Recent (open) charm results from LHCb

with some personal reminiscences

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Higgs Maxwell Workshop 2026
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Royal Society of Edinburgh

AN ANNIVERSARY...

AN ANNIVERSARY. . .

RICH/hadron identification to be calibrated with samples of

$$D^{*+} \to D^0(hh')\pi^+$$

My first post-doc assignment:

- Develop a programme of **charm physics** measurements with them!

LHCb-2007-049

A study of tagged $D^0 \to hh'$ decays for D^0–$\overline{D^0}$ mixing measurements *

Public Note

Issue: [redacted]
Revision: 3

Reference: LHCb-2007-049
Created: April 30, 2008
Last modified: April 30, 2008

Prepared by: Patrick Spradlin[a], Guy Wilkinson[a], Funai Xing[a]
[a]University of Oxford, United Kingdom

NOW A MAJOR PART OF LHCb PHYSICS!

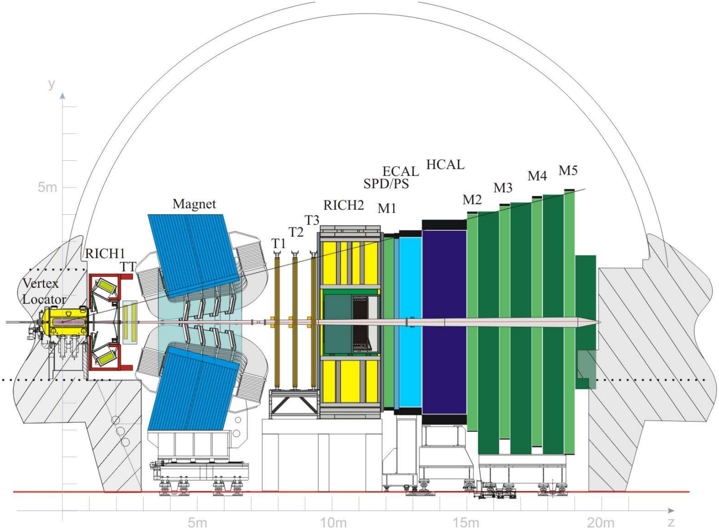
'Charm Physics' responsible for 112/824 LHCb physics publications!

Within the last year, these include

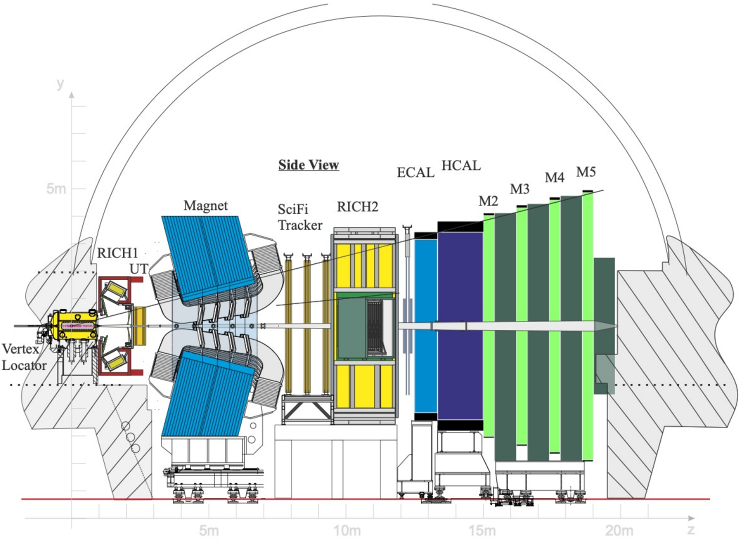
Production measurements	
Measurements of charmed meson and antimeson production asymmetries at $\sqrt{s} = 13.6$ TeV	JHEP 10 (2025) 050
Particle properties	
Amplitude analysis of the $\Xi_c^+ \to pK^-\pi^+$ decay and Ξ_c^+ baryon polarization measurement in semileptonic beauty-hadron decays	Phys. Rev. D 112 (2025), 092003
Measurement of the Ω_c^0 and Ξ_c^0 baryon lifetimes using hadronic -baryon decays	JHEP 09 (2025) 157
First determination of the spin-parity of the $\Xi_c(3055)^{+,0}$ baryons	Phys. Rev. Lett. 134 (2025) 081901
New states and Spectroscopy	
Observation of a new charmed baryon decaying to $\Xi_c^+\pi^+\pi^-$	Phys. Rev. Lett. 132 (2025) 161901
Rare decays and decay properties	
Observation of the doubly-charmed-baryon decay $\Xi_{cc}^{++} \to \Xi_c^0\pi^+\pi^+$	JHEP 10 (2025) 136
Observation of Cabibbo-suppressed two-body hadronic decays and precision mass measurement of the Ω_c^0 baryon	Phys. Rev. Lett. 132 (2024) 081802
Search for D^0 meson decays to $\pi^+\pi^-e^+e^-$ and $K^+K^-e^+e^-$ final states	Phys. Rev. D111 (2025), L091101
Mixing and *CP* violation	
Search for resonance-enhanced *CP* and angular asymmetries in the $\Lambda_c^+ \to p\mu^+\mu^-$ decay at LHCb	Phys. Rev. D111 (2025) L091102
Search for charge-parity violation in semileptonically tagged $D^0 \to K^+\pi^-$ decays	JHEP 03 (2025) 149
Study of charm mixing and *CP* violation with $D^0 \to K^\pm\pi^\mp\pi^\pm\pi^\mp$ decays	JHEP 12 (2025) 153
Measurement of *CP* asymmetry in $D^0 \to K_S^0 K_S^0$ decays with the upgraded LHCb detector	LHCb-PAPER-2025-036 (submitted to

THE LHCb DETECTOR IN RUN 1 & 2

JINST 3 (2008) S08005



THE LHCb UPGRADE (I) DETECTOR
JINST 19 (2024) 05, P05065

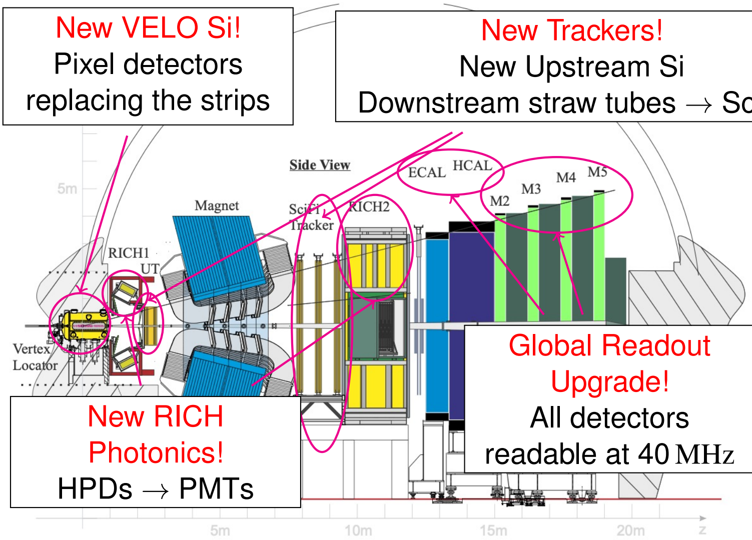


The LHCb Upgrade (I) detector

JINST 19 (2024) 05, P05065

New VELO Si!
Pixel detectors
replacing the strips

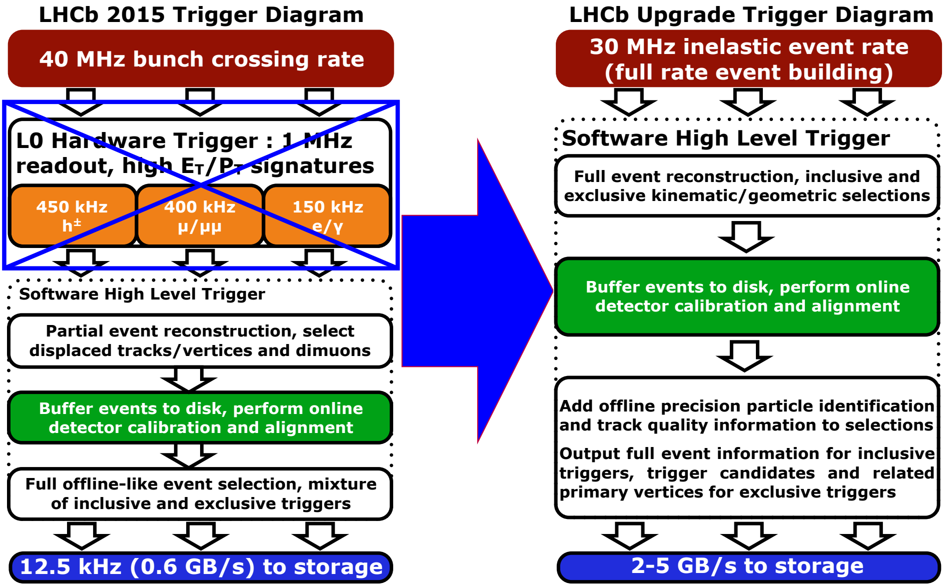
New Trackers!
New Upstream Si
Downstream straw tubes → SciFi



New RICH
Photonics!
HPDs → PMTs

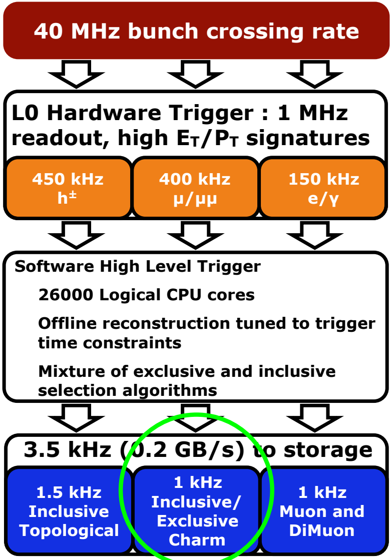
Global Readout
Upgrade!
All detectors
readable at 40 MHz

Upgrade removed hardware trigger



TRIGGER EVOLUTION FOR CHARM

LHCb 2011 Trigger Diagram



2010-2011 Trigger pipeline

1. L0 Hardware trigger
   - Hard 1 MHz readout limit.
2. HLT1 ‘fast’ software trigger
3. HLT2 ‘full’ reconstruction trigger

Calibration and alignment done offline

Physics-quality reconstruction offline

We developed charm physics into a physics priority, but. . .

- L0 very inefficient for ‘soft’ charm,
- HLT2-offline reconstruction differences affect precision,
- Very large samples required for interesting precision.

STEP 1: BUFFER FOR LARGER SAMPLES

LHCb 2011 Trigger Diagram

40 MHz bunch crossing rate

L0 Hardware Trigger : 1 MHz readout, high E_T/P_T signatures

450 kHz $h^{\pm}$	400 kHz $\mu/\mu\mu$	150 kHz e/γ

Software High Level Trigger

- 26000 Logical CPU cores
- Offline reconstruction tuned to trigger time constraints
- Mixture of exclusive and inclusive selection algorithms

3.5 kHz (0.2 GB/s) to storage

1.5 kHz Inclusive Topological	1 kHz Inclusive/ Exclusive Charm	1 kHz Muon and DiMuon

LHCb 2012 Trigger Diagram

40 MHz bunch crossing rate

L0 Hardware Trigger : 1 MHz readout, high E_T/P_T signatures

450 kHz $h^{\pm}$	400 kHz $\mu/\mu\mu$	150 kHz e/γ

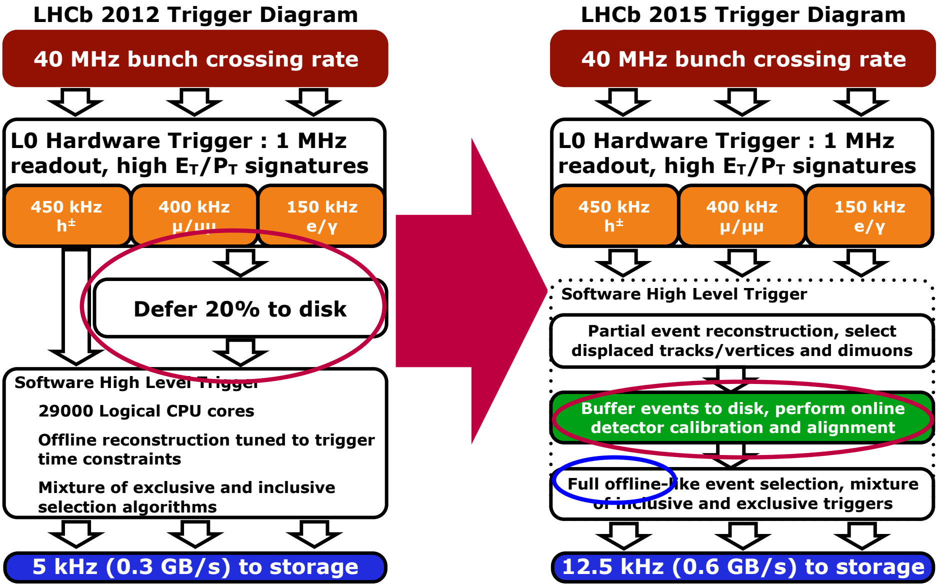
Defer 20% to disk

Software High Level Trigger

- 29000 Logical CPU cores
- Offline reconstruction tuned to trigger time constraints
- Mixture of exclusive and inclusive selection algorithms

5 kHz (0.3 GB/s) to storage

STEP 2: REAL-TIME ALIGNMENT AND CALIBRATION



Finally: Remove the L0 inefficiency

LHCb 2015 Trigger Diagram

40 MHz bunch crossing rate

~~**L0 Hardware Trigger : 1 MHz readout, high E_T/P_T signatures**~~

~~450 kHz $h^{\pm}$~~ | ~~400 kHz $\mu/\mu\mu$~~ | ~~150 kHz e/γ~~

Software High Level Trigger

- Partial event reconstruction, select displaced tracks/vertices and dimuons
- Buffer events to disk, perform online detector calibration and alignment
- Full offline-like event selection, mixture of inclusive and exclusive triggers

12.5 kHz (0.6 GB/s) to storage

LHCb Upgrade Trigger Diagram

30 MHz inelastic event rate (full rate event building)

Software High Level Trigger

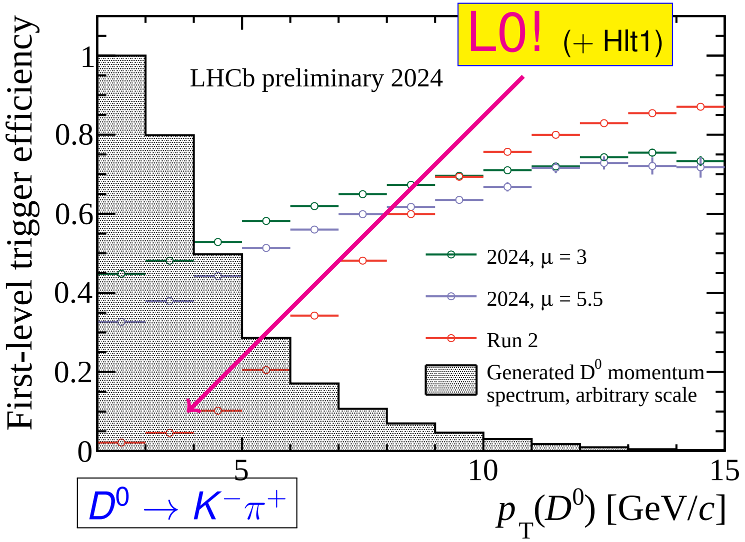
- Full event reconstruction, inclusive and exclusive kinematic/geometric selections
- Buffer events to disk, perform online detector calibration and alignment
- Add offline precision particle identification and track quality information to selections

  Output full event information for inclusive triggers, trigger candidates and related primary vertices for exclusive triggers

2-5 GB/s to storage

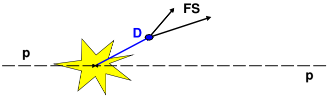
(IT WAS PRETTY BAD)

LHCB-FIGURE-2024-006



USING COMPLEMENTARY PRODUCTION

Prompt production



Enormous generated samples!

Some measurements can only be made with prompt samples

. . . but

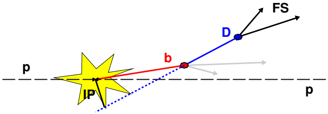
- Challenging background environments,
- Complicatd acceptance functions,

. . . which are less problematic for secondary production

- Smaller backgrounds,
- Less dynamic efficiency variation,
- Improved efficiency for smaller proper times.

Additionaly, provides constrained systems for spin-parity studies.

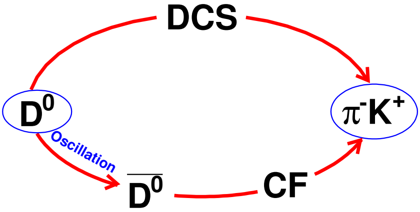
$H_b \to H_c X$



WS MIXING: WHERE ARE WE NOW?

Two paths from D^0 to the 'wrong sign' (WS) $\pi^- K^+$

- Tree-level doubly Cabibbo suppressed (DCS) decay,
- FCNC transition to $\bar{D}^0$ followed by Cabbibo favored (CF) decay.



The system that yielded the first single-measurement observation of charm mixing: LHCb, Phys. Rev. Lett. 110 (2013), 101802!

Two recent complementary measurements search for indirect CP violation in D^0-$\bar{D}^0$ mixing:

- Phys. Rev. D 111 (2025) 012001
  - Promptly produced $D^{*+} \to D^0(\pi^- K^+)\pi^+$
- JHEP 03 (2025) 149
  - Doubly tagged secondary $H_b \to \mu^- D^{*+} X$, $D^{*+} \to D^0(\pi^+ K^-)\pi^+$

EXPERIMENTAL OBSERVABLES

Our primary experimental observables are wrong sign to right sign decay rate ratios such as

$$R^{+}_{K\pi}(t) \equiv \frac{\Gamma\left(D^0(t) \to \pi^- K^+\right)}{\Gamma\left(\bar{D}^0(t) \to K^+ \pi^-\right)} \text{ and } R^{-}_{K\pi}(t) \equiv \frac{\Gamma\left(\bar{D}^0(t) \to \pi^+ K^-\right)}{\Gamma\left(D^0(t) \to K^- \pi^+\right)}.$$

The two papers use different parameterizations relating these observables to physical parameters,

- Following will sketch the parameterization of Phys. Rev. D 111 (2025) 012001,
  - Based on Kagan and Silverstrini, Phys. Rev. D 103 (2021) 053008,
  - Clean factorization into *CP*-conserving and *CP*-violating parameters,
- Results for this convention are included in an appendix of JHEP 03 (2025) 149.

FORMALISM 1/3: DIRECT CP VIOLATION

Parameterize direct *CP* violation in terms of the the decay amplitudes

$$\mathcal{A}_f = \mathcal{A}\left(D^0 \to K^-\pi^+\right), \qquad \mathcal{A}_{\bar{f}} = \mathcal{A}\left(D^0 \to \pi^-K^+\right),$$
$$\overline{\mathcal{A}}_f = \mathcal{A}\left(\bar{D}^0 \to \pi^+K^-\right), \qquad \overline{\mathcal{A}}_{\bar{f}} = \mathcal{A}\left(\bar{D}^0 \to K^+\pi^-\right).$$

in the observable ratios with

$$A_{K\pi} \equiv \frac{\left|\mathcal{A}_{\bar{f}}/\overline{\mathcal{A}}_{\bar{f}}\right|^2 - \left|\overline{\mathcal{A}}_f/\mathcal{A}_f\right|^2}{\left|\mathcal{A}_{\bar{f}}/\overline{\mathcal{A}}_{\bar{f}}\right|^2 + \left|\overline{\mathcal{A}}_f/\mathcal{A}_f\right|^2}$$

and define the mean ratio

$$R_{K\pi} \equiv \frac{1}{2}\left(\left|\frac{\mathcal{A}_{\bar{f}}}{\overline{\mathcal{A}}_{\bar{f}}}\right|^2 + \left|\frac{\overline{\mathcal{A}}_f}{\mathcal{A}_f}\right|^2\right).$$

FORMALISM 2/3: MIXING WITH CP VIOLATION

Time evolution of D^0-$\bar{D}^0$ described by an effective 2×2 Hamiltonian

$$\boldsymbol{H} \equiv \boldsymbol{M} + \frac{i}{2}\boldsymbol{\Gamma} \text{ (let the off-diagonal elements be } M_{12}^{(*)} \text{ and } \Gamma_{12}^{(*)})$$

with mass eigenstates

$$\left|D_{1,2}\right\rangle = p\left|D^0\right\rangle \pm q\left|\bar{D}^0\right\rangle \text{ that have mass } m_{1,2} \text{ and decay width } \Gamma_{1,2},$$

from which we get the usual mixing observables

$$x = \frac{m_2 - m_1}{\Gamma_D} \equiv \frac{m_2 - m_1}{\frac{1}{2}(\Gamma_1 + \Gamma_2)}, \qquad y = \frac{\Gamma_2 - \Gamma_1}{2\Gamma_D},$$

Define a parameterization into two *CP*-conserving parameters

$$x_{12} \equiv \frac{2|M_{12}|}{\Gamma_D} \approx |x| \text{ and } y_{12} \equiv \frac{|\Gamma_{12}|}{\Gamma_D} \approx |y|$$

and one *CP*-violating pure mixing phase

$$\phi_{12} \equiv \arg\left(M_{12}\Gamma_{12}\right) = \phi^M - \phi^\Gamma \text{ where } \phi^M = \arg\left(M_{12}\right) \text{ and } \phi^\Gamma = \arg\left(\Gamma_{12}\right)$$

FORMALISM 3/3: TIME EVOLUTION OF RATIOS

Up to second order in x_{12} and y_{12}, the time evolution $R^{\pm}_{K\pi}(t)$ is

$$R^{\pm}_{K\pi}(t) \approx R_{K\pi}(1 \pm A_{K\pi}) + \sqrt{R_{K\pi}(1 \pm A_{K\pi})}(c_{K\pi} \pm \Delta c_{K\pi})t + (c'_{K\pi} \pm \Delta c'_{K\pi})t^2,$$

where the *CP*-even combinations of mixing parameters are

$$c_{K\pi} \approx y_{12} \cos\phi^{\Gamma}_f \cos\delta_f + x_{12} \cos\phi^{M}_f \sin\delta_f$$
$$c'_{K\pi} \approx \frac{1}{4}\left(x^2_{12} + y^2_{12}\right)$$

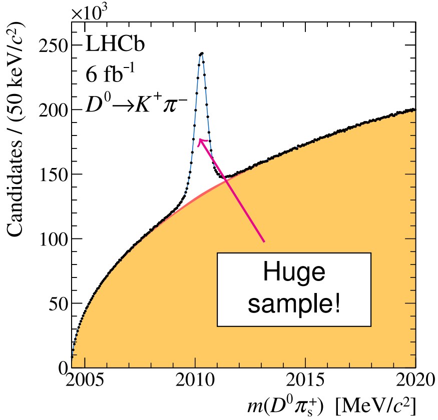
and the *CP*-odd combinations of mixing parameters are

$$\Delta c_{K\pi} \approx x_{12} \sin\phi^{M}_f \cos\delta_f - y_{12} \sin\phi^{\Gamma}_f \sin\delta_f$$
$$\Delta c'_{K\pi} \approx \frac{1}{2} x_{12} y_{12} \sin\left(\phi^{M}_f - \sin\phi^{\Gamma}_f\right)$$

Non-zero values for $\Delta c_{K\pi}$ and $\Delta c'_{K\pi}$ would be evidence for indirect *CP* violation.

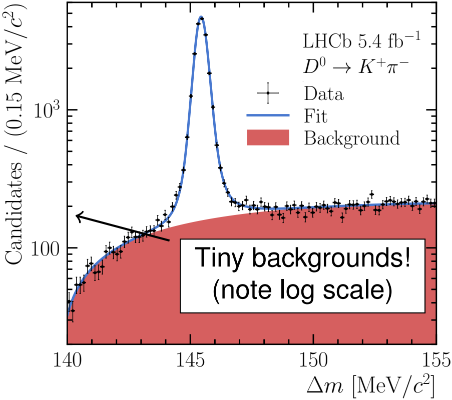
COMPLEMENTARITY IN ACTION

Promptly produced
$D^{*+} \to D^0(\pi^- K^+)\pi^+$
Phys. Rev. D 111 (2025) 012001



$\sim 1.6 \times 10^6$ WS decays, Run 2, 6 fb^{-1}

Secondary $H_b \to \mu^- D^{*+} X$,
$D^{*+} \to D^0(\pi^+ K^-)\pi^+$
JHEP 03 (2025) 149

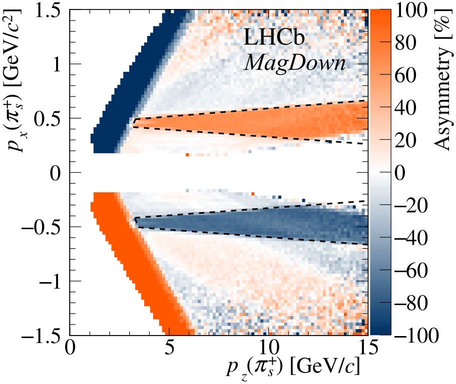


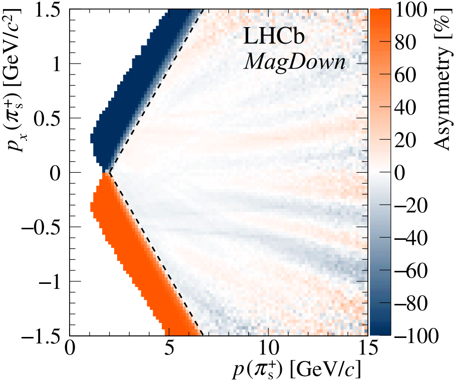
$\sim 2.0 \times 10^4$ WS decays, Run 2, 5.4 fb^{-1}

COPING WITH DETECTOR ASYMMETRIES

FROM PHYS. REV. D 111 (2025) 012001

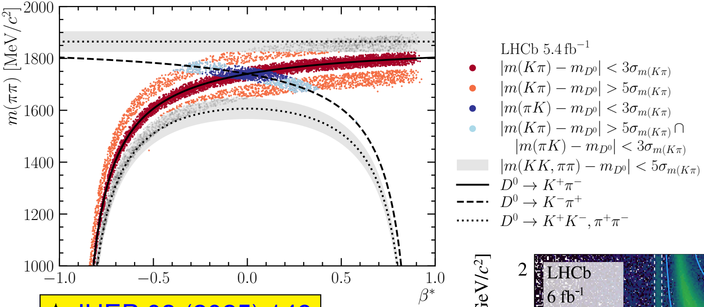
Some prominent blind spots for soft pions due to beam pipe and spectrometer magnet: vetoed!





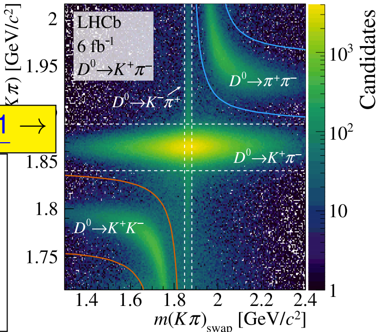
Production asymmetries and more subtle detection asymmetries corrected with extensive use of control modes and independent calibrations.

MISIDENTIFYING $\pi^- K^+$ AS SOME OTHER $h^- h'^+$



↑ JHEP 03 (2025) 149

PRD 111 (2025) 012001 →



Double mis-ID most problematic

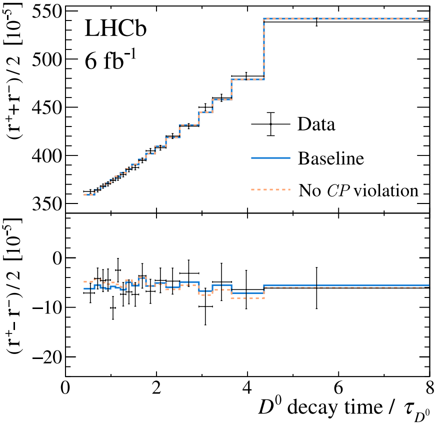
- $\pi^- K^+ \to K^- \pi^+$,
- Corrected by analyzing swapped-mass distributions.

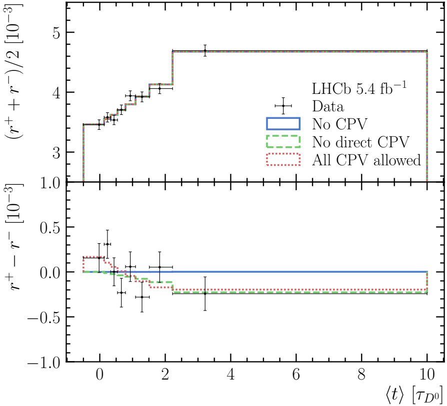
FITS TO QUADRATIC MODEL

$$R^{\pm}_{K\pi}(t) \approx R_{K\pi}(1 \pm A_{K\pi}) + \sqrt{R_{K\pi}(1 \pm A_{K\pi})}(c_{K\pi} \pm \Delta c_{K\pi})t + (c'_{K\pi} \pm \Delta c'_{K\pi})t^2$$

Promptly produced $D^{*+} \to D^0(\pi^- K^+)\pi^+$
Phys. Rev. D 111 (2025) 012001

Secondary $H_b \to \mu^- D^{*+} X$, $D^{*+} \to D^0(\pi^+ K^-)\pi^+$
JHEP 03 (2025) 149





RESULTS OF *CP* VIOLATION-ALLOWED FITS

$R^{\pm}_{K\pi}(t) \approx R_{K\pi}(1 \pm A_{K\pi}) + \sqrt{R_{K\pi}(1 \pm A_{K\pi})}(c_{K\pi} \pm \Delta c_{K\pi})t + (c'_{K\pi} \pm \Delta c'_{K\pi})t^2$

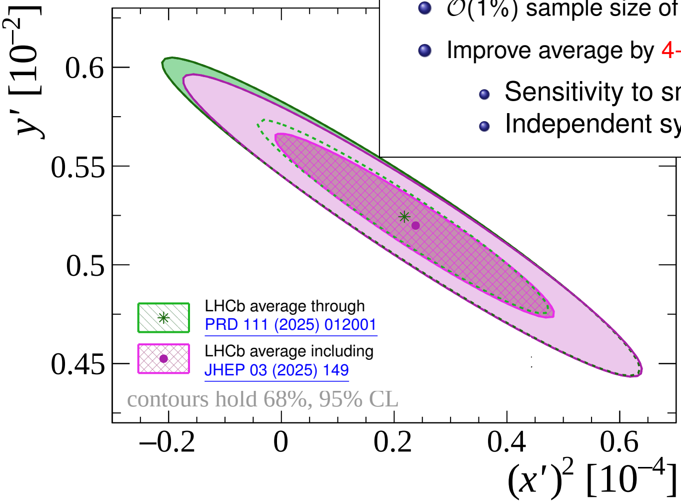
	Prompt		Secondary	
	PRD 111 (2025) 012001		JHEP 03 (2025) 149	
$R_{K\pi}$	$(343.1 \pm 2.0)\times$	10^{-5}	$(347.2 \pm 5.8)\times$	10^{-5}
$c_{K\pi}$	$(51.4 \pm 3.5)\times$	10^{-4}	$(58 \pm 16)\times$	10^{-4}
$c'_{K\pi}$	$(13.1 \pm 3.7)\times$	10^{-6}	$(9 \pm 26)\times$	10^{-6}
$A_{K\pi}$	$(-7.1 \pm 6.0)\times$	10^{-3}	$(23 \pm 17)\times$	10^{-3}
$\Delta c_{K\pi}$	$(3.0 \pm 3.6)\times$	10^{-4}	$(-23 \pm 16)\times$	10^{-4}
$\Delta c'_{K\pi}$	$(-1.9 \pm 3.8)\times$	10^{-6}	$(21 \pm 26)\times$	10^{-6}

No evidence for *CP* violation in either decay or mixing.

Limiting uncertainties for both measurents still statistical!

Final comment on complementarity

Combination of LHCb WS mixing measurements from JHEP 03 (2025) 149



Outsized impact for secondary measurement

- $\mathcal{O}(1\%)$ sample size of prompt analysis
- Improve average by 4-5%
  - Sensitivity to small decay times,
  - Independent systematics

Extension to $K^{\pm}\pi^{\mp}\pi^{\pm}\pi^{\mp}$ decays

JHEP 12 (2025) 153

The WS/RS mixing and *CP*-violation analysis can applied other decay modes with the same tree-level process,

- *e.g.*, $D^0 \to K^+\pi^-\pi^+\pi^-$.

However, strong phases vary throughout the phase space of the decay,

- Strong phase differences averaged over phase space region *i*: δ_i,
- Mixing sensivity diluted by coherence factor κ_i:
  $\kappa_i \exp(i\delta_i) \equiv \langle\cos\delta\rangle + i\langle\sin\delta\rangle$
- Region *i* can be full phase space or selected subvolumes.

The time evolution of the ratio observables for region *i* is then

$$R^{\pm}_{K3\pi,i}(t) \approx r_i^{\pm} - r_i^{\pm}(\kappa y'^{\pm})_i t + \frac{(x^{\pm 2} + y^{\pm 2})}{4} t^2$$

where

$$(\kappa y'^{\pm})_i \equiv \kappa_i(y\cos\delta_i - x\sin\delta_i)$$

FOUR PHASE-SPACE BINS

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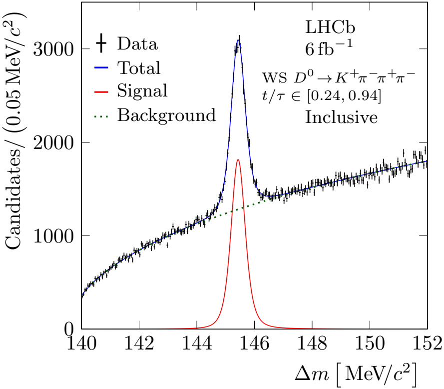
Full sample: 4.4×10^5 WS decays (Run 2, $6\,\mathrm{fb}^{-1}$).



Simultaneous decay-time fits to four-phase space bins

- Bins selected to optimize CKM γ measurements,
- Analysis can both use and provide external input for γ

Fits determine 18 observables (9 for no CPV fit): $r_i^{\pm}$, $(\kappa y'^{\pm})_i$, and $(x^{\pm 2} + y^{\pm 2})$

External inputs used for further interpretation

- External mixing (w/out *CP* violation) $(x, y) \Rightarrow (\kappa_i, \delta_i)$
- External $(\kappa_i, \delta_i) \Rightarrow$ mixing $(x^{\pm}, y^{\pm})$.

EXTERNAL MIXING $(x, y) \Rightarrow (\kappa_i, \delta_i)$

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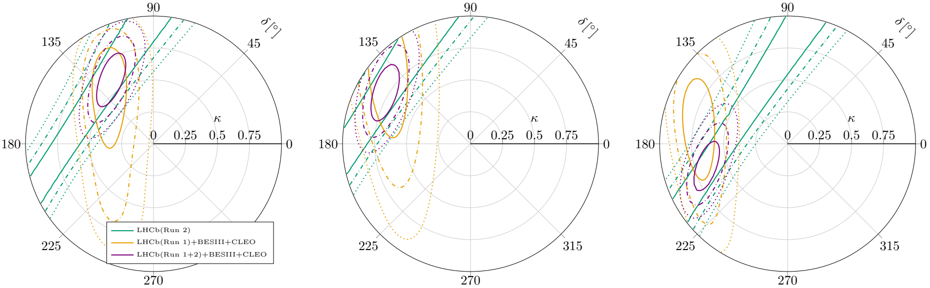
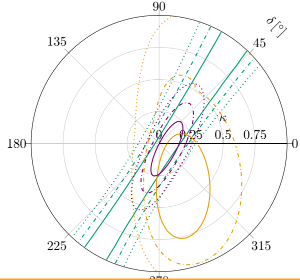




This analysis produces the bands in green

- Mixing parameters do not conatrain (κ_i, δ_i) to a unique solution

Contours show previous knowledge from CLEO, BESIII, and LHCb Run 1 in yellow.

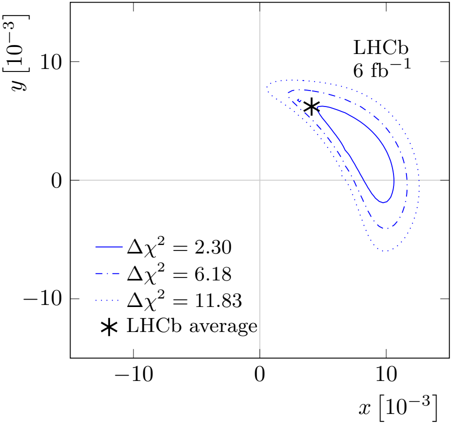
Combinaation with inclusion of this analysis in blue.

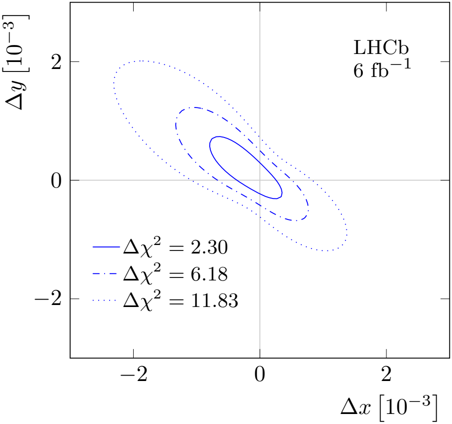
EXTERNAL $(\kappa_i, \delta_i) \Rightarrow$ MIXING $(x^{\pm}, y^{\pm})$

JHEP 12 (2025) 153

Using previous knowledge of (κ_i, δ_i) from CLEO, BESIII, and LHCb Run 1

Phase differences confer sensitivity to both x and y!





No evidence for *CP* violation in mixing

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LHCb announces a charming new particle

06 July 2017
EPS-HEP 2017
Venice, Italy

Science & Technology Facilities Council
10 Years of Impact and Inspiration

CERN experiment discovers a new, very charming particle

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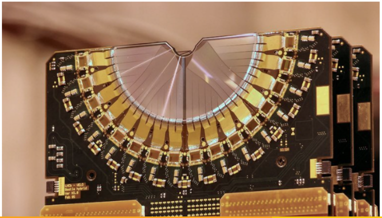
SCIENCE

CERN Physicists Find a Particle With a Double Dose of Charm

By KENNETH CHANG JULY 6, 2017



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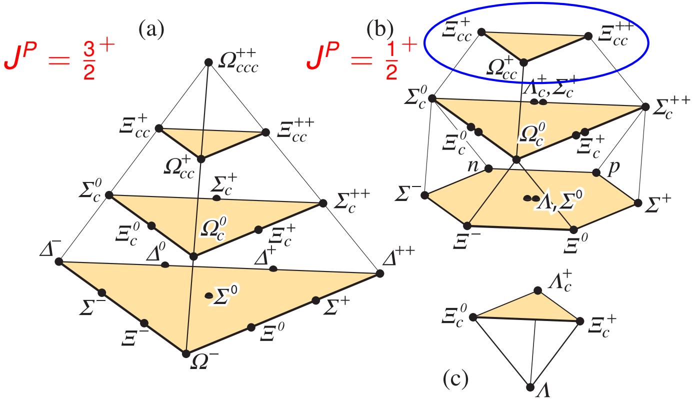
Science & Environment

LHC double heavy particle to shine light on strong force

By Pallab Ghosh

SOME GROUP THEORY OF QUARK FLAVOR SYMMETRY

Flavor symmetry of baryons containing combinations of *d*, *u*, *s*, and *c* quarks;
A broken symmetry, but illustrative of expected ground states.



SU(4) flavor multiplets, PDG Review of Particle Physics, Phys.Rev. D86, 010001.

Bottom line: We expect three *ccq* particles with relatively long half-lives, $\mathcal{O}(100\,\mathrm{fs})$, and related properties.

SELEX AND Ξ_{cc}^{+}

PHYS.REV.LETT. 89 (2002) 112001, PHYS.LETT. B628 (2005) 18-24

In 2002, SELEX, a fixed-target charm hadroproduction experiment at Fermilab, claimed the first observation of Ξ_{cc}^{+} in decays to $\Lambda_c^+ K^- \pi^+$.

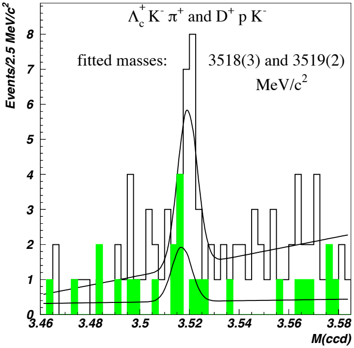
Followed by a confirmation in 2004 in $D^+ p K^-$,

- $\Lambda_c^+ K^- \pi^+$: 15.9 sig over 6.1 bkg (6.3σ),
- $D^+ p K^-$: 5.62 sig over 1.38 bkg (4.8σ).

Combined mass:
$m(\Xi_{cc}^{+}) = 3518.7 \pm 1.7\,\mathrm{MeV}/c^2$.

Unexpected properties of the observation:

- Short lifetime, $\tau < 33\,\mathrm{fs}$ at 90% C.L.
- 20% of all Λ_c^+ production with baryon beams.

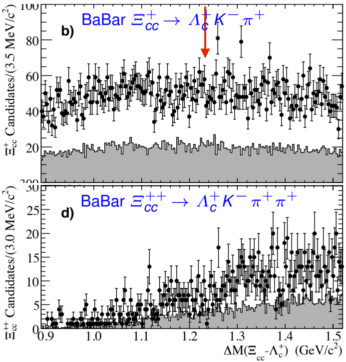


SELEX $\Lambda_c^+ K^- \pi^+$ and $D^+ p K^-$ distributions superposed
Phys.Lett. B628 (2005) 18-24

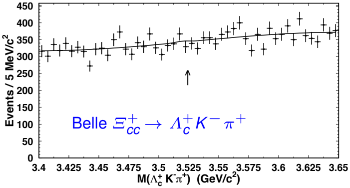
Unique production environment:

- Hyperon beam: admixture of Σ^- (68%), proton (18%), and π^- (13%),
- Thin foil target: Cu or diamond.

DOUBLY CHARMED BARYONS AT OTHER EXPERIMENTS



BaBar: Phys.Rev. D74 (2006) 011103



Belle: Phys.Rev.Lett. 97 (2006) 162001

FOCUS: Photon beam on Be fixed target

Nucl.Phys.Proc.Suppl. 115 (2003) 33-36

- Search for both Ξ_{cc}^{+} and Ξ_{cc}^{++},
- 7 exclusive $\Xi_{cc} \to \Lambda_c^{+} X$ modes,
- 14 exclusive $\Xi_{cc} \to D^{0,+} Y$ modes,
- No evidence of Ξ_{cc}.

BaBar: $e^{+}e^{-}$ at $\Upsilon(4S)$ Phys.Rev. D74 (2006) 011103

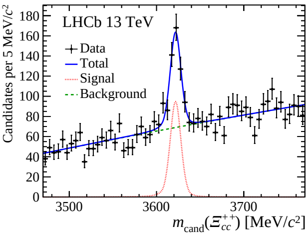
- Search for both Ξ_{cc}^{+} and Ξ_{cc}^{++},
- $\Xi_{cc}{}^{+(+)} \to \Lambda_c^{+} K^{-} \pi^{+} (\pi^{+})$
- $\Xi_{cc}{}^{+(+)} \to \Xi_c^{0} \pi^{+} (\pi^{+})$
- No evidence of Ξ_{cc}.

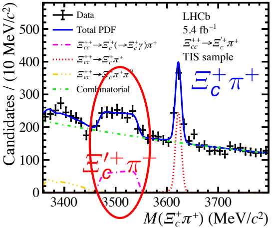
Belle: $e^{+}e^{-}$ at $\Upsilon(4S)$ Phys.Rev.Lett. 97 (2006) 162001

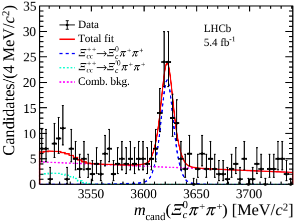
- Searched for $\Xi_{cc}^{+} \to \Lambda_c^{+} K^{-} \pi^{+}$,
- Found new Ξ_c^{+} resonance decaying to $\Lambda_c^{+} K^{-} \pi^{+}$
- No evidence of Ξ_{cc}.

Ξ_{cc} AT LHCb SO FAR

Ξ_{cc}^{++} (ccu) baryon observed in four decay modes







$\Xi_{cc}^{++}\to\Lambda_c^+K^-\pi^+\pi^+$ — Phys.Rev.Lett. 119 (2017) 11, 112001

$\Xi_{cc}^{++}\to\Xi_c^{(\prime)+}\pi^+$ — $\Xi_c^+\pi^+$: Phys.Rev.Lett. 121 (2018) 16, 162002; $\Xi_c'^+\pi^+$: JHEP 05 (2022) 038

$\Xi_{cc}^{++}\to\Xi_c^0\pi^{\pm}\pi^+$ — JHEP 10 (2025) 136

With properties:

- Mass $m = 3621.55 \pm 0.23 \pm 0.30\,\mathrm{MeV}$ (JHEP 02 (2020) 049)
- Lifetime $\tau = 0.256^{+0.024}_{-0.022} \pm 0.014\,\mathrm{ps}$ (Phys.Rev.Lett. 121 (2018) 5, 052002)
- $\left(\frac{\sigma(\Xi_{cc}^{++})\mathcal{B}(\Xi_{cc}^{++}\to\Lambda_c^+K^-\pi^+\pi^+)}{\sigma\Lambda_c^+}\right)_{\rm fid} = (2.22 \pm 0.27 \pm 0.29) \times 10^{-4}$ (Chin.Phys.C 44 (2020) 2, 022001)

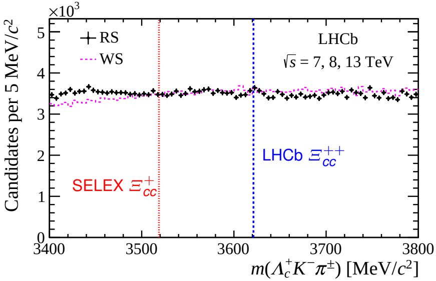
Ξ_{cc}^{+}: ITS ELUSIVE ISOSPIN PARTNER

Ξ_{cc}^{+} (*ccd*) baryon expected to have a shorter lifetime,

- $\tau(\Xi_{cc}^{+}) <\sim \frac{1}{3}\tau(\Xi_{cc}^{++})$

Not yet evidence for Ξ_{cc}^{+} at LHCb,

- Not near LHCb's observed Ξ_{cc}^{++} mass $\sim 3622\,\mathrm{MeV}$,
- Nor at SELEX's claimed Ξ_{cc}^{+} mass $3518.7 \pm 1.7\,\mathrm{MeV}$
  Phys.Lett.B 628 (2005) 18-24



LHCb's search for $\Xi_{cc}^{+} \to \Lambda_c^{+} K^{-} \pi^{+}$
Sci.China Phys.Mech.Astron. 63 (2020) 2, 221062

Extended LHCb's first double charm search to the full Run 1 and Run 2 dataset, JHEP 12 (2013) 090.

Upper limits set as functions of mass for several hypothetical lifetimes.

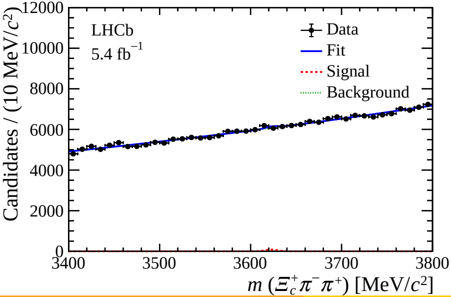
SEARCH FOR $\Xi_{cc}^{+} \to \Xi_{c}^{+}\pi^{-}\pi^{+}$

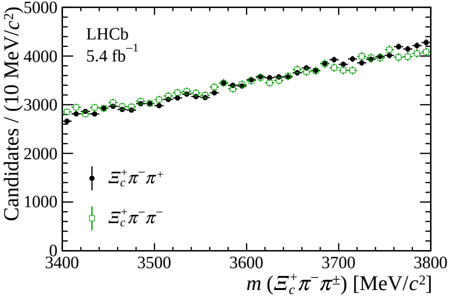
JHEP 12 (2021) 107 (ARXIV:2109.07292 [HEP-EX])

Search with a two-tiered selection.

Most restrictive: *default trigger* set,

- Selection and trigger requirements matched to $\Xi_{cc}^{++} \to \Xi_{c}^{+}\pi^{+}$,
- Best precision/upper limits of production $\times$ branching ratio.





Superset: *extended trigger* set.

- More inclusive set of triggers.

Best chance of detecting a signal.

Full analysis, including decision tree of how to present results in all scenarios, fully defined before unblinding.

COMBINATION OF $\Xi_c^+\pi^-\pi^+$ AND $\Lambda_c^+K^-\pi^+$

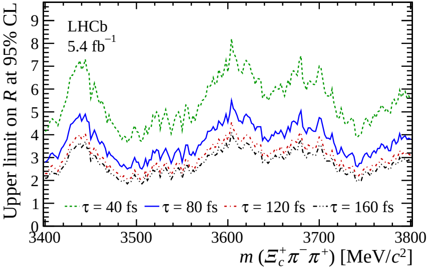
JHEP 12 (2021) 107 (ARXIV:2109.07292 [HEP-EX])

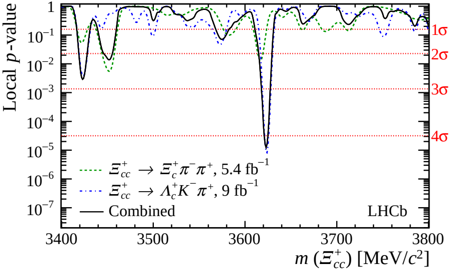
No evidence for $\Xi_{cc}^+ \to \Xi_c^+\pi^-\pi^+$.

Determination of mass-dependent upper limit for

$$R \equiv \frac{\sigma(\Xi_{cc}^+)\times\mathcal{B}(\Xi_{cc}^+\to\Xi_c^+\pi^-\pi^+)}{\sigma(\Xi_{cc}^{++})\times\mathcal{B}(\Xi_{cc}^{++}\to\Xi_c^+\pi^+)}$$

R estimated for several hypothetical lifetimes.





Statistical combination with $\Xi_{cc}^+ \to \Lambda_c^+K^-\pi^+$ search

Sci.China Phys.Mech.Astron. 63 (2020) 2, 221062

Joint fit to the mass spectra.

No evidence for Ξ_{cc}^+

- Largest deviation: 2.9σ after systematics and look-elsewhere.

A first search for Ω_{cc}^{+} at LHCb

Sci. China Phys. Mech. Astron. 64, 101062 (2021)

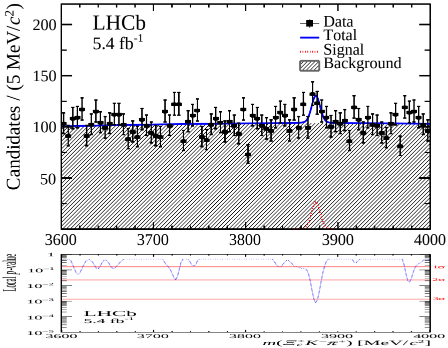
Expect existence of a third weakly decaying doubly-charmed baryon

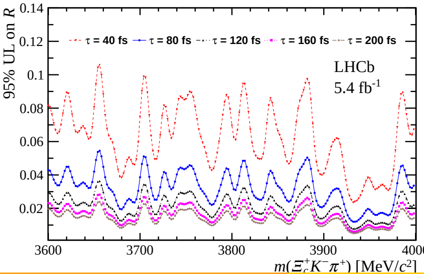
- Ω_{cc}^{+}: ccs

LHCb recently performed its first search for Ω_{cc}^{+} via $\Omega_{cc}^{+} \to \Xi_c^{+} K^{-} \pi^{+}$

No evidence for Ω_{cc}^{+}

- Largest excursion: 1.8σ global





Determination of mass-dependent upper limit for R defined as

$$\frac{\sigma(\Omega_{cc}^{+})\mathcal{B}(\Omega_{cc}^{+} \to \Xi_c^{+} K^{-} \pi^{+})\mathcal{B}(\Xi_c^{+} \to pK^{-}\pi^{+})}{\sigma(\Xi_{cc}^{++})\mathcal{B}(\Xi_{cc}^{++} \to \Lambda_c^{+} K^{-} \pi^{+}\pi^{+})\mathcal{B}(\Lambda_c^{+} \to pK^{-}\pi^{+})}$$

for several hypothetical lifetimes.

WE HAVE DONE SOME IMPRESSIVE WORK SINCE 2006

'Charm Physics' responsible for 112/824 LHCb physics publications!

Within the last year, these include

Production measurements	
Measurements of charmed meson and antimeson production asymmetries at $\sqrt{s} = 13.6\,\mathrm{TeV}$	JHEP 10 (2025) 050
Particle properties	
Amplitude analysis of the $\Xi_c^+ \to pK^-\pi^+$ decay and Ξ_c^+ baryon polarization measurement in semileptonic beauty-hadron decays	Phys. Rev. D 112 (2025), 092003
Measurement of the Ω_c^0 and Ξ_c^0 baryon lifetimes using hadronic -baryon decays	JHEP 09 (2025) 157
First determination of the spin-parity of the $\Xi_c(3055)^{+,0}$ baryons	Phys. Rev. Lett. 134 (2025) 081901
New states and Spectroscopy	
Observation of a new charmed baryon decaying to $\Xi_c^+\pi^+\pi^-$	Phys. Rev. Lett. 132 (2025) 161901
Rare decays and decay properties	
Observation of the doubly-charmed-baryon decay $\Xi_{cc}^{++} \to \Xi_c^0\pi^+\pi^+$	JHEP 10 (2025) 136
Observation of Cabibbo-suppressed two-body hadronic decays and precision mass measurement of the Ω_c^0 baryon	Phys. Rev. Lett. 132 (2024) 081802
Search for D^0 meson decays to $\pi^+\pi^-e^+e^-$ and $K^+K^-e^+e^-$ final states	Phys. Rev. D111 (2025), L091101
Mixing and *CP* violation	
Search for resonance-enhanced *CP* and angular asymmetries in the $\Lambda_c^+ \to p\mu^+\mu^-$ decay at LHCb	Phys. Rev. D111 (2025) L091102
Search for charge-parity violation in semileptonically tagged $D^0 \to K^+\pi^-$ decays	JHEP 03 (2025) 149
Study of charm mixing and *CP* violation with $D^0 \to K^\pm\pi^\mp\pi^\pm\pi^\mp$ decays	JHEP 12 (2025) 153
Measurement of *CP* asymmetry in $D^0 \to K_S^0 K_S^0$ decays with the upgraded LHCb detector	LHCb-PAPER-2025-036 (submitted to