{2}\sin\theta_{D_s}^{c\bar{s}}\cos\theta_{D_s}^{c\bar{s}}\sin\theta_D^{c\bar{s}}\sin\phi_D^{c\bar{s}}$
	3	$\frac{\sqrt{15}}{10}(-2\sin\theta_{D_s}^{c\bar{s}}\cos\theta_{D_s}^{c\bar{s}}\sin\theta_D^{c\bar{s}}\cos\phi_D^{c\bar{s}} + 3\sin^2\theta_{D_s}^{c\bar{s}}\cos\theta_D^{c\bar{s}} - 2\cos\theta_D^{c\bar{s}})$

Amplitude analysis of $B^+ \to D^{*-} D_s^+ \pi^+$ decays

arXiv: 2405.0098
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- Fit Fractions and phases.

Component	Fit fraction [%]	Phase [rad]
$D_1(2420)$ S-wave	$3.8 \pm 1.7 \pm 0.8^{+1.3}_{-0.1}$	$-1.96 \pm 0.16 \pm 0.10^{+0.17}_{-0.05}$
$D_1(2420)$ D-wave	$71.0 \pm 4.4 \pm 4.6^{+0.0}_{-6.0}$	0 (fixed)
$D_1(2430)$ S-wave	$14.2 \pm 2.5 \pm 2.4^{+3.1}_{-2.0}$	$+0.14 \pm 0.11 \pm 0.13^{+0.06}_{-0.18}$
$D_1(2430)$ D-wave	$0.5 \pm 0.9 \pm 1.5^{+0.2}_{-0.5}$	$-2.99 \pm 0.42 \pm 0.84^{+0.23}_{-0.55}$
$D_2^*(2460)$	$11.7 \pm 1.4 \pm 0.8^{+0.0}_{-0.7}$	$+3.14 \pm 0.11 \pm 0.14^{+0.05}_{-0.04}$
$D_0(2550)$	$2.3 \pm 0.8 \pm 0.7^{+0.3}_{-1.7}$	$-2.24 \pm 0.21 \pm 0.26^{+0.05}_{-0.25}$
$D_1^*(2600)$	$4.8 \pm 1.0 \pm 0.9^{+1.1}_{-2.0}$	$+0.32 \pm 0.16 \pm 0.16^{+0.37}_{-0.01}$
$D_2(2740)$ P-wave	$0.4 \pm 0.4 \pm 0.2^{+0.1}_{-0.1}$	$-0.02 \pm 0.56 \pm 0.32^{+0.16}_{-0.59}$
$D_2(2740)$ F-wave	$2.3 \pm 0.7 \pm 0.9^{+0.4}_{-0.1}$	$-0.09 \pm 0.27 \pm 0.21^{+0.08}_{-0.23}$
Sum of fit fractions	$111.0 \pm 5.2 \pm 4.2$	

Amplitude analysis of $B^+ \to D^{*\pm} D^{\mp} K^+$ decays

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submitted to PRL

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- Amplitudes for $B^+ \to R(D^{*+} D^-) K^+$ and $B^+ \to R(D^{*-} D^+) K^+$ linked by *C*-parity.
- Total amplitude: coherent sum of resonant and non-resonant components in all channels.

$$\mathcal{A}(x) = \frac{1+d}{2}\left\{\sum_{j\in R(D^{*\pm}D^{\mp})} c_j A_j(x) + \sum_{k\in R(D^{*-}K^+,\ D^+K^+)} c_k A_k(x)\right\} + \frac{1-d}{2}\left\{\sum_{j\in R(D^{*\pm}D^{\mp})} C_j \times c_j A_j(x) + \sum_{l\in R(D^{*+}K^+,\ D^-K^+)} c_l A_l(x)\right\},$$

- Both S-wave and D-wave amplitudes contribute significantly to $R \to D^{*\pm} D^{\mp}$ decays for $J^P = 1^+$.
- Line shapes for these partial waves:

$$f_{R,S/D}(m) = \frac{\gamma_{S/D}}{m_0^2 - m^2 - i m_0[\gamma_S^2 \Gamma_S(m) + \gamma_D^2 \Gamma_D(m)]},$$

Amplitude analysis of $B^+ \to D^{*-} D_s^+ \pi^+$ decays

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Table 1: Resonant and nonresonant components included in the baseline fit and their spin parities, fit fractions and product branching fractions ($\mathcal{B}(B^+ \to RC) \times \mathcal{B}(R \to AB)$), where A, B, C are the three final-state particles. To obtain the branching fractions including both $R \to D^{*+}D^-$ and $R \to D^{*-}D^+$, the values in the table should be multiplied by a factor of two. The first uncertainties are statistical, estimated with a bootstrap method [32], the second are systematic and and the third are from the uncertainty of the $B^+ \to D^{*+}D^-K^+$ branching fraction. The masses and widths of the resonances marked with the † symbol are fixed to their PDG values [6].

Component	$J^{P(C)}$	Fit fraction [%] $B^+ \to D^{*+}D^-K^+$	Fit fraction [%] $B^+ \to D^{*-}D^+K^+$	Branching fraction $[10^{-4}]$
$\mathrm{EFF}_{1^{++}}$	1^{++}	$10.9\,^{+2.3}_{-1.2}\,^{+1.6}_{-2.1}$	$9.9\,^{+2.1}_{-1.0}\,^{+1.4}_{-1.9}$	$0.74\,^{+0.16}_{-0.08}\,^{+0.11}_{-0.14} \pm 0.07$
$\eta_c(3945)$	0^{-+}	$3.4\,^{+0.5}_{-1.0}\,^{+1.9}_{-0.7}$	$3.1\,^{+0.5}_{-0.9}\,^{+1.7}_{-0.6}$	$0.23\,^{+0.04}_{-0.07}\,^{+0.13}_{-0.05} \pm 0.02$
$\chi_{c2}(3930)^\dagger$	2^{++}	$1.8\,^{+0.5}_{-0.4}\,^{+0.6}_{-1.2}$	$1.7\,^{+0.5}_{-0.4}\,^{+0.6}_{-1.1}$	$0.12\,^{+0.03}_{-0.03}\,^{+0.04}_{-0.08} \pm 0.01$
$h_c(4000)$	1^{+-}	$5.1\,^{+1.0}_{-0.8}\,^{+1.5}_{-0.8}$	$4.6\,^{+0.9}_{-0.7}\,^{+1.4}_{-0.7}$	$0.35\,^{+0.07}_{-0.05}\,^{+0.10}_{-0.05} \pm 0.03$
$\chi_{c1}(4010)$	1^{++}	$10.1\,^{+1.6}_{-0.9}\,^{+1.3}_{-1.6}$	$9.1\,^{+1.4}_{-0.8}\,^{+1.2}_{-1.4}$	$0.69\,^{+0.11}_{-0.06}\,^{+0.09}_{-0.11} \pm 0.06$
$\psi(4040)^\dagger$	1^{--}	$2.8\,^{+0.5}_{-0.4}\,^{+0.5}_{-0.5}$	$2.6\,^{+0.5}_{-0.4}\,^{+0.4}_{-0.5}$	$0.19\,^{+0.04}_{-0.03}\,^{+0.03}_{-0.03} \pm 0.02$
$h_c(4300)$	1^{+-}	$1.2\,^{+0.2}_{-0.5}\,^{+0.2}_{-0.2}$	$1.1\,^{+0.2}_{-0.5}\,^{+0.2}_{-0.2}$	$0.08\,^{+0.01}_{-0.03}\,^{+0.02}_{-0.01} \pm 0.01$
$T^*_{\bar{c}s0}(2870)^{0\,\dagger}$	0^+	$6.5\,^{+0.9}_{-1.2}\,^{+1.3}_{-1.6}$	–	$0.45\,^{+0.06}_{-0.08}\,^{+0.09}_{-0.10} \pm 0.04$
$T^*_{\bar{c}s1}(2900)^{0\,\dagger}$	1^-	$5.5\,^{+1.1}_{-1.5}\,^{+2.4}_{-1.6}$	–	$0.38\,^{+0.07}_{-0.10}\,^{+0.16}_{-0.11} \pm 0.03$
$\mathrm{NR}_{1^{--}}(D^{*\mp}D^\pm)$	1^{--}	$20.4\,^{+2.3}_{-0.6}\,^{+2.1}_{-2.6}$	$18.5\,^{+2.1}_{-0.5}\,^{+1.9}_{-2.3}$	$1.39\,^{+0.16}_{-0.04}\,^{+0.14}_{-0.17} \pm 0.12$
$\mathrm{NR}_{0^{--}}(D^{*\mp}D^\pm)$	0^{--}	$1.2\,^{+0.6}_{-0.1}\,^{+0.7}_{-0.6}$	$1.1\,^{+0.6}_{-0.1}\,^{+0.6}_{-0.5}$	$0.08\,^{+0.04}_{-0.01}\,^{+0.05}_{-0.04} \pm 0.01$
$\mathrm{NR}_{1^{++}}(D^{*\mp}D^\pm)$	1^{++}	$17.8\,^{+1.9}_{-1.4}\,^{+3.6}_{-2.6}$	$16.1\,^{+1.7}_{-1.3}\,^{+3.3}_{-2.3}$	$1.21\,^{+0.13}_{-0.10}\,^{+0.24}_{-0.17} \pm 0.11$
$\mathrm{NR}_{0^{-+}}(D^{*\mp}D^\pm)$	0^{-+}	$15.9\,^{+3.3}_{-1.2}\,^{+3.3}_{-3.3}$	$14.5\,^{+3.0}_{-1.1}\,^{+3.0}_{-3.0}$	$1.09\,^{+0.23}_{-0.08}\,^{+0.22}_{-0.23} \pm 0.09$

Amplitude analysis of $B^+ \to D^{*-} D_s^+ \pi^+$ decays

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Table 2: Comparison of the $T^{*0}_{\bar{c}\bar{s}0,1}$ properties obtained in this work to those found previously in $B^+ \to D^+ D^- K^+$ decays [2]. In the branching fractions determined in this work, the $T^{*0}_{\bar{c}\bar{s}0,1}$ masses and widths are fixed to the previously measured values [2].

Property	This work	Previous work
$T^*_{\bar{c}\bar{s}0}(2870)^0$ mass [MeV]	$2914 \pm 11 \pm 15$	2866 ± 7
$T^*_{\bar{c}\bar{s}0}(2870)^0$ width [MeV]	$128 \pm 22 \pm 23$	57 ± 13
$T^*_{\bar{c}\bar{s}1}(2900)^0$ mass [MeV]	$2887 \pm 8 \pm 6$	2904 ± 5
$T^*_{\bar{c}\bar{s}1}(2900)^0$ width [MeV]	$92 \pm 16 \pm 16$	110 ± 12
$\mathcal{B}(B^+ \to T^*_{\bar{c}\bar{s}0}(2870)^0 D^{(*)+})$	$(4.5\,^{+0.6}_{-0.8}\,^{+0.9}_{-1.0} \pm 0.4) \times 10^{-5}$	$(1.2 \pm 0.5) \times 10^{-5}$
$\mathcal{B}(B^+ \to T^*_{\bar{c}\bar{s}1}(2900)^0 D^{(*)+})$	$(3.8\,^{+0.7}_{-1.0}\,^{+1.6}_{-1.1} \pm 0.3) \times 10^{-5}$	$(6.7 \pm 2.3) \times 10^{-5}$
$\frac{\mathcal{B}(B^+ \to T^*_{\bar{c}\bar{s}0}(2870)^0 D^{(*)+})}{\mathcal{B}(B^+ \to T^*_{\bar{c}\bar{s}1}(2900)^0 D^{(*)+})}$	$1.17 \pm 0.31 \pm 0.48$	0.18 ± 0.05