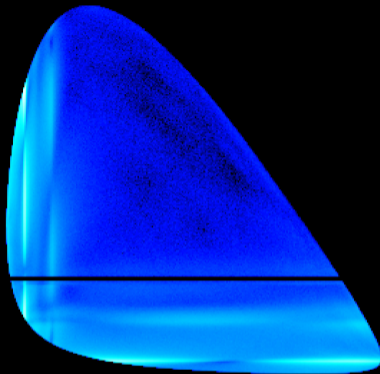


Heavy flavour spectroscopy at LHCb

Daniel Craik

on behalf of
the LHCb collaboration

2024-09-11



Universität
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Outline

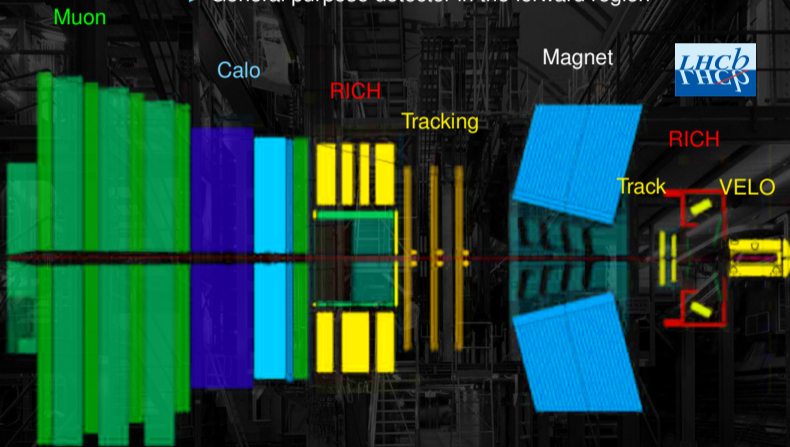
- ▶ Recent results in b -baryon spectroscopy
- ▶ Recent results in c -meson spectroscopy

The LHCb detector

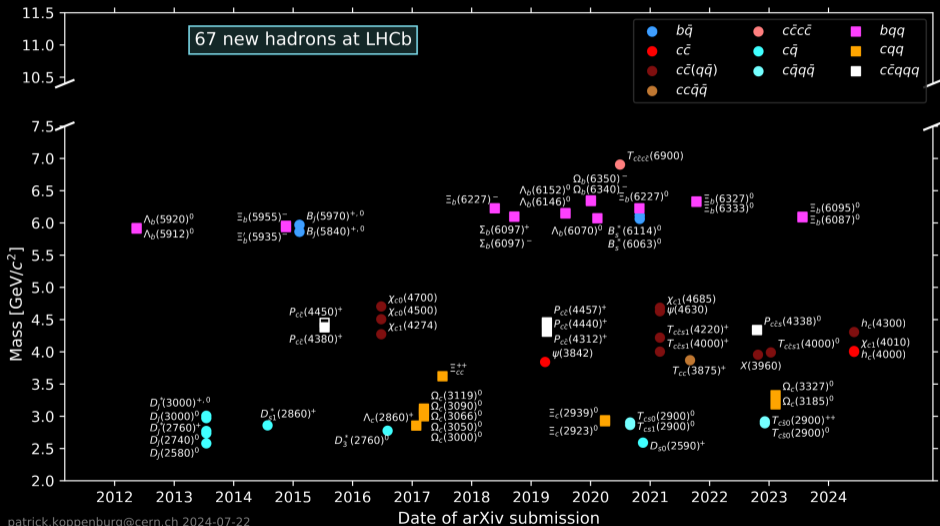


The LHCb detector

- ▶ Precise **vertexing** and **charged particle ID** information
- ▶ General purpose detector in the forward region

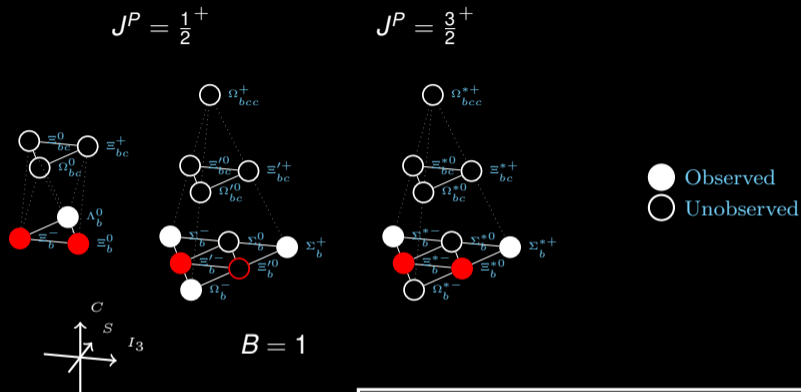


Hadron spectroscopy at LHCb

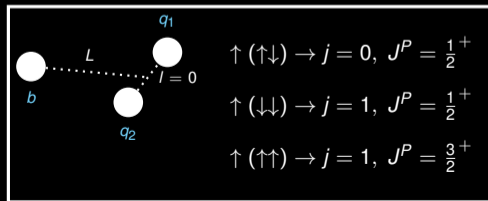


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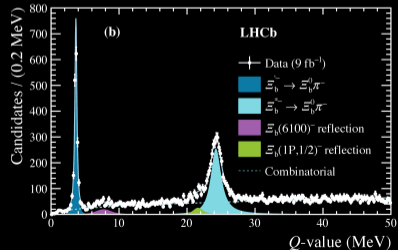
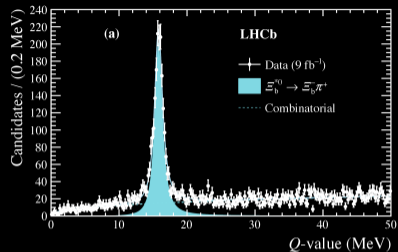
Baryon spectroscopy: meet the beauty baryons

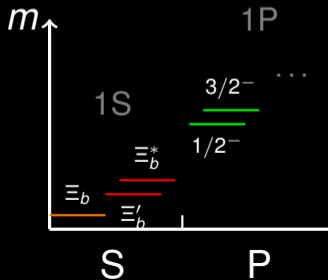
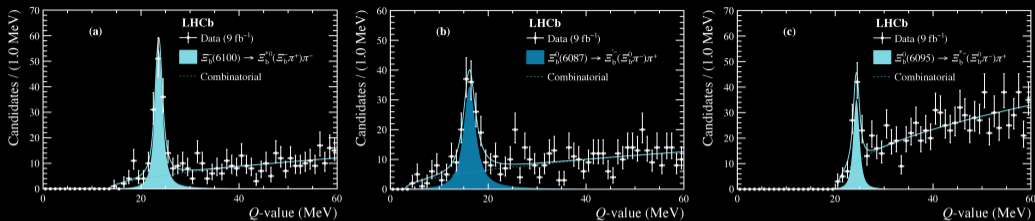


- ▶ Baryons provide a rich zoo of states to study
- ▶ Most singly-heavy $L = 0$ states observed
- ▶ Focus on recent LHCb study of $\Xi_b^{-(0)}$ states
- ▶ Isospin doublets with quark content bsq



- ▶ Study feed-down decays of promptly produced excited states
- ▶ Ξ_b reconstructed from $\Xi_c \pi^-$ and $\Xi_c \pi^- \pi^+ \pi^-$
- ▶ Clear signals from (top) Ξ_b^{*0} , (bottom) $\Xi_b^{\prime-}$ and Ξ_b^{*-} in $\Xi_b \pi$ combinations
- ▶ Unobserved $\Xi_b^{\prime0}$ likely below $\Xi_b^- \pi^+$ threshold
- ▶ Masses and widths measured to high precision



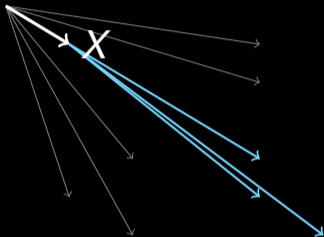


- ▶ Significant signals observed when combining each $\Xi_b \pi$ resonance with an additional pion
- ▶ $\Xi_b^-(6100)$ confirmed with 12σ significance
- ▶ $\Xi_b^0(6087)$ and $\Xi_b^0(6095)$ observed for first time with 10σ and 8σ significance, respectively
- ▶ Quantum numbers, $j J^P$, unknown but likely two of the $1P$ excited states

Amplitude analysis

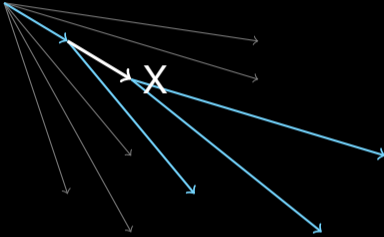
Prompt production

PV



from b

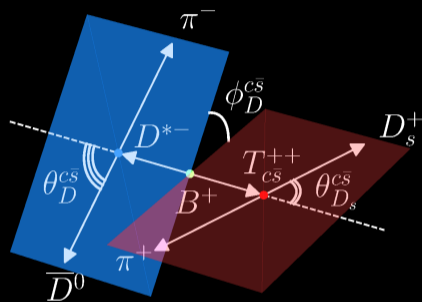
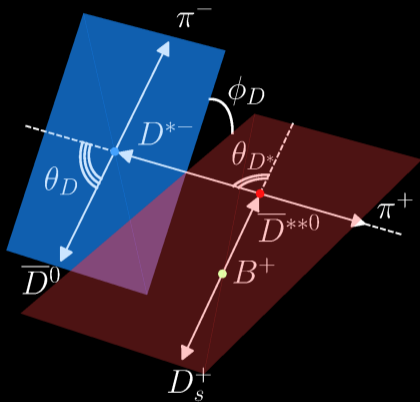
PV



- ▶ Resonant production of states in b -decays gives knowledge of both production and decay
- ▶ Determine J^P quantum numbers in addition to mass, width and decay mode
- ▶ Describe phasepace of b -decay with a coherent sum of amplitudes corresponding to different resonant and non-resonant decay pathways
- ▶ Also exploit interference between different contributions

$$B^+ \rightarrow D^{*-} D_s^+ \pi^+$$

arXiv:2405.00098 (Submitted to JHEP)



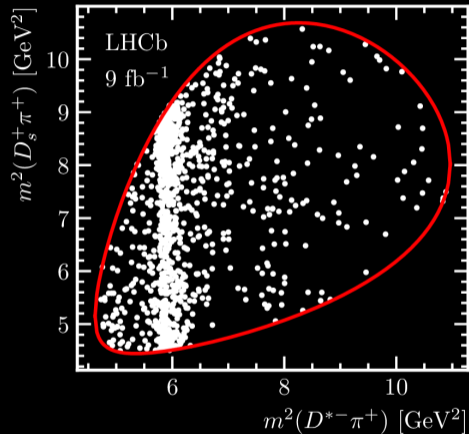
► Conventional c -meson resonances expected in $D^{*-} \pi^+$

► Additionally sensitive to exotic $T_{c\bar{s}}^{++}$ and $\bar{T}_{c\bar{s}}^0$ contributions

$$B^+ \rightarrow D^{*-} D_s^+ \pi^+$$

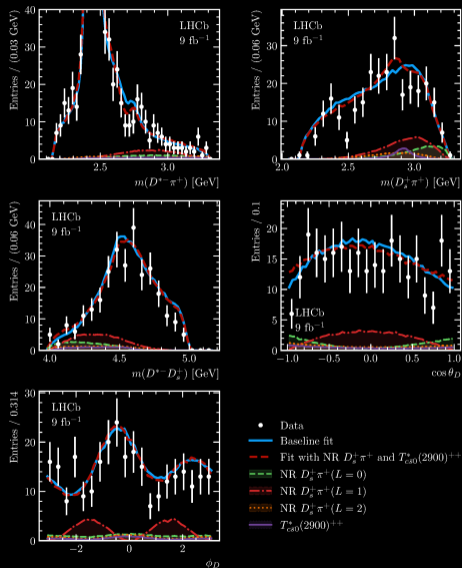
arXiv:2405.00098 (Submitted to JHEP)

- ▶ Phasespace appears dominated by $D^{**0} \rightarrow D^{*-} \pi^+$ contributions
- ▶ Amplitude analysis required. . .



$$B^+ \rightarrow D^{*-} D_s^+ \pi^+$$

arXiv:2405.00098 (Submitted to JHEP)



- ▶ Amplitude analysis shows data consistent with a **baseline model** composed of only $D^{*-} \pi^+$ contributions
- ▶ Slight improvement from **alternative model** including exotic component but not significant
- ▶ Fit fraction of $T_{cs0}^*(2900)^{++}$ contribution $< 2.3\%$ at 90% CI

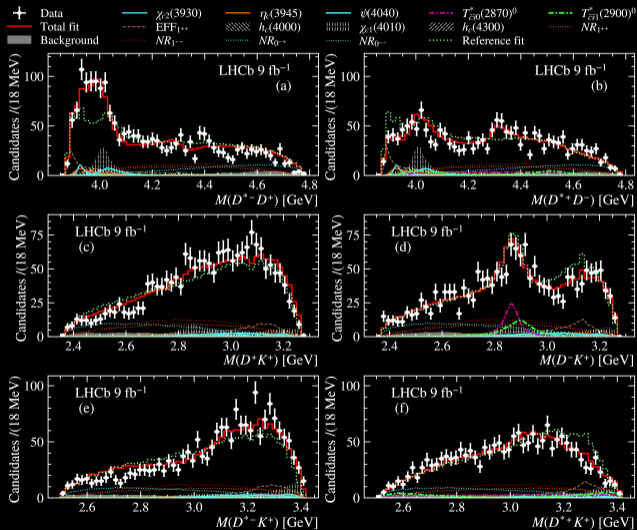
- ▶ Simultaneous analysis of $D^{*+} D^- K^+$ and $D^{*-} D^+ K^+$ final states
- ▶ Sensitive to $T_{c\bar{s}}$ states previously seen in $D^+ D^- K^+$
- ▶ Charmonium-like resonances strongly decaying to $D^{*\pm} D^\mp$ must conserve C -parity
- ▶ Amplitude model constructed to enforce C -parity in these contributions:

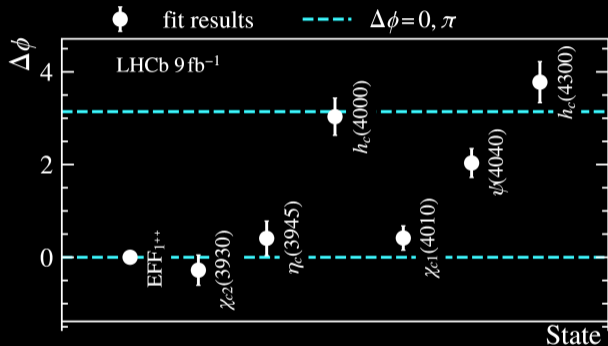
$$\begin{aligned} \mathcal{A}_{[c\bar{c}]_j \rightarrow D^{*+} D^-} &= C_j \mathcal{A}_{[c\bar{c}]_j \rightarrow D^{*-} D^+}, \\ C_j &= \pm 1 \quad \forall j \end{aligned}$$

$$B^+ \rightarrow D^{*\pm} D^{\mp} K^+$$

arXiv:2406.03156 (Submitted to PRL)

- ▶ Fit to data shows significant contributions from $T_{c\bar{s}}$ states to $D^- K^+$
- ▶ Upper limit set on decay of $T_{c\bar{s}1}(2900)^0 \rightarrow D^{*-} K^+$
- ▶ Baseline fit model shows improvement over reference model by including three new charmonium-like states all with significances in excess of 6σ





► Additional fit performed with $C_j \rightarrow \exp(i\Delta\phi_j)$ to test C -parities

► States generally show good agreement with $\Delta\phi = 0$ ($C = +$) or $\Delta\phi = \pi$ ($C = -$)

Summary

- ▶ The first two runs of LHCb have yielded an impressive haul of new hadrons
- ▶ Particular success with b -baryons and charm sector
- ▶ Many more analyses in the pipeline

Questions, utterances or friendly bugs?

