LHCb Overview

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On behalf of the LHCb Collaboration

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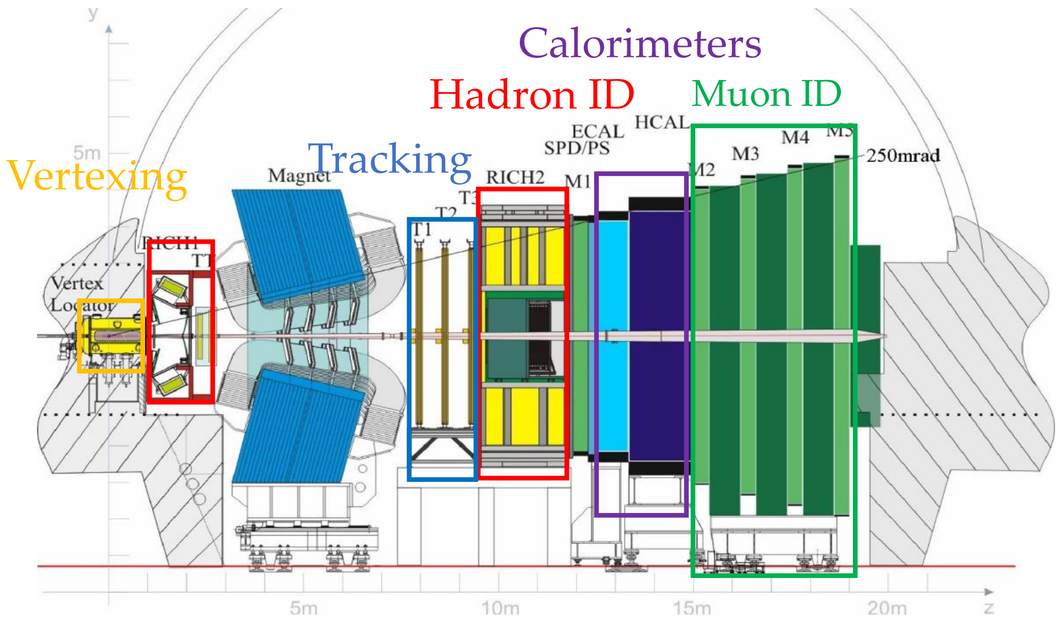
CONTENTS

1 Introduction

LHCb detector

General purpose detector specialized in beauty and charm hadrons



Int.J.Mod.Phys.A 30 (2015) 07

- Single-arm forward designed to study the b and c hadrons in forward region $2<\eta<5$
- Excellent tracking, momentum resolution and particle identification.

$\delta P/P \lesssim 1\%$ for $P < 100 GeV/c$
97% efficiency for e/μ with 3% pion mis-ID

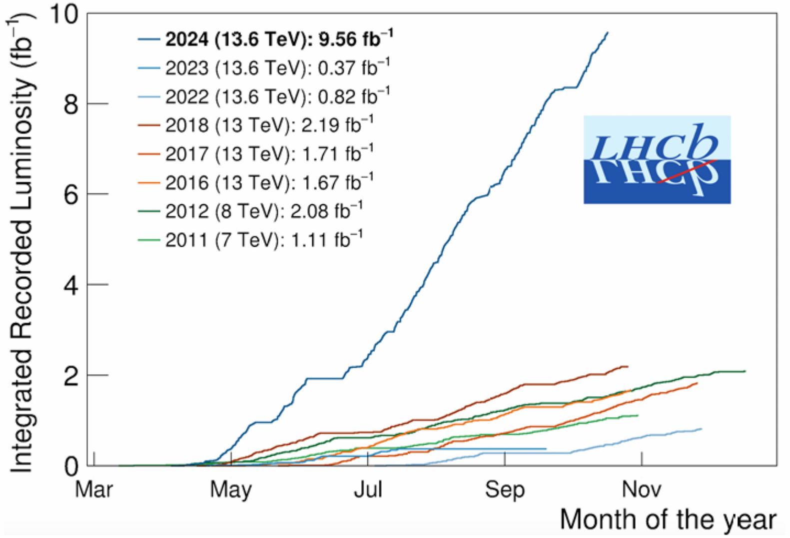
Indirectly search for New Physics

Luminosity and publication

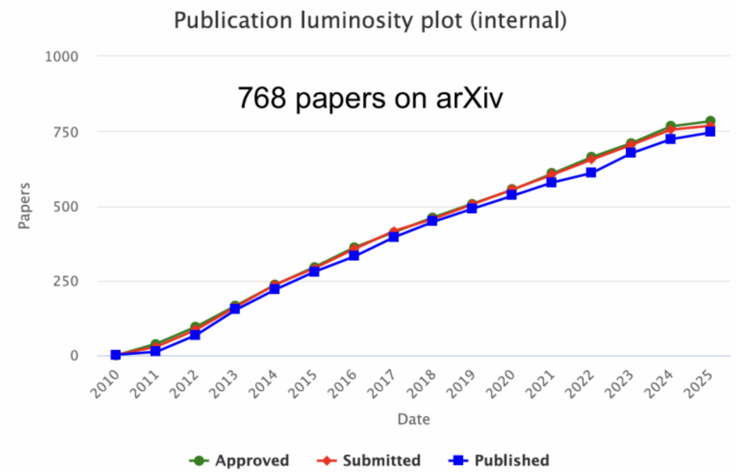
- Running Condition
  - Run 1: 2011+2012, 7, 8 TeV
  - Run 2: 2015-2018, 13 TeV
  - Run 3: 2022-2026, 13.6 TeV

Run3 data taking ongoing!

- Run 1(2011+2012): 3 fb^{-1} + Run 2 (2015-2018): 6 fb^{-1}
- 2024: 9.6 fb^{-1}



- Publication in 2025,
  - 13 paper submitted to arxiv
  - 22 papers published on journal



This talk cannot cover all the recent results; you can refer to the publication page for a full list of LHCb publications

See LHCb ALCM statistics page

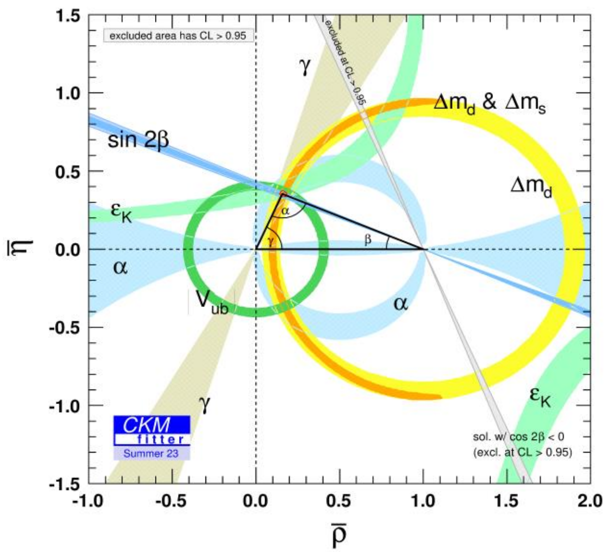
2 CKM matrix & CPV

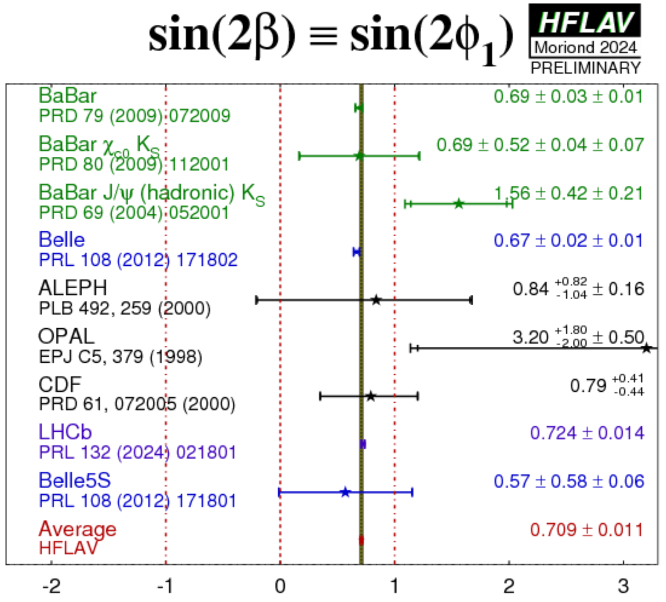
CPV measurements at LHCb

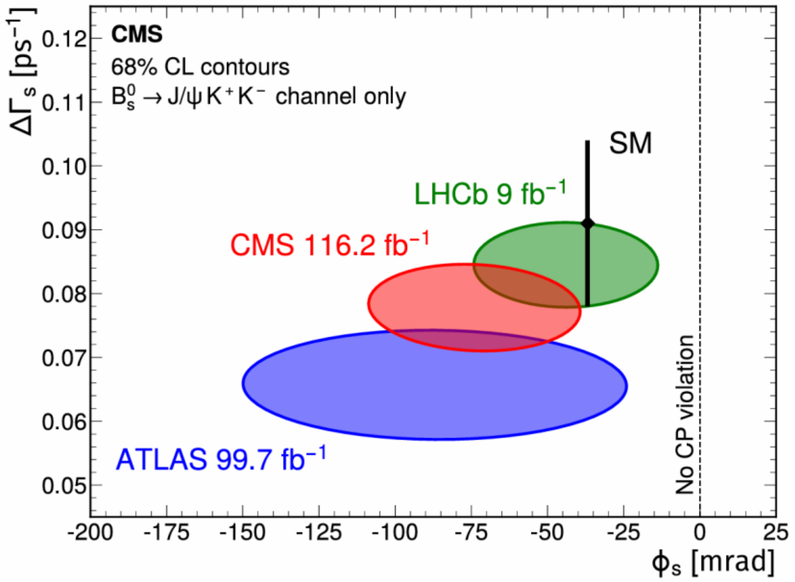
- CP violation arises from the presence of a complex phase in the CKM quark-mixing matrix
- Measuring the properties of the UT allows for precision tests of the SM assumptions
- Additional sources needed, within or beyond the SM， to explain the observed matter-antimatter asymmetry

$$\begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

LHCb plays an important role in CPV&CKM measurements:







CPV in $B^+ \to J/\psi\pi^+$ Decays

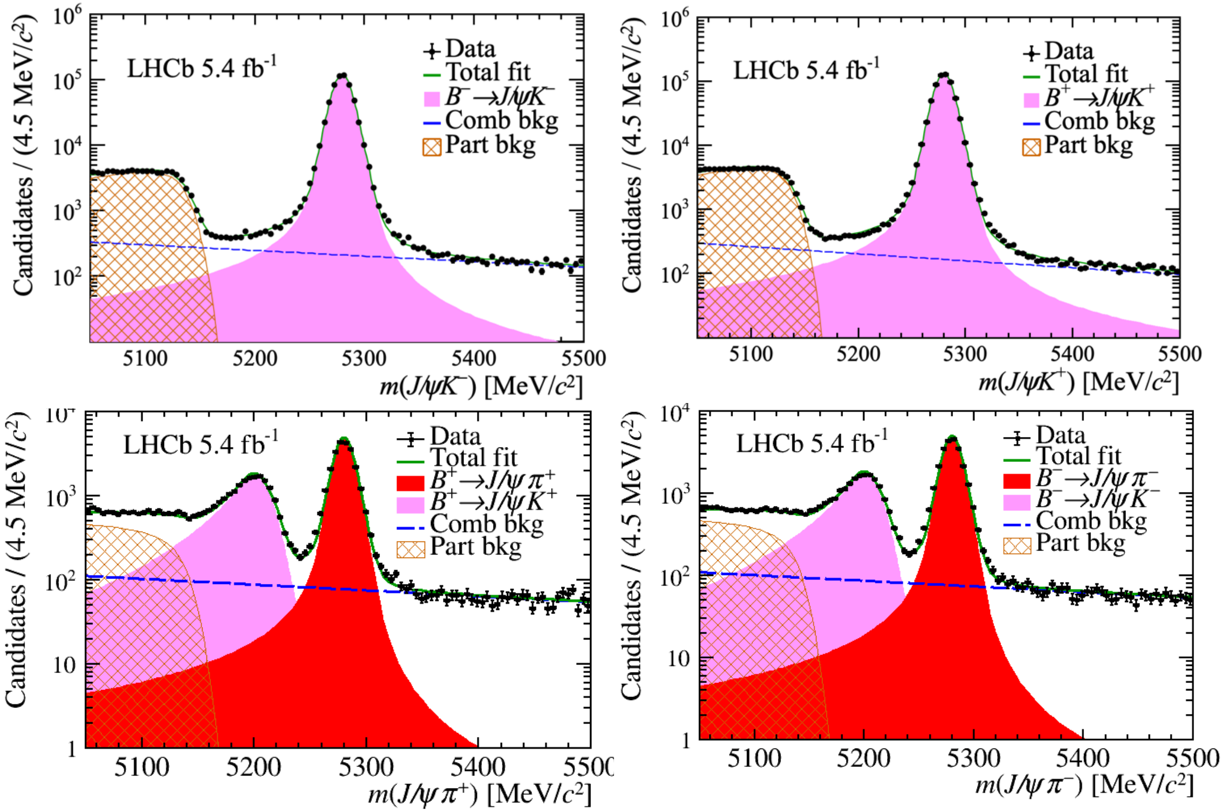
- $b \to c\bar{c}d$ decay penguin diagrams contribution not negligible wrt to tree-level, expect $\mathcal{O}(1\%)$ direct CP violation. [JHEP 03 (2015) 145 JPG 48, 065002 (2021)]

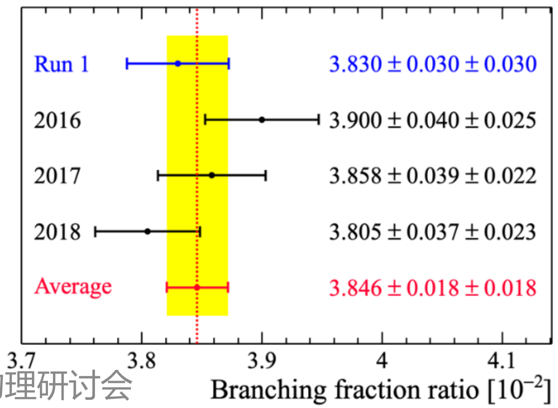
- Can improve understanding of penguin contribution to transitions (β from $B^0 \to J/\psi K^0$)

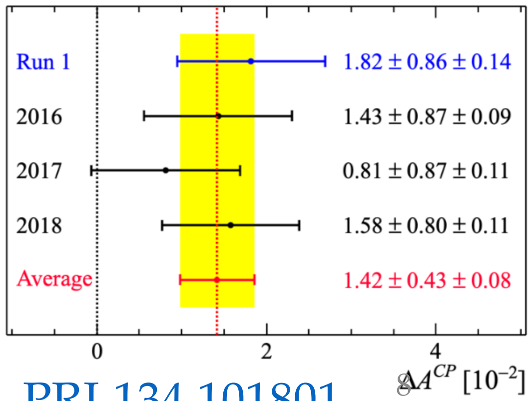
- Measured relative to control sample of $B^+ \to J/\psi K^+$ decays: cancellation of many systematics

$$\Delta A_{CP} = (1.42 \pm 0.43 \pm 0.08)\,\%$$

First evidence of direct violation in beauty to charmonia decays(3.2σ)







PRL134.101801

TD-CPV in $B \to DD$ decays

- For tree-level dominated decays,
  $S_f = \sin(2\beta + \Delta\phi_d + \Delta\phi_{d\,NP}) \approx \sin 2\beta$

- $B \to DD$ decays can probe the loop contribution to the measured values of $\beta_{(s)}$

- Results for $B^0 \to D^+D^-$:

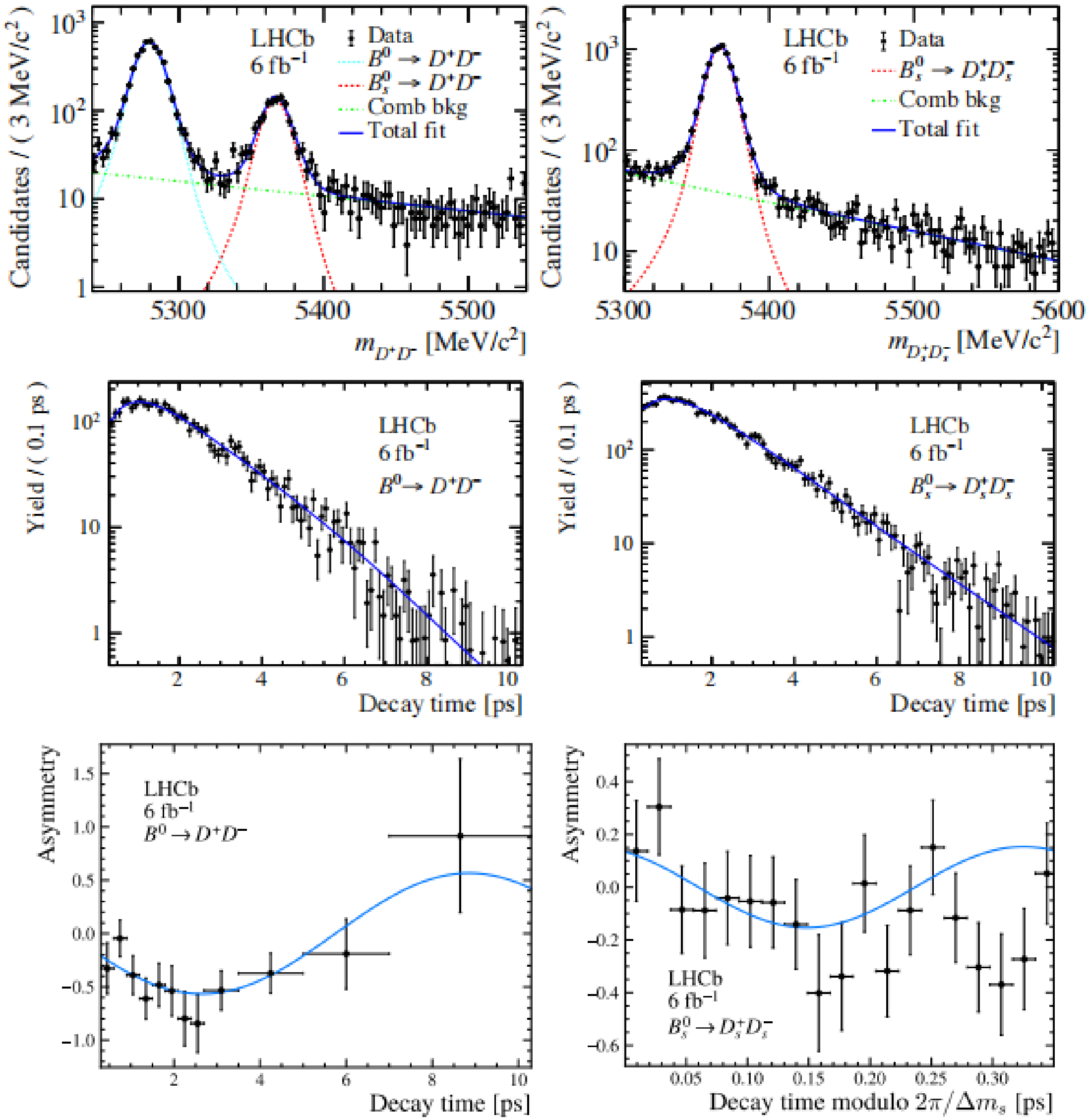
$$S_{D^+D^-} = -0.55 \pm 0.10\,(stat) \pm 0.01\,(syst),$$
$$C_{D^+D^-} = 0.13 \pm 0.10\,(stat) \pm 0.01\,(syst),$$

CP conservation excluded by > 6σ

- Results for $B_s^0 \to D_s^+D_s^-$:

$$\phi_s = -0.086 \pm 0.106\,(stat) \pm 0.028\,(syst)rad,$$
$$|\lambda_{D_s^+D_s^-}| = 1.145 \pm 0.126\,(stat) \pm 0.031\,(syst),$$

compatible with *CP* conservation



JHEP01(2025)061

TD-CPV in $B_s \to D_s K$ decays

▶ CPV in $B_s \to D_s K$ is highly sensitivity to $\gamma - 2\beta_s$ thanks to large ratio of interfering amplitudes

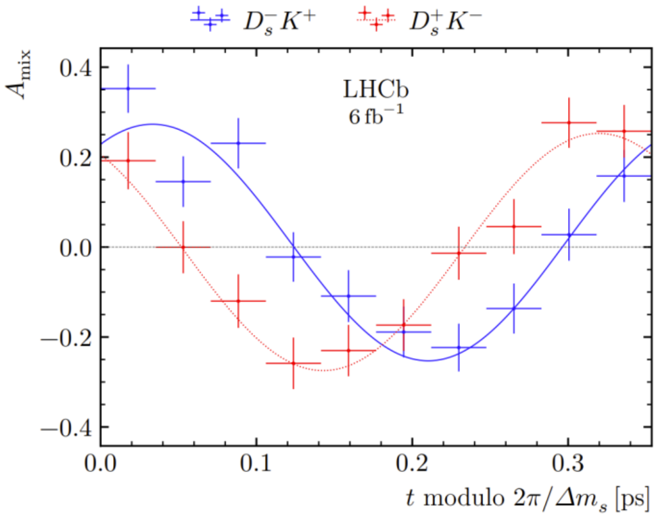
$$r_{D_sK} = |A(\bar{B}_s^0 \to D_s^- K^+)/A(B_s^0 \to D_s^- K^+) \approx 0.4$$

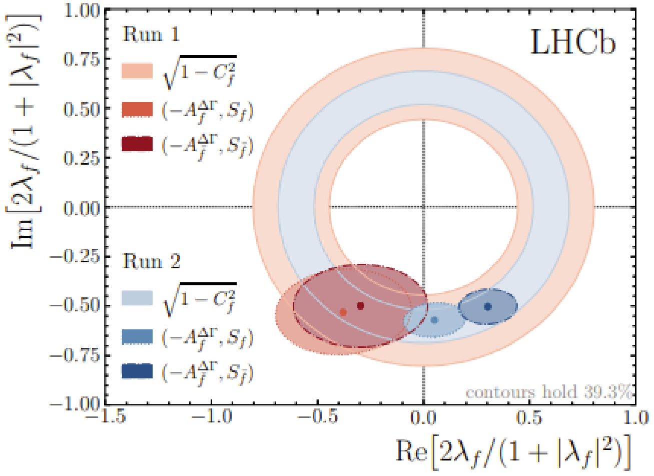
The CP-violating parameters are measured with a tagged decay-time fit

$$\begin{aligned}
C_f &= 0.791 \pm 0.061 \pm 0.022\,, \\
A_f^{\Delta\Gamma} &= -0.051 \pm 0.134 \pm 0.058\,, \\
A_{\bar{f}}^{\Delta\Gamma} &= -0.303 \pm 0.125 \pm 0.055\,, \\
S_f &= -0.571 \pm 0.084 \pm 0.023\,, \\
S_{\bar{f}} &= -0.503 \pm 0.084 \pm 0.025\,,
\end{aligned}$$

→

$$\begin{aligned}
\gamma &= (74 \pm 12)^\circ\,, \\
\delta &= (346.9^{+6.8}_{-6.6})^\circ\,, \\
r_{D_sK} &= 0.33 \pm 0.04,
\end{aligned}$$





JHEP 03(2025) 139

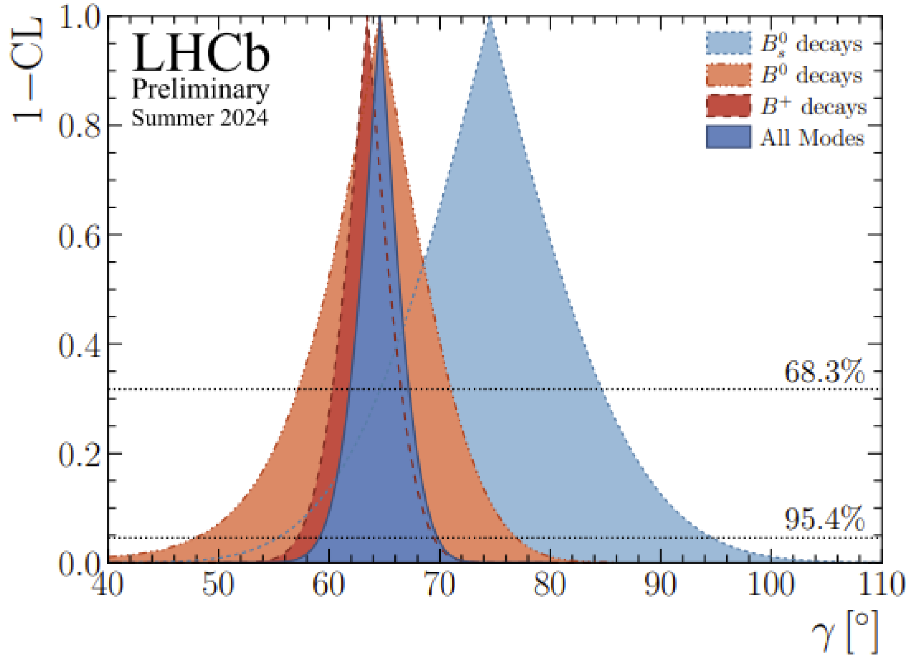
New combination of γ

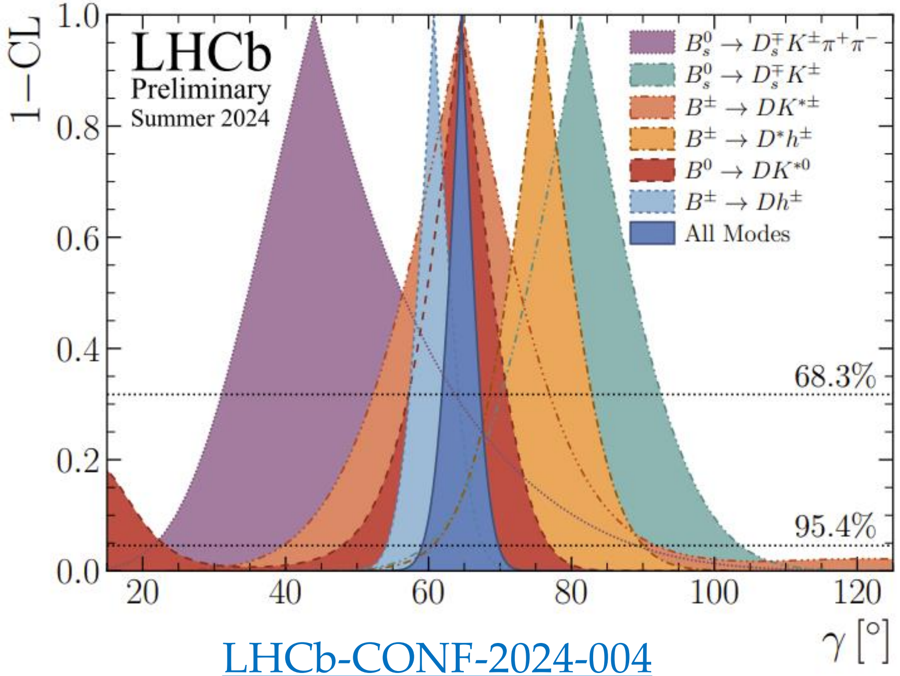
LHCb has previously measured CKM angle γ using $B^{\pm,0} \to Dh^{\pm,0}$ decays

Final combination on angle γ

$$\gamma = (64.6 \pm 2.8)^\circ$$

Combined precision on γ now below 3°





LHCb-CONF-2024-004

CPV in Baryon Decays

➢ *CP* asymmetries with $\Lambda_b^0 \to ph^-$ decays

Baryon CPV could appear in decays mediated by similar quark transition as known CP-violating meson decays (e.g. $B^0 \to K^+\pi^-$)

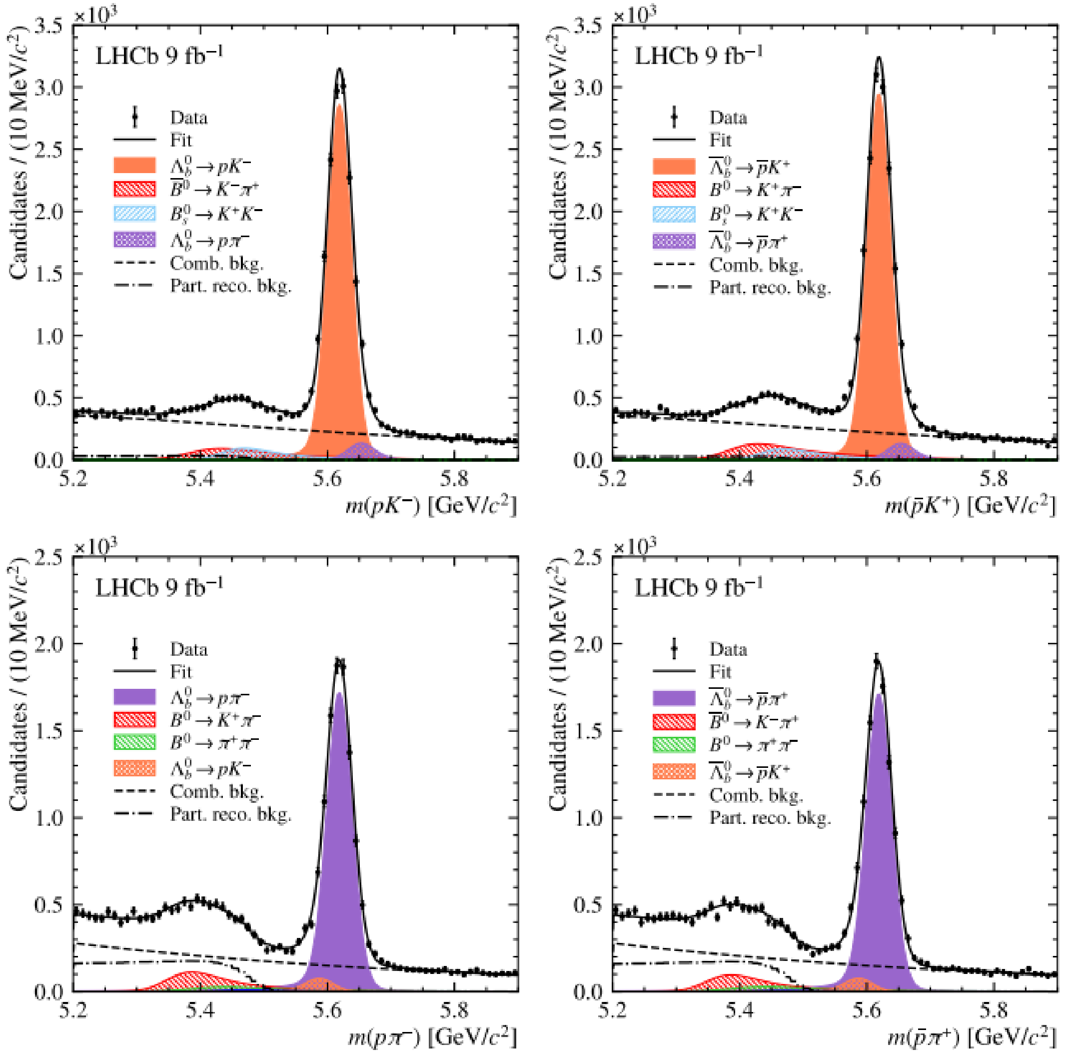
➢ Combined Run 1+2 results

$$A_{CP}(\Lambda_b^0 \to pK^-) = (-1.1 \pm 0.7 \pm 0.4)\,\%$$

$$A_{CP}(\Lambda_b^0 \to p\pi^-) = (0.2 \pm 0.8 \pm 0.4)\,\%$$

No CPV

- 3× improvement over current PDG average
- Statistic uncertainty dominated



arxiv:2412.13958

Measurement of Λ_b^0 decay parameters

- Decay parameters have been proposed by Lee and Yang (1957) to study hyperon decays ($\Lambda \to p\pi$)

$$\frac{d\Gamma}{d\cos\theta_1} \propto 1 + \alpha_{\Lambda_b^0}\alpha_{\Lambda_c^+}\cos\theta_1, \qquad \alpha \equiv \frac{2\Re(s^*p)}{|s|^2+|p|^2}, \quad \beta \equiv \frac{2\Im(s^*p)}{|s|^2+|p|^2}, \quad \gamma \equiv \frac{|s|^2-|p|^2}{|s|^2+|p|^2},$$

CP observable: $A_{CP}^{\alpha} \equiv \dfrac{\alpha(\Lambda)+\alpha(\overline{\Lambda})}{\alpha(\Lambda)-\alpha(\overline{\Lambda})}$

s and p denote the parity-violating S-wave and parity-conserving P-wave amplitude

- Results of angular fit

Decay	α	$\bar{\alpha}$	$\langle\alpha\rangle$	A_α
$\Lambda_b^0 \to \Lambda_c^+\pi^-$	$-1.010 \pm 0.011 \pm 0.003$	$0.996 \pm 0.011 \pm 0.003$	$-1.003 \pm 0.008 \pm 0.005$	$0.007 \pm 0.008 \pm 0.005$
$\Lambda_b^0 \to \Lambda_c^+K^-$	$-0.933 \pm 0.042 \pm 0.014$	$0.995 \pm 0.036 \pm 0.013$	$-0.964 \pm 0.028 \pm 0.015$	$-0.032 \pm 0.029 \pm 0.006$

- First measurement of Λ_b^0 decay parameters

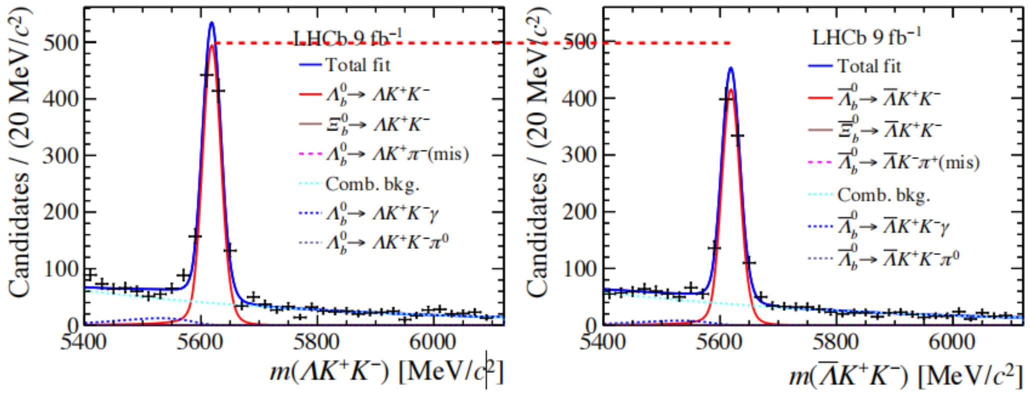
- All A_α consistent with zero

No CPV observed

Evidence for CPV in $\Lambda_b^0 \to \Lambda h^+ h^-$

- CP violation in $\Lambda_b^0/\Xi_b^0 \to \Lambda h^+ h^- (h = \pi, K)$ decays
  - similar dynamics $B \to hh'h''$
  - possible CPV enhancement

PRL134(2024)101902

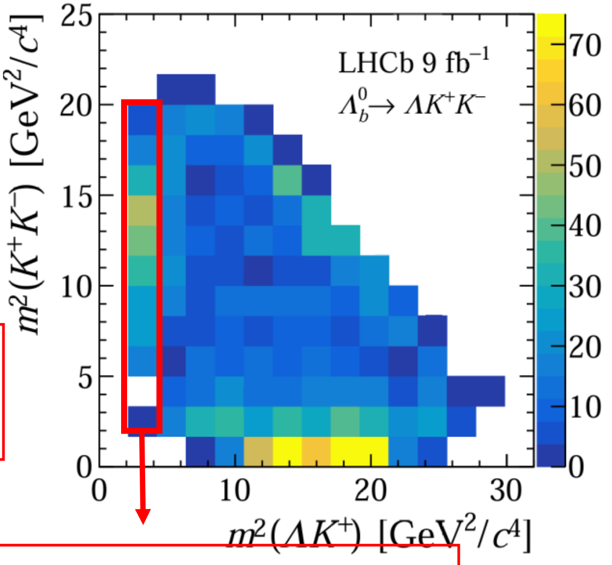


- $\Lambda_b^0/\Xi_b^0 \to \Lambda h^- h'^-$ decays

$$\Delta A^{CP}(\Lambda_b^0 \to \Lambda \pi^+ \pi^-) = -0.013 \pm 0.053 \pm 0.018,$$
$$\Delta A^{CP}(\Lambda_b^0 \to \Lambda K^+ \pi^-) = -0.118 \pm 0.045 \pm 0.021,$$
$$\Delta A^{CP}(\Lambda_b^0 \to \Lambda K^+ K^-) = 0.083 \pm 0.023 \pm 0.016,$$
$$\Delta A^{CP}(\Xi_b^0 \to \Lambda K^- \pi^+) = 0.27 \pm 0.12 \pm 0.05,$$

- CP asymmetries measured as difference wrt to control mode $\Lambda_b^0 \to \Lambda_c^+ (\to \Lambda\pi^+)\pi^-$ (null CPV expected)
- Evidence of direct violation in $\Lambda_b^0/\Xi_b^0 \to \Lambda K^+ K^-$ decays (3.1σ)
- Possible interpretation: enhancement from $N^{*+} \to \Lambda K^+$ (3.2σ) resonance

Amplitude analysis needed to clarify

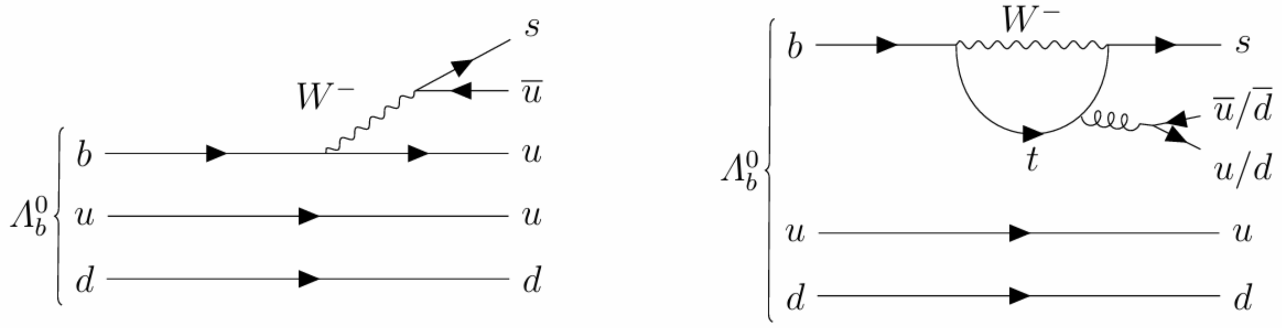


$\Delta A_{CP} = (16.5 \pm 5.1)\%$

Observation of CPV in $\Lambda_b^0 \to pK^-\pi^+\pi^-$ decays

arxiv:2503.16954

- CPV arises from interference between tree and loop amplitudes
- Resonant structure may enhance CPV across the phase space



$$A_{CP} \equiv \frac{N(\Lambda_b^0 \to K^-\pi^+\pi^-) - N(\Lambda_b^0 \to \overline{p}K^+\pi^-\pi^+)}{N(\Lambda_b^0 \to K^-\pi^+\pi^-) + N(\overline{\Lambda}_b^0 \to \overline{p}K^+\pi^-\pi^+)}$$

$$A_{CP} = (2.45 \pm 0.46 \pm 0.10)\ \%$$

- First observation of direct violation in baryon decays (5.2 σ from 0)

Amplitude analysis needed!

Decay topology	Mass region (GeV/c^2)	$\mathcal{A}_{CP}$
$\Lambda_b^0 \to R(pK^-)R(\pi^+\pi^-)$ (4σ)	$m_{pK^-} < 2.2$, $m_{\pi^+\pi^-} < 1.1$	$(5.3 \pm 1.3 \pm 0.2)\%$
$\Lambda_b^0 \to R(p\pi^-)R(K^-\pi^+)$	$m_{p\pi^-} < 1.7$, $0.8 < m_{\pi^+K^-} < 1.0$ or $1.1 < m_{\pi^+K^-} < 1.6$	$(2.7 \pm 0.8 \pm 0.1)\%$
$\Lambda_b^0 \to R(p\pi^+\pi^-)K^-$ (6σ)	$m_{p\pi^+\pi^-} < 2.7$	$(5.4 \pm 0.9 \pm 0.1)\%$
$\Lambda_b^0 \to R(K^-\pi^+\pi^-)p$	$m_{K^-\pi^+\pi^-} < 2.0$	$(2.0 \pm 1.2 \pm 0.3)\%$

The details of baryon CPV will be presented by Shanzhen this afternoon

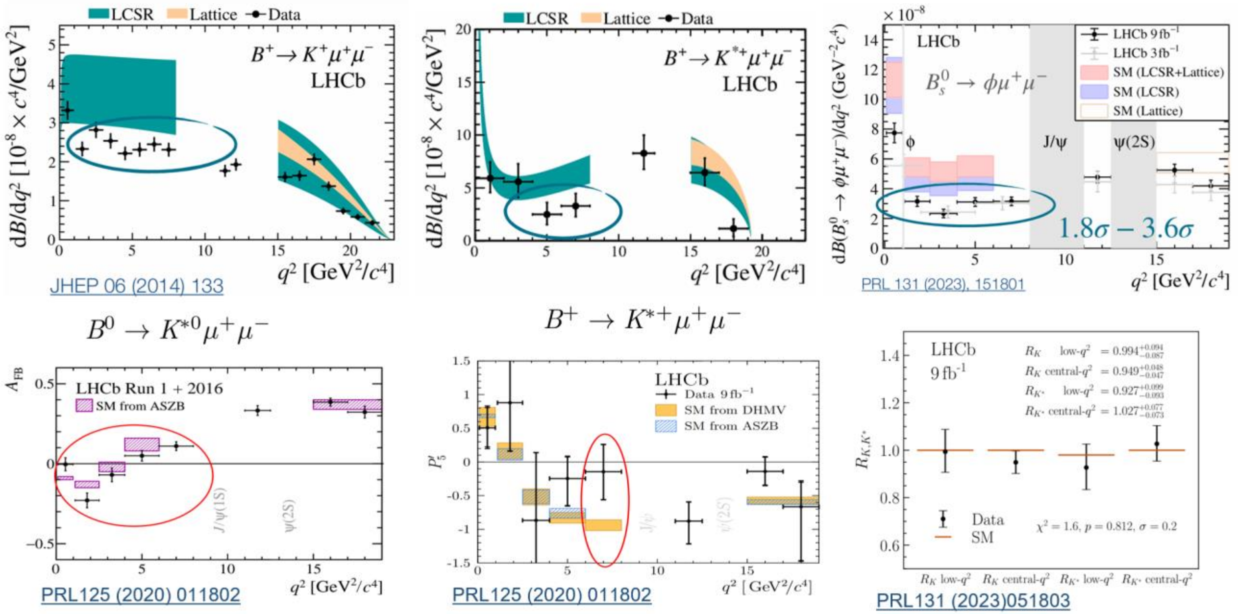
3

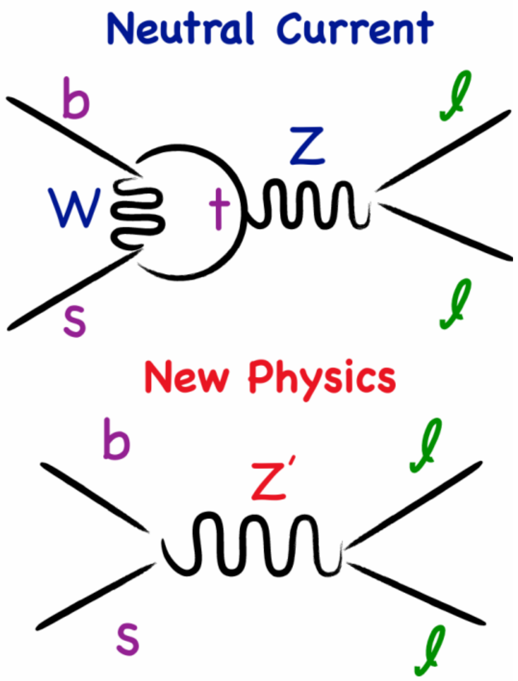
Rare Decays & LFU

Study of b →sℓℓ transitions at LHCb

Processes mediated by b →sℓℓ transitions are sensitive to New Physics (NP) ($Br \sim 10^{-7} - 10^{-6}$)

- Suppressed in the SM:
- High energy mediators can modify the amplitudes & CPV observables





LHCb has performed many interesting measurements in b →sℓℓ decays including BF, Angular observables and LFV ratio.

Angular analysis of $\Lambda_b^0 \to pK\mu^+\mu^-$

▶ Study BF and angular observables coefficients measured in q^2 and m_{pK} bins

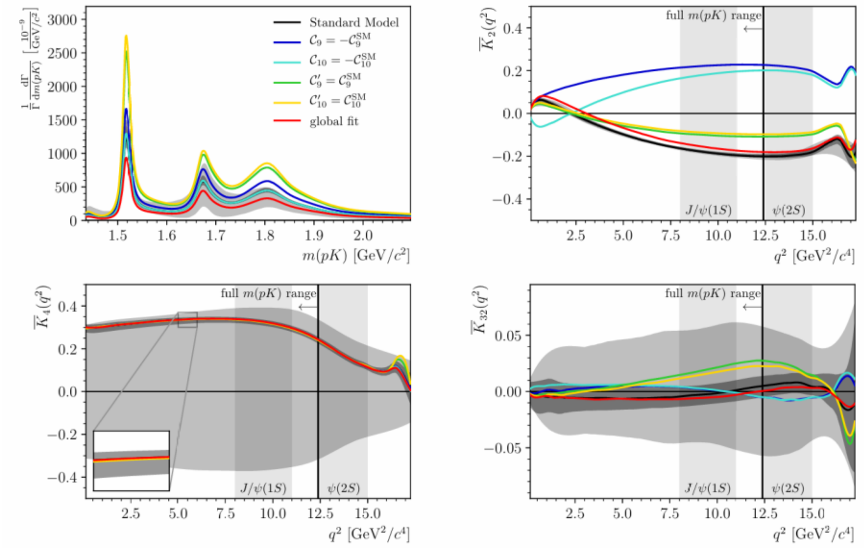
▶ BF measured with respect to $\Lambda_b^0 \to J/\psi pK$

▶ Decay rate described by 46 angular moments K_i

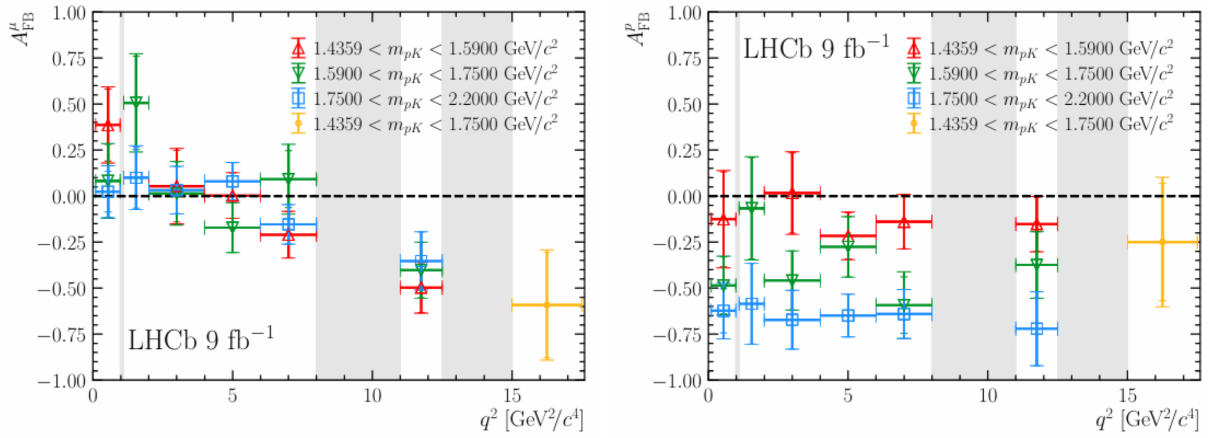
$$\frac{d^5\Gamma}{d\boldsymbol{\Phi}} = \frac{3}{8\pi}\sum_{i=1}^{46} K_i\left(q^2, m_{pK}^2\right) f_i(\boldsymbol{\Omega})$$

$$\boldsymbol{\Phi} = \left(q^2, m_{pK}^2, \cos\theta_\mu, \cos\theta_p, \phi\right)$$

$$\boldsymbol{\Omega} = \left(\cos\theta_\mu, \cos\theta_p, \phi\right)$$



- Enhancement at very low dimuon invariant mass which disagrees with quark-model predictions
- Low signal significance at high di-hadron mass (no angular observables determined)
- Angular moments statistically limited



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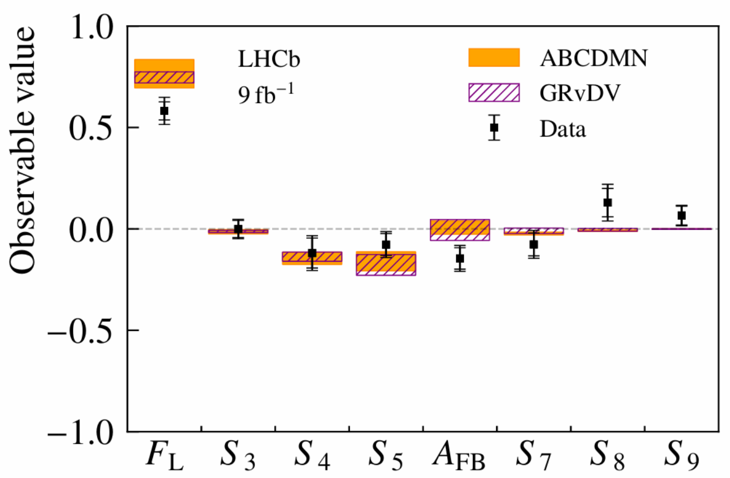
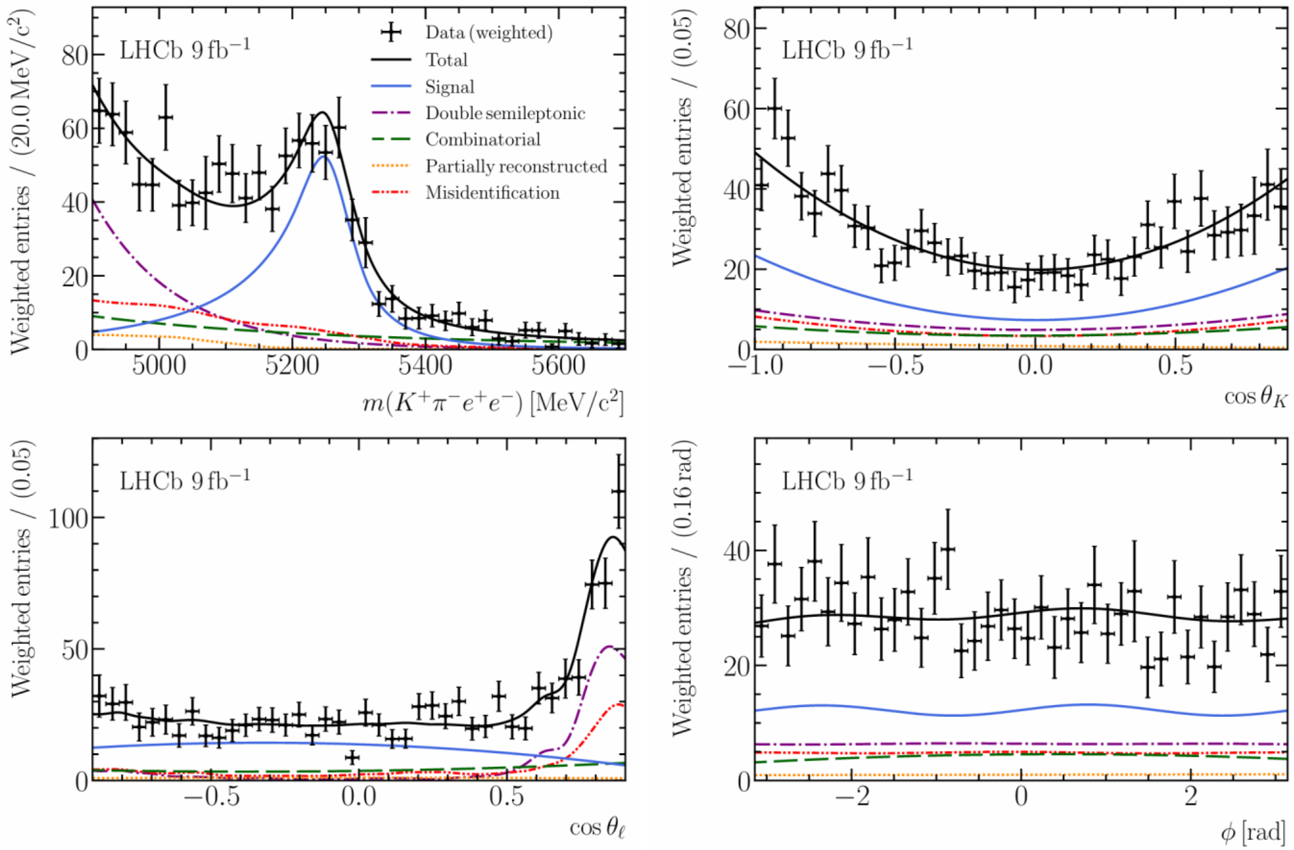
Angular analysis of $B^0 \to K^{*0}e^+e^-$

- Decay rates fully described in terms of angular coefficients, related to wilson coefficients
- Angular observables extracted from 4D fit: General good agreement with SM predictions
  - Most precise measurements up to date
- No strong sign of LFU violation





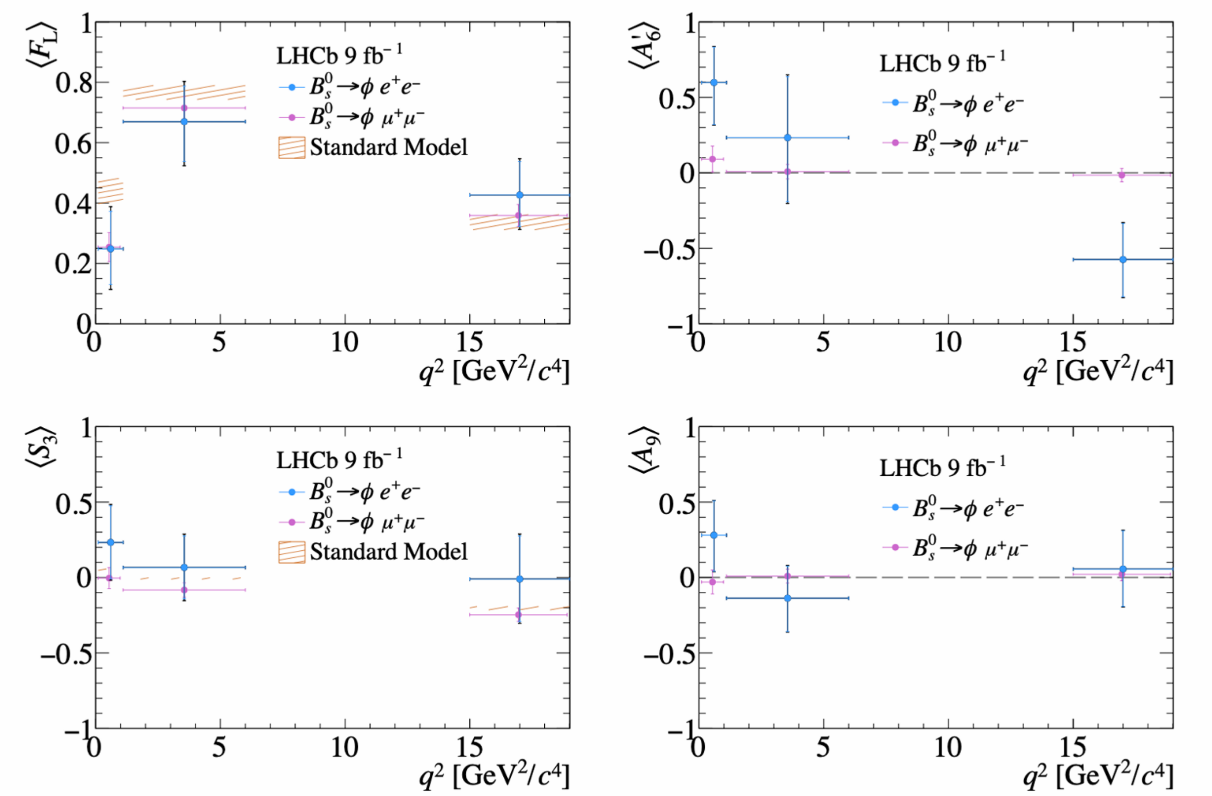
[arxiv:2502.10291](https://arxiv.org/abs/2502.10291)

Angular analysis of $B_s^0 \to \phi e^+ e^-$ decay

- Angular analysis of similar decay mode in the low, central and high q^2 regions, to extract angular coefficients

- Results compatible with SM predictions and previous measurements on $B_s^0 \to \phi\mu^+\mu^-$ [JHEP 11 (2021) 43]

Observable	$0.1 < q^2 < 1.1\,\mathrm{GeV}^2/c^4$	$1.1 < q^2 < 6.0\,\mathrm{GeV}^2/c^4$	$15.0 < q^2 < 19.0\,\mathrm{GeV}^2/c^4$
$\langle F_\mathrm{L}\rangle$	$0.25\,^{+0.12}_{-0.12} \pm 0.06$	$0.67\,^{+0.12}_{-0.13} \pm 0.06$	$0.43\,^{+0.11}_{-0.10} \pm 0.05$
$\langle A_6'\rangle$	$0.60\,^{+0.23}_{-0.28} \pm 0.05$	$0.24\,^{+0.40}_{-0.42} \pm 0.09$	$-0.57\,^{+0.24}_{-0.25} \pm 0.05$
$\langle S_3\rangle$	$0.23\,^{+0.24}_{-0.24} \pm 0.07$	$0.07\,^{+0.21}_{-0.21} \pm 0.07$	$-0.01\,^{+0.29}_{-0.28} \pm 0.08$
$\langle A_9\rangle$	$0.28\,^{+0.23}_{-0.24} \pm 0.04$	$-0.14\,^{+0.23}_{-0.24} \pm 0.04$	$0.06\,^{+0.25}_{-0.25} \pm 0.05$



Statistic limited， require more data for further improvement

arxiv:2504.06346

Photon polarisation constraints from $B_s^0 \to \phi e^+ e^-$

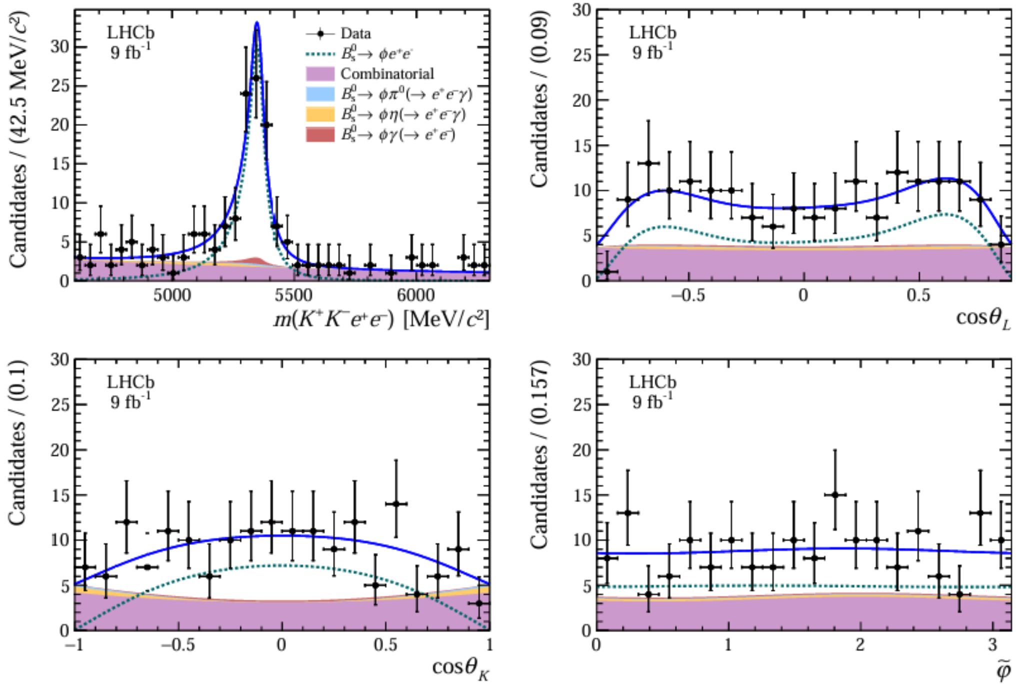
- Perform angular analysis at very low q^2 region , angular observables are sensitive to C_7 and C_7'

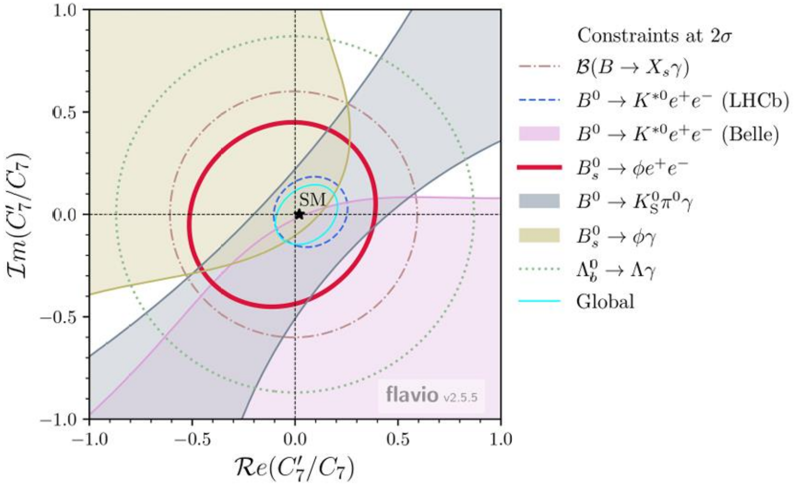
  *First observation of $B_s^0 \to \phi e^+ e^-$ decay

- Consistent with the SM predictions

$q^2 \in [0.0009, 0.2615]\ \mathrm{GeV}^2/c^4$

JHEP03(2025)047





$A_T^{(2)} = -0.045 \pm 0.235 \pm 0.014,$

$A_T^{\mathcal{I}mCP} = 0.002 \pm 0.247 \pm 0.016,$

Sensitive to photon polarisation

$A_T^{\mathcal{R}eCP} = 0.116 \pm 0.155 \pm 0.006,$

Fwd-bkd asymmetry

$F_L = (0.4 \pm 5.6 \pm 1.2)\%,$

Longitudinal polarisation

LFU ratio with $B_s^0 \to \phi e^+ e^-$ decays (R_ϕ)

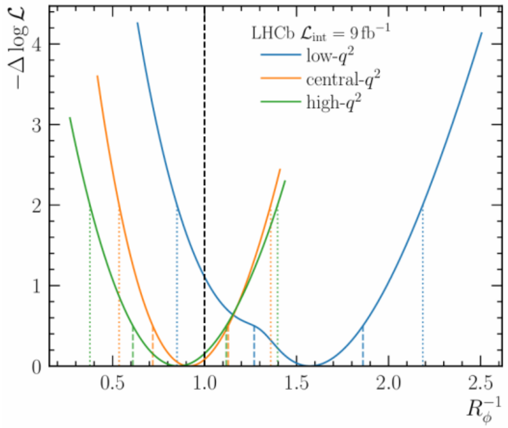
- ✓ First LFU test with B_s^0 decay
- ✓ Measurement performed in three q^2 regions
  - ▶ low − q^2: $0.1 < q^2 < 1.1$ Gev$^2/c^4$
  - ▶ central − q^2: $1.1 < q^2 < 6.0$ Gev$^2/c^4$
  - ▶ high − q^2: $15 < q^2 < 19$ Gev$^2/c^4$
- ✓ Cross checks using J/ψ and $\psi(2S)$ region:

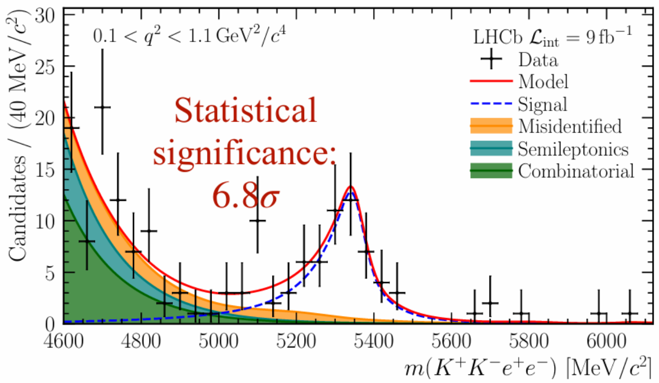
$$R_{J/\psi} = 0.997 \pm 0.013, R_{\psi(2S)} = 1.010 \pm 0.026$$

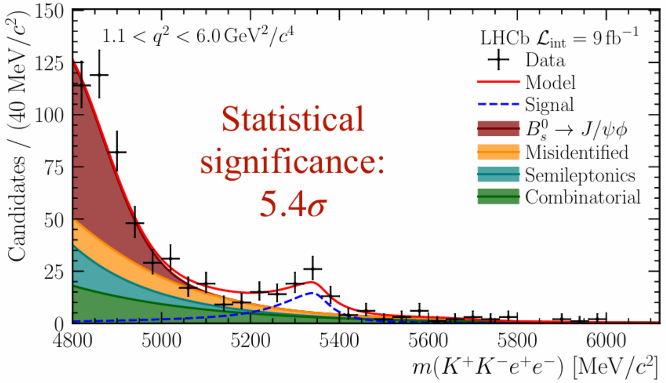
- ✓ Results in agreement with SM predictions

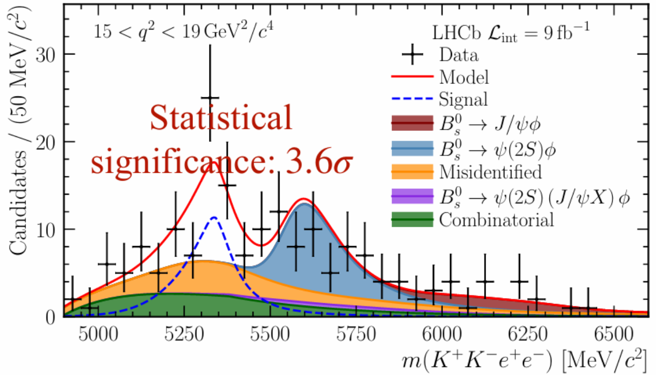
First time

q^2 [GeV$^2/c^4$]	R_ϕ^{-1}
$0.1 < q^2 < 1.1$	$1.57\,^{+0.28}_{-0.25} \pm 0.05$
$1.1 < q^2 < 6.0$	$0.91\,^{+0.20}_{-0.19} \pm 0.05$
$15.0 < q^2 < 19.0$	$0.85\,^{+0.24}_{-0.23} \pm 0.10$









PRL134(2025), 121803

LFU ratio with $B^+ \to K^+\pi^+\pi^- l^+ l^- (R(K\pi\pi))$

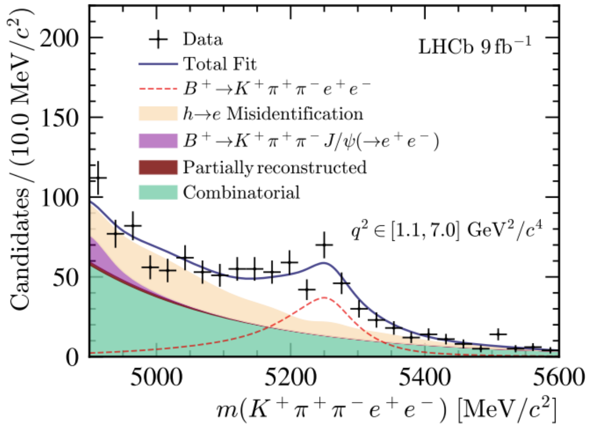
- ✓ Measurement performed in central-q^2 region and inclusive $K\pi\pi$ system
- ✓ First observation of $B^+ \to K^+\pi^+\pi^- e^+ e^-$ decay
- ✓ Cross checks using J/ψ and $\psi(2S)$ region:

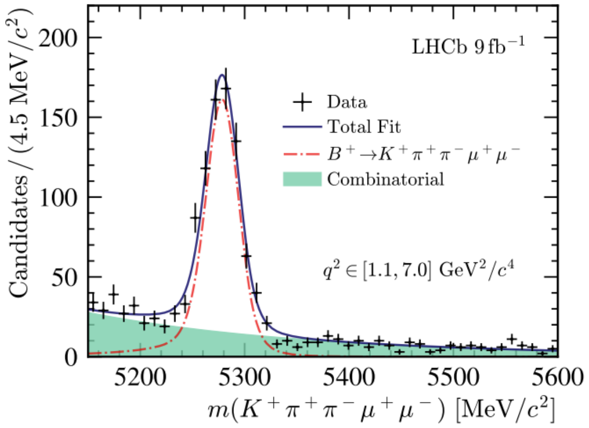
$$R_{J/\psi} = 1.033 \pm 0.017\ ,\ R_{\psi(2S)} = 1.033 \pm 0.017$$

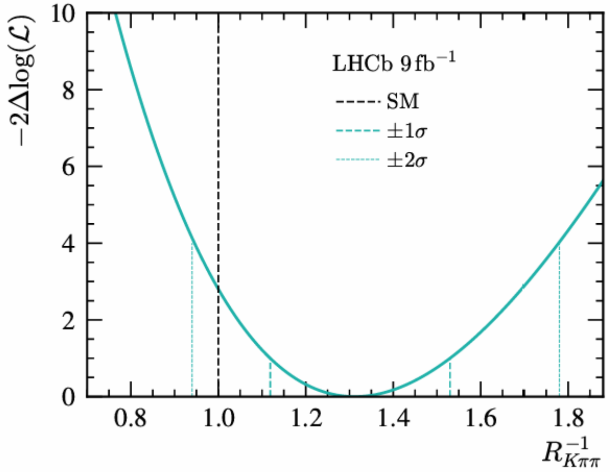
- ✓ Compatible with the SM

$$R_{K\pi\pi} = 1.31^{+0.18}_{-0.17}(\text{stat})\ ^{+0.12}_{-0.09}(\text{syst})$$

Potential to perform the measurement in more q^2 region using larger stat.







arxiv:2412.11645

LFU ratio with $B^+ \to K^+ l^+ l^-$ in high $q^2 (R_K)$

LHCb-PAPER-2024-056, in preparation

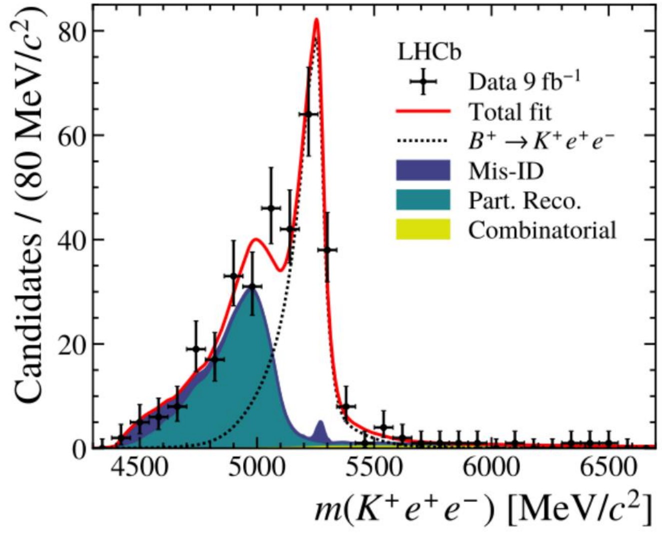
- Measurement performed in high-q^2 region
- Most precise LFU test above the psi(2S) mass
- Cross checks using J/ψ and $\psi(2S)$ region:

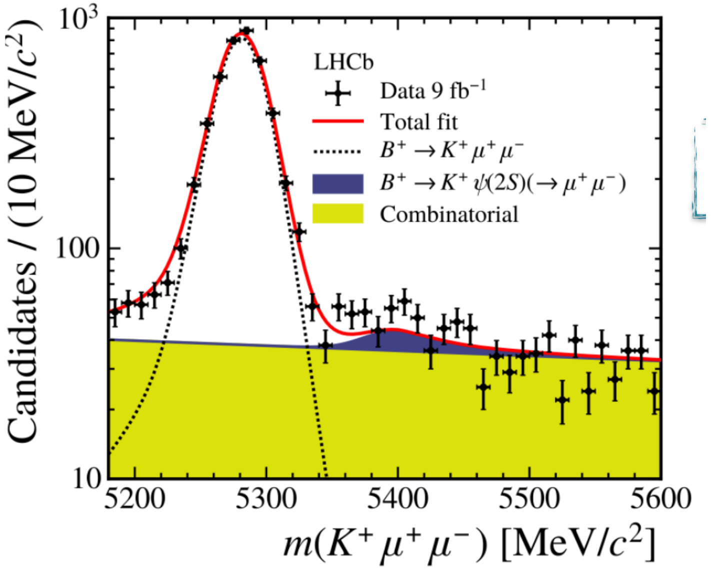
$$R_{J/\psi} = 0.997 \pm 0.003 \pm 0.055,$$
$$R_{\psi(2S)} = 1.002 \pm 0.009 \pm 0.004$$

- Result of R_K

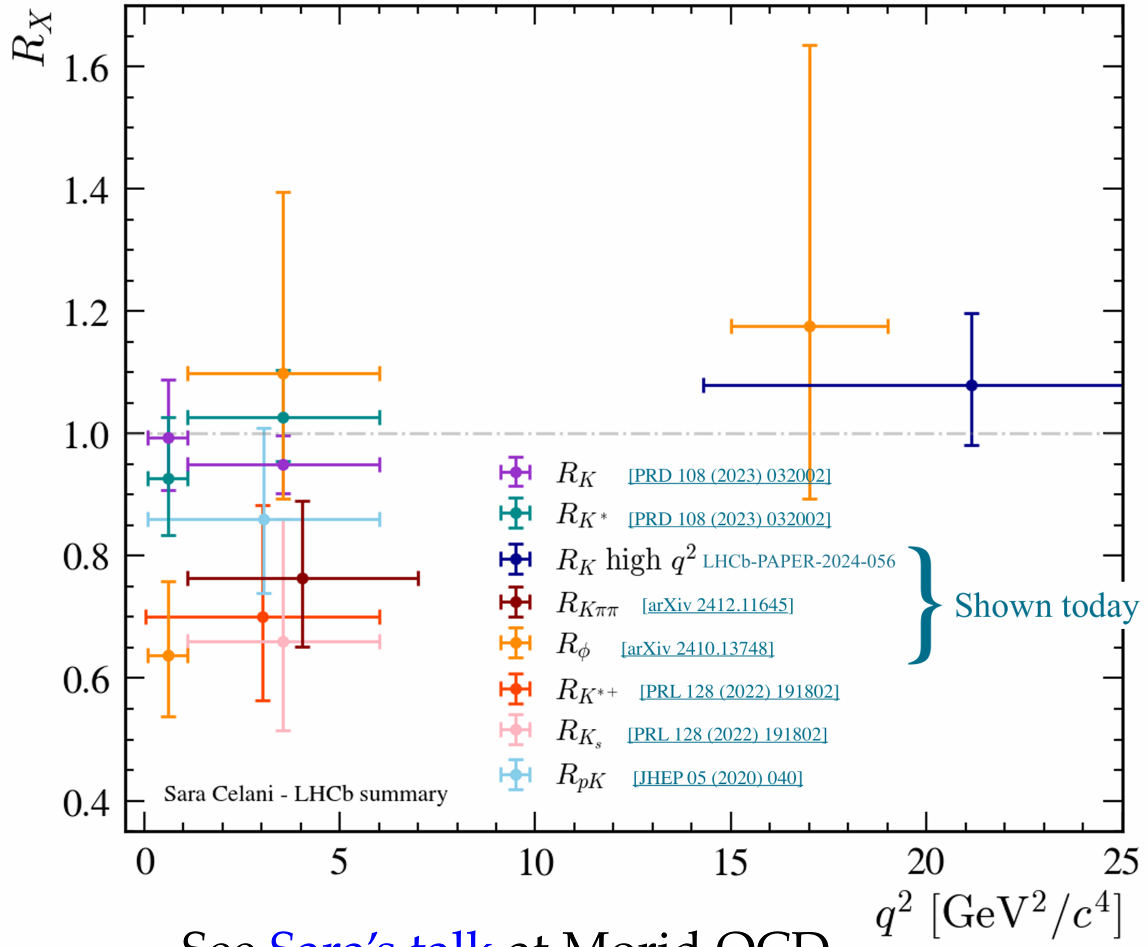
$$R_K(q^2 > 14.3\ \mathrm{GeV}^2/c^4) = 1.08^{+0.11}_{-0.09}{}^{+0.04}_{-0.04}$$

Compatible with the SM





Summary of LFU ratio measurements



See Sara's talk at Morid QCD

Search for LFV decays

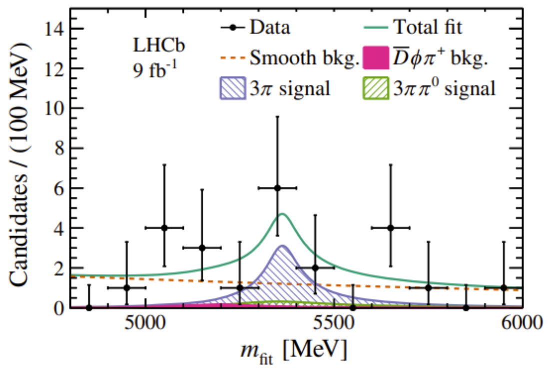
Any observation of a charged LFV decay would provide clear evidence for physics beyond the SM

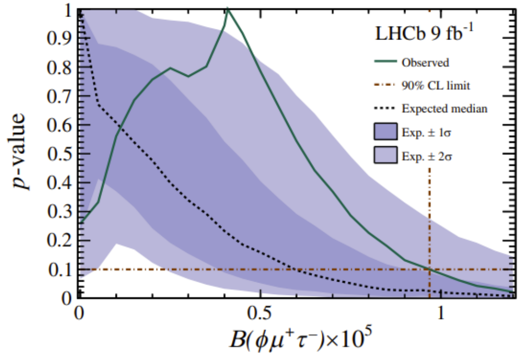
Phys. Rev. D110 (2024) 7

- Search for rare decay $B_s^0 \to \phi\mu\tau$
  - The first limit on this LFV decay

$\mathcal{B}(B_s^0 \to \phi\mu^+\tau^-) < 1.0 \times 10^{-5}$at 90%CL,

$\mathcal{B}(B_s^0 \to \phi\mu^+\tau^-) < 1.1 \times 10^{-5}$at 95%CL.

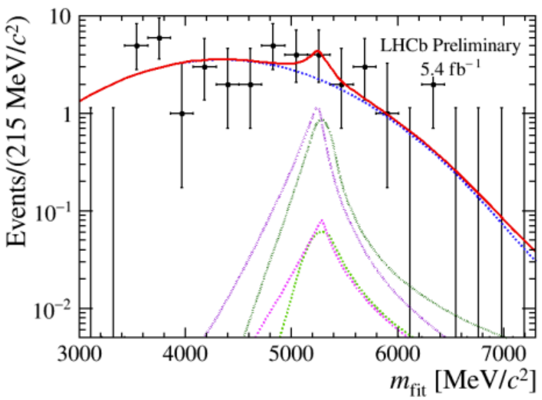


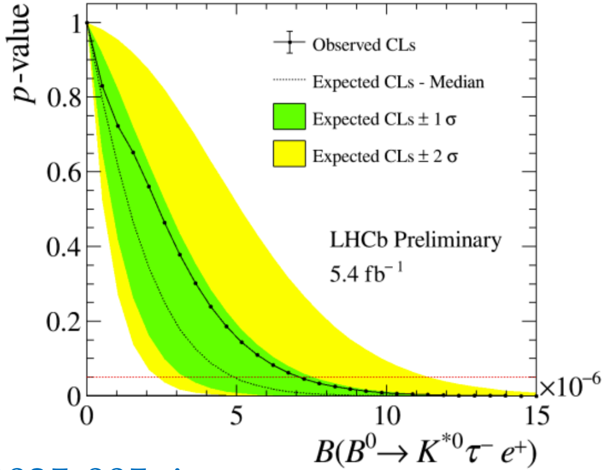


- Search for rare decay $B^0 \to K^{*0}\tau^{\pm}e^{\mp}$
  - Mass re-fitted including missing neutrino momentum and kinematic constraints

Model	Upper limit $[10^{-6}]$ $B^0 \to K^{*0}\tau^-e^+$	$B^0 \to K^{*0}\tau^+e^-$
Phase-space	5.9 (7.1)	4.9 (5.9)
Left-handed	6.3 (7.7)	5.4 (6.4)
Scalar	6.6 (8.0)	5.7 (6.8)

the most stringent upper limits placed on $b \to s\tau l$ transitions

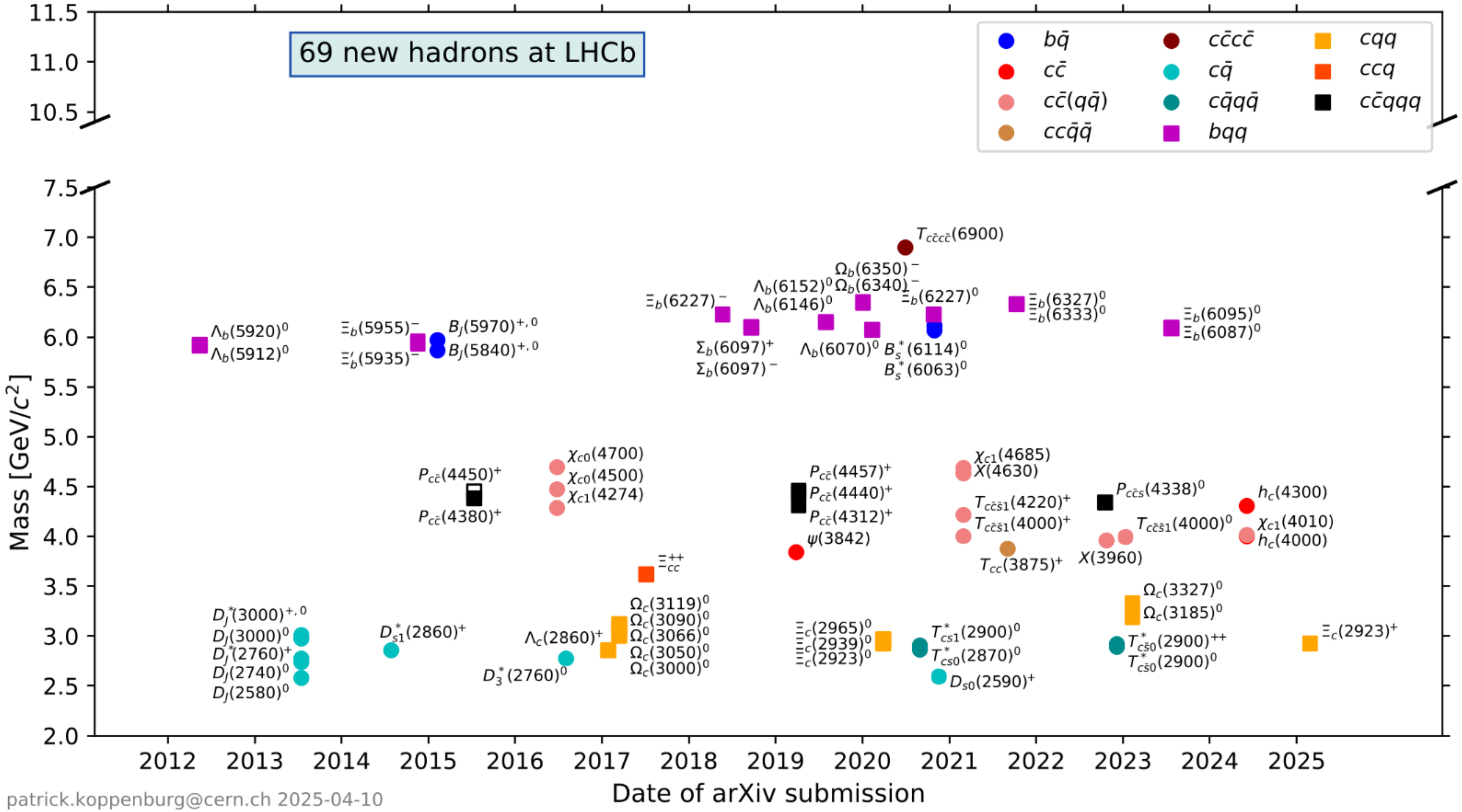




LHCb-PAPER-2025-005, in preparation

4 Spectroscopy

New hadrons at LHCb



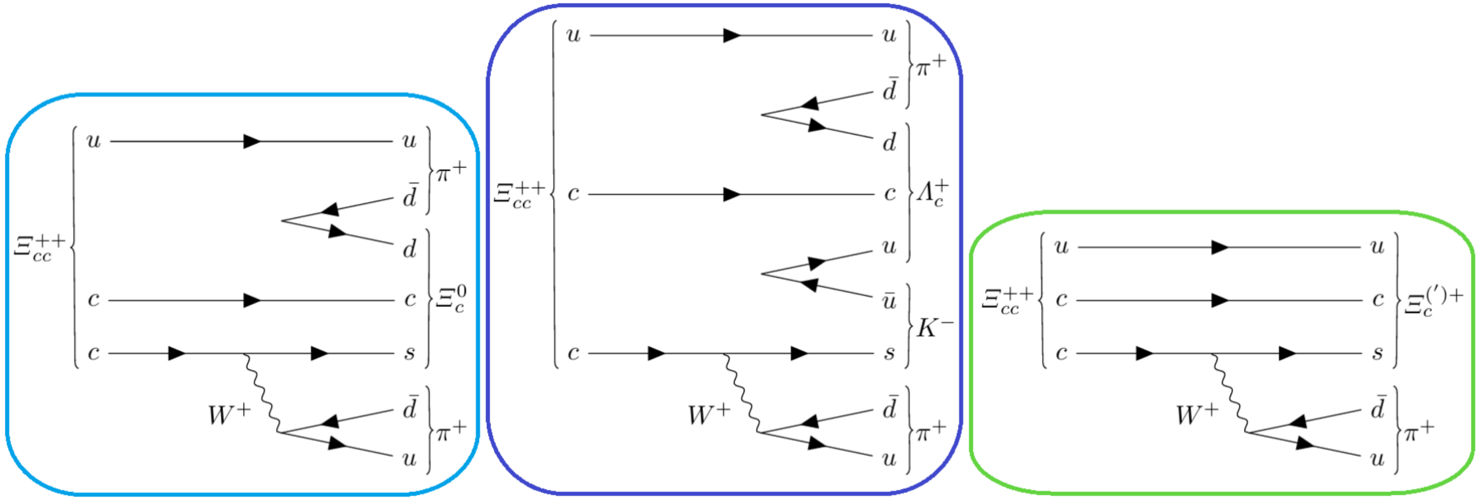
https://koppenburg.ch/particles.html

Doubly-charmed-baryon decay

- Doubly charmed baryon Ξ_{cc}^{++} observed in the $\Lambda_c^+ K^- \pi^+ \pi^+$ mass spectrum by LHCb in 2017 [Phys.Rev.Lett.119,112001(2017)]

- Only three decay modes observed so far, additional measurements essential to better understand the decay dynamics of doubly charmed baryons

- $\Xi_{cc}^{++} \to \Xi_c^0 \pi^+ \pi^+$ mediated by the same $b \to s u \bar{d}$ weak transition of $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$ and $\Xi_{cc}^{++} \to \Xi_c^{(\prime)+} \pi^+$



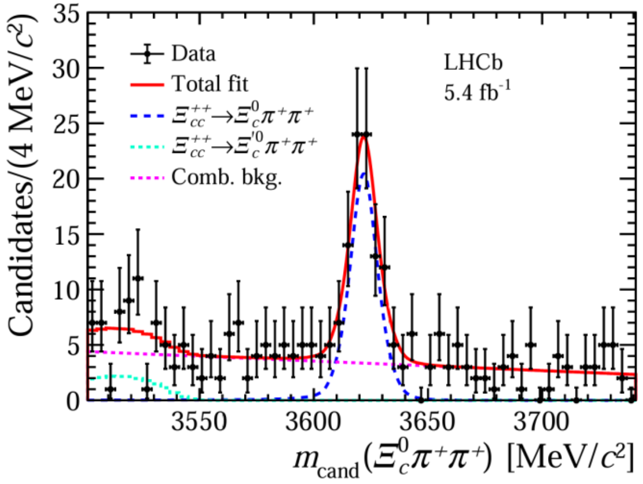
Doubly-charmed baryon decay

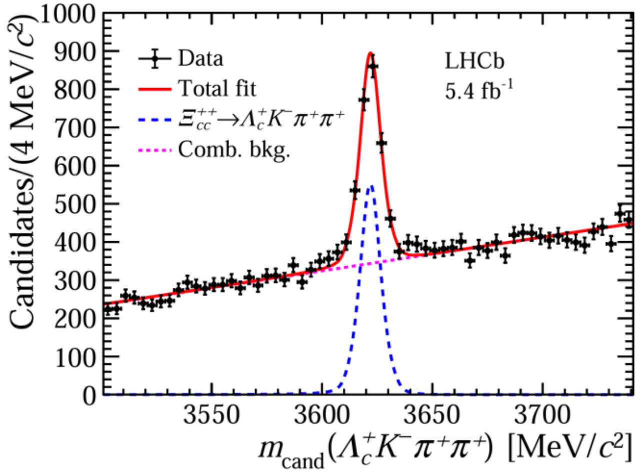
- The significance of the $\Xi_{cc}^{++} \to \Xi_c^0 \pi^+ \pi^+$ signal is estimated to be above 10 σ Most of the systematics cancel in the ratio of branching fractions

- Use $\Lambda_c^+ K^- \pi^+ \pi^+$ decay as the normalization channel

$$\mathcal{R} = \frac{B(\Xi_{cc}^{++} \to \Xi_c^0 \pi^+ \pi^+) \times B(\Xi_c^0 \top K^- K^- \pi^+)}{B(\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+) \times B(\Lambda_c^+ \top K^- \pi^+)} = 0.105 \pm 0.014_{\text{stat}} \pm 0.007_{\text{syst}}$$

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



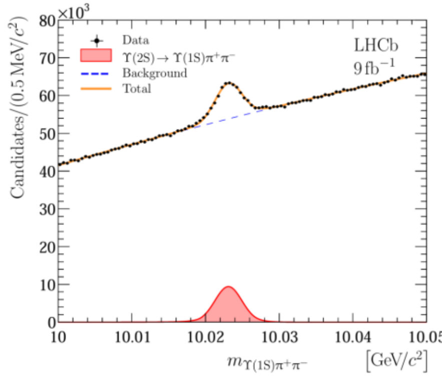


LHCb-PAPER-2024-053 ,in preparation

Spectroscopy of hidden-beauty states

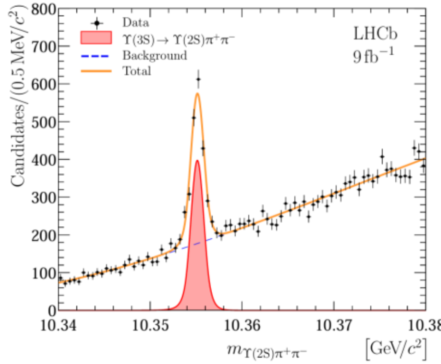
- ✓ Experimental knowledge of hidden beauty states is still limited
- ✓ Measuring Υ mass using decay modes

$$\Upsilon(3S) \to (\Upsilon(2S) \to \mu^+\mu^-)\pi^+\pi^-$$
$$\Upsilon(2S) \to (\Upsilon(1S) \to \mu^+\mu^-)\pi^+\pi^-$$



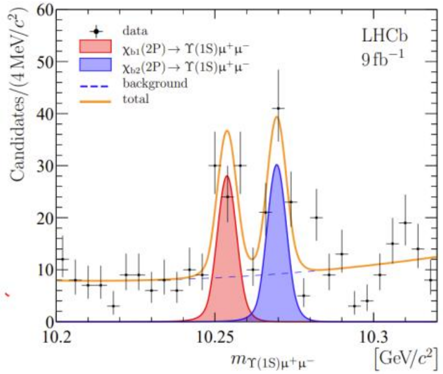
- ✓ Result：Consistent and comparable with world average

$$m_{\Upsilon(1S)} = 9460.37 \pm 0.01_{\text{stat}} \pm 2.85_{\text{syst}}\ \text{MeV}/c^2 \qquad m_{\Upsilon(1S)_{PDG}} = 9460.40 \pm 0.09 \pm 0.04\ \text{MeV}/c^2$$
$$m_{\Upsilon(2S)} = 10023.28 \pm 0.03_{\text{stat}} \pm 0.12_{\text{syst}} \pm 0.09_{\text{ext}}\ \text{MeV}/c^2 \qquad m_{\Upsilon(2S)_{PDG}} = 10023.4 \pm 0.5\ \text{MeV}/c^2$$
$$m_{\Upsilon(3S)} = 10355.28 \pm 0.03_{\text{stat}} \pm 0.04_{\text{syst}} \pm 0.48_{\text{ext}}\ \text{MeV}/c^2 \qquad m_{\Upsilon(3S)_{PDG}} = 10355.1 \pm 0.5\ \text{MeV}/c^2$$



- ✓ First observation of the muonic Dalitz decays of the $\chi_{b1}(1P)$, $\chi_{b2}(1P)$, $\chi_{b1}(2P)$, and $\chi_{b2}(2P)$ mesons decay to the $\Upsilon(1S)$ state and measurement of the masses

<u>Significances above 5σ for all the states</u>



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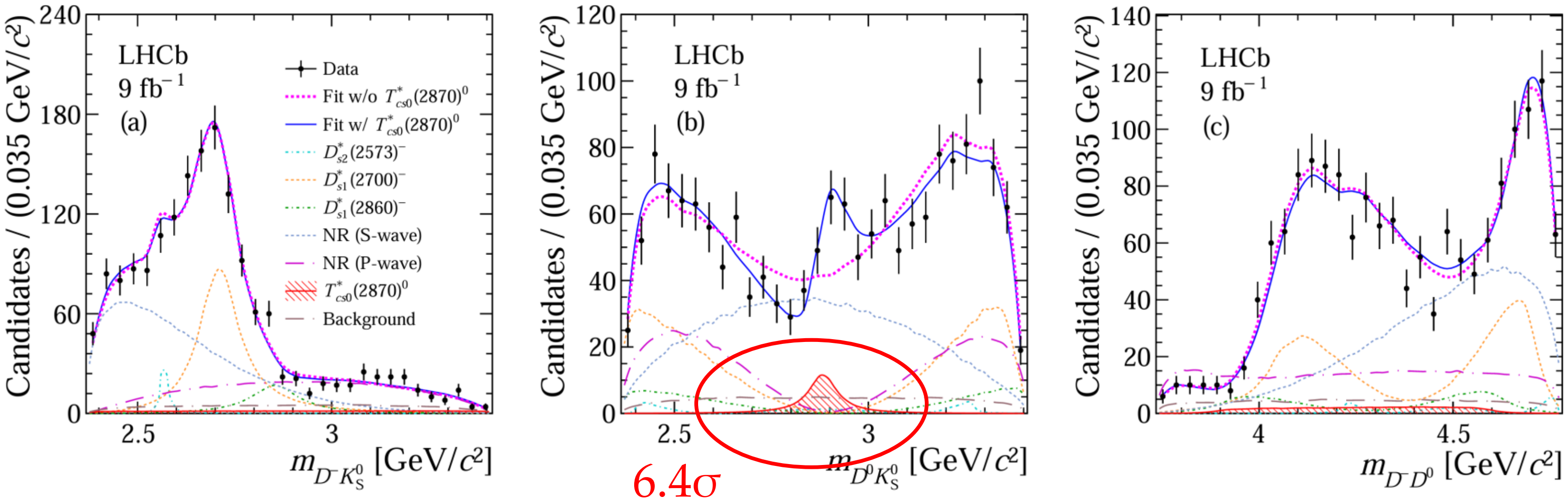
Open-charm tetraquark in $B^- \to D^- D^0 K_S^0$ decay

- Perform Amplitude analysis of the $\boldsymbol{B^- \to D^- D^0 K_S^0}$ decay
- Spin-0 open-charm tetraquark $T_{cs0}^{*0}(2870)$ observed in the $D^0 K^0$ final state for the first time
- No significant T_{cs0}^{*0} states with $J^P = 1^-$ or charmonium-like tetraquarks observed

$$m\left(T_{cs0}^{*0}(2870)\right) = 2883 \pm 11_{\text{stat}} \pm 8_{\text{syst}}\ \text{MeV}/c^2$$

$$\Gamma\left(T_{cs0}^{*0}(2870)\right) = 87^{+22\text{stat}}_{-47\text{stat}} \pm 17_{\text{syst}}\ \text{MeV}$$

$$\text{FF}\left(T_{cs0}^{*0}(2870) \to D^0 K_S^0\right) = \left(2.6 \pm 1.2_{\text{stat}} \pm 0.4_{\text{syst}}\right)\%$$



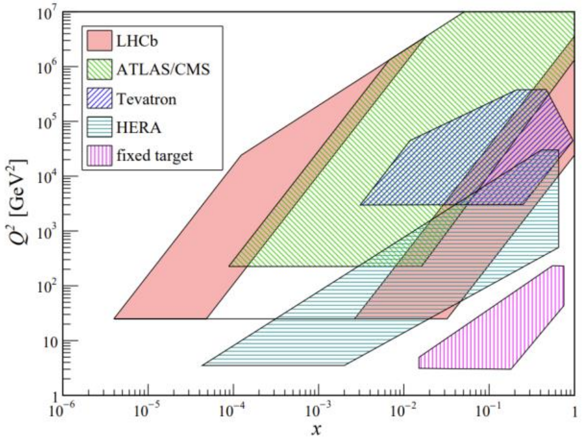
arXiv:2411.19781

5

ElectroWeak &Heavy Ion

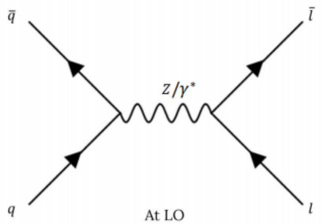
Measurement of weak mixing angle

- LHCb covers the forward region, with access to low and high Bjorken-x regions of the phase-space



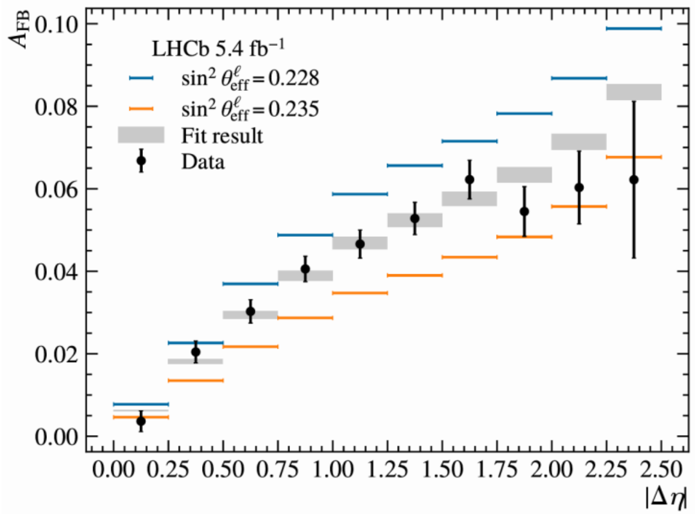
- Complementary coverage with other experiments has big implications on modelling – especially with PDFs

- Extracted using Fwd-Bkd asymmetry of $Z \to \mu^+\mu^-$ decays at LHCb



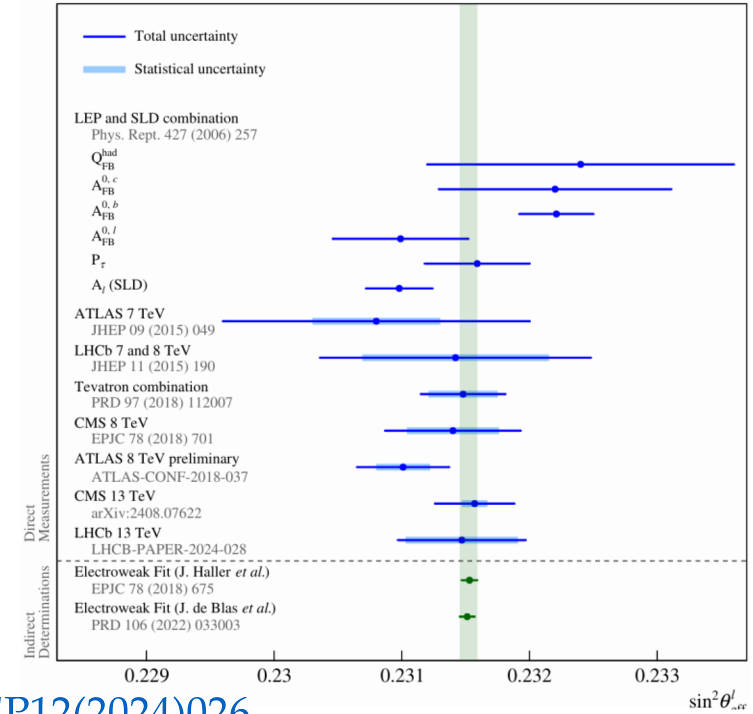
$$\propto 1 + \cos^2\theta^* + A_4 \cos\theta$$

$$A_{FB} = \frac{3}{8} A_4$$



- Results：

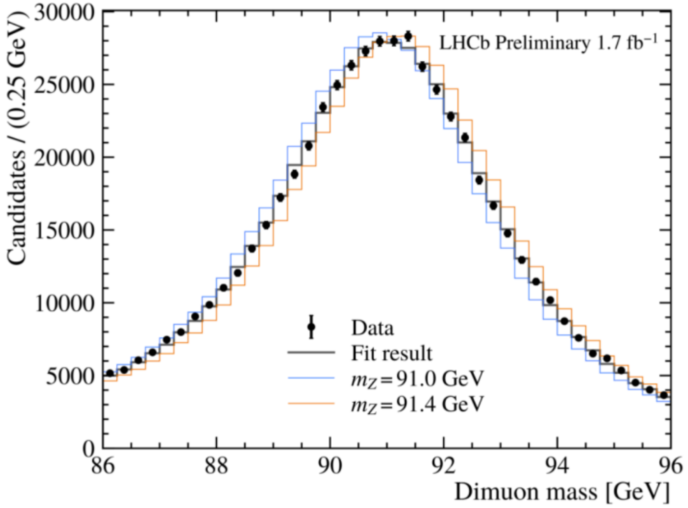
$$\sin^2\theta^{\rm lept}_{\rm eff} = 0.23152 \pm 0.00044_{stat} \pm 0.00005_{syst} \pm 0.00022_{theo}$$



JHEP12(2024)026

Measurement of Z boson mass

Simple fit to the dimuon mass spectrum following all calibrations

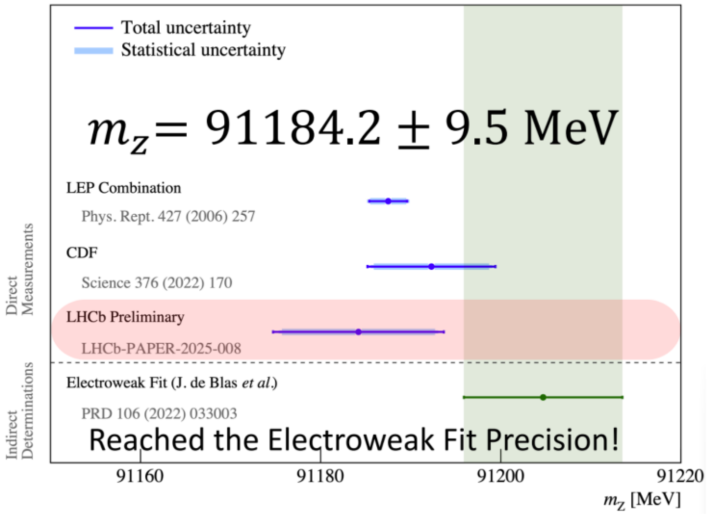


Data correction with pseudo-mass method

LHCb-PAPER-2025-008, in preparation

Source	Size [MeV]
Momentum calibration	4.1
Signal QED corrections	0.8
Parton distribution functions	0.7
Detection Efficiency	0.1
Statistical uncertainty	8.5
Total	**9.5**

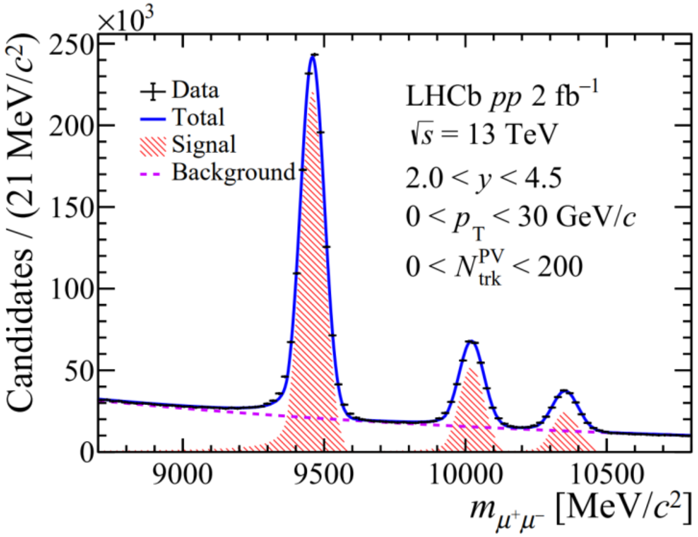
First dedicated measurement of m_Z at the LHC



- ✓ Encouraging prospects for m_Z at the LHC
  - Eagerly anticipate dedicated m_Z results from ATLAS and CMS
  - An LHC average may challenge LEP soon!

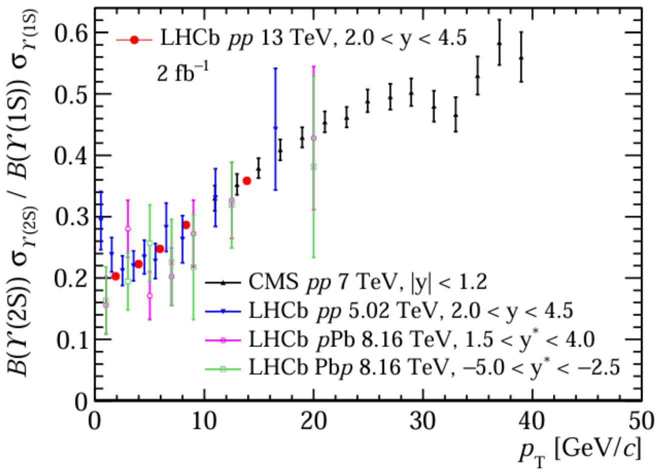
ϒ production vs multiplicity in pp

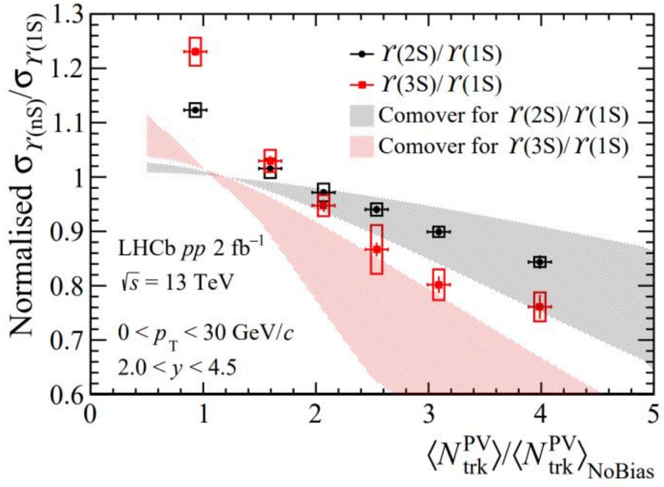
- ✓ Measured ϒ(2S) and ϒ(3S) production as a function of multiplicity (primary vertex charged tracks)
- ✓ Probe for Cold Nuclear Matter effects in the simplest hadronic collision system
  - Baseline for final-state effects study in pN and NN collisions



arXiv:2501.12611, submitted to JHEP

- ✓ Dependencies compared with Comover model predictions [PLB 731 (2014) 57]
- Overall trend reproduced, but for low multiplicity
- Values not fully compatible, especially for ϒ(3S)

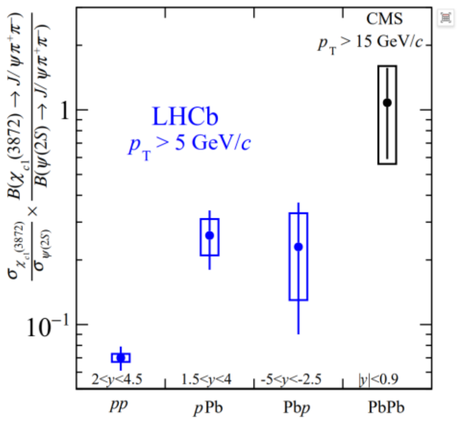


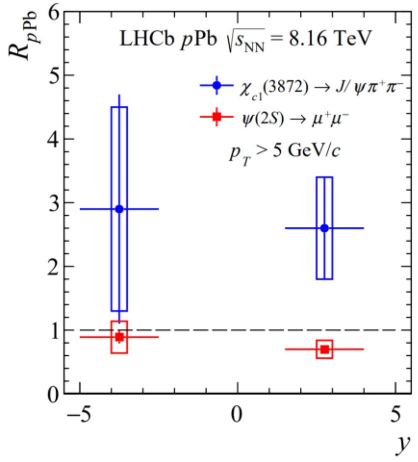


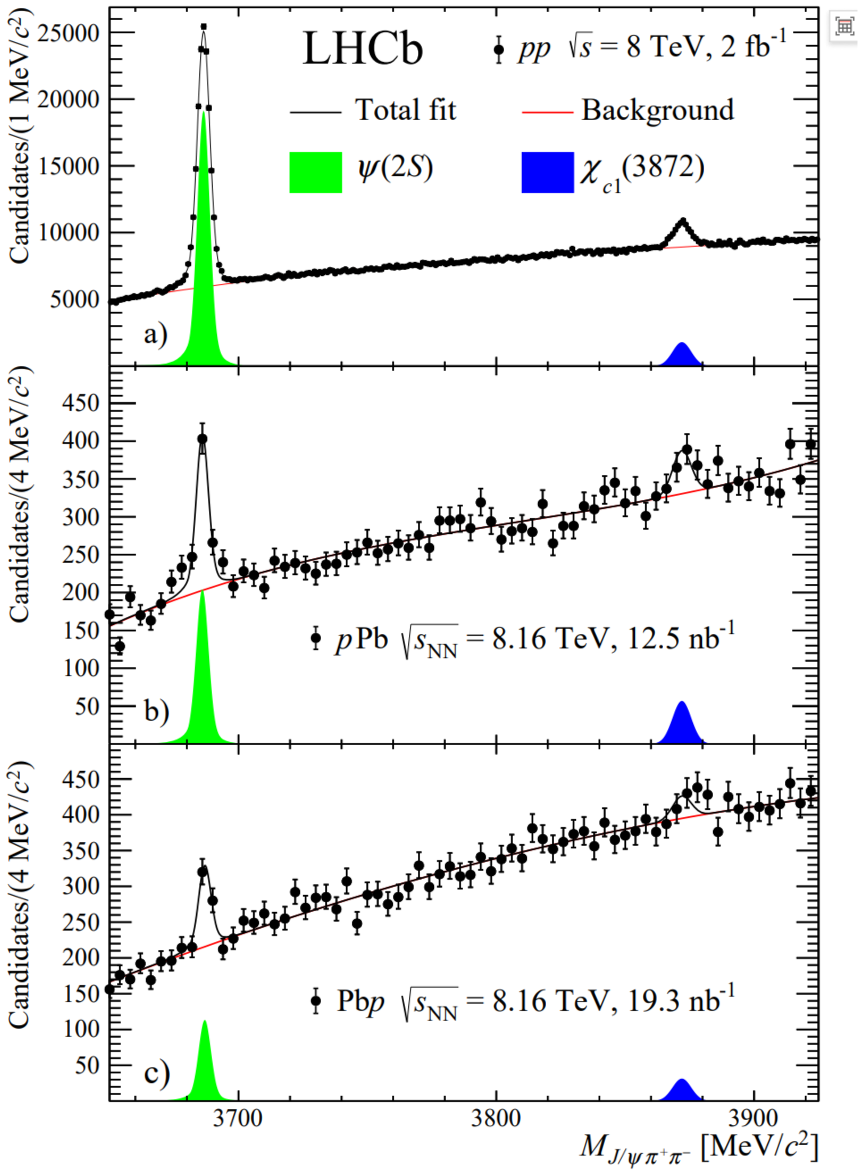
$\chi_{c1}(3872)$ and $\psi(2S)$ production in pPb

- First measurement of nuclear modification factor of an exotic hadron in $J/\psi\pi^+\pi^-$ state
  —Probe for exotic vs conventional hadron

- Increase of χ_{c1} (3872) /ψ(2S) cross-section ratio with interacting nucleons
  —Suggest different χ_{c1} (3872) dynamics in nuclear medium compared to ψ(2S)
  — Enhanced exotic production is suggested







arxiv: 2410.18018

Λ polarization in fixed-target p-Ne

- Excellent Λ dataset purity Measured Λ and $\bar{\Lambda}$ polarisation
  - Transverse to production plane for parity conservation

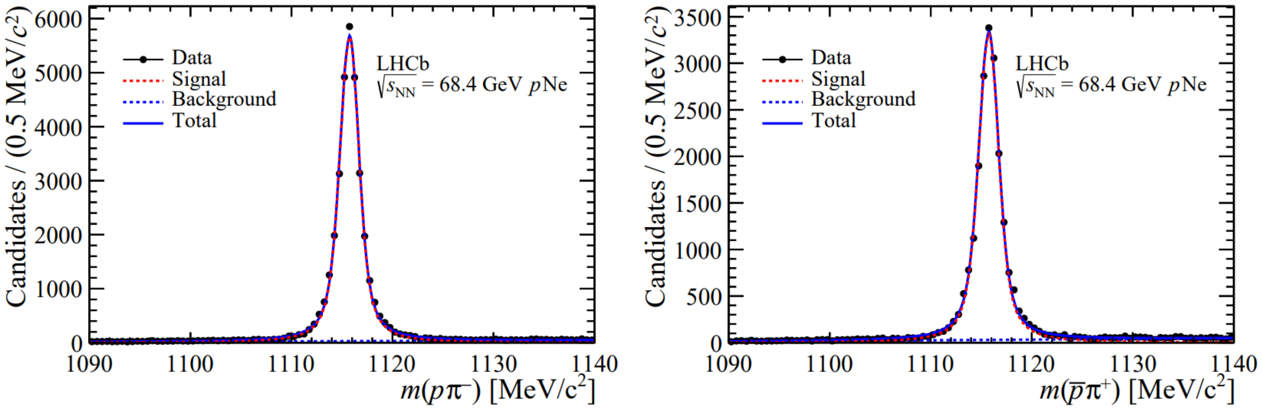
- Analysis of $\Lambda \rightarrow p\pi$ decay distribution

$$P(\cos\theta) = \frac{1}{2}(1 + \alpha P \cos\theta)$$

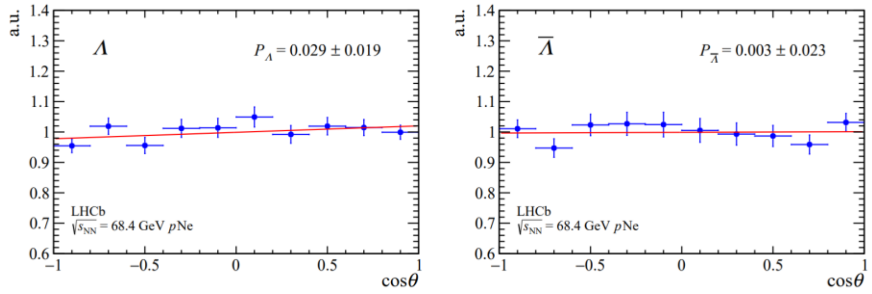
  - θ proton polar angle in Λ rest frame
  - α fixed from PDG

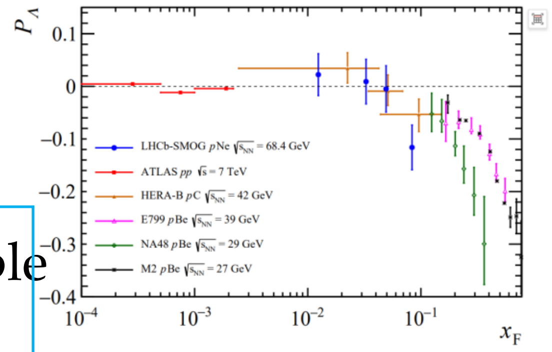
- Averaged result:

$$P_{\Lambda}[\%] = 2.9 \pm 1.9(\text{stat}) \pm 1.2(\text{syst})$$
$$P_{\bar{\Lambda}}[\%] = 0.3 \pm 2.3(\text{stat}) \pm 1.4(\text{syst})$$



JHEP 09 (2024) 082





Tendency of increasing negative polarisation with x_F compatible with current measurements

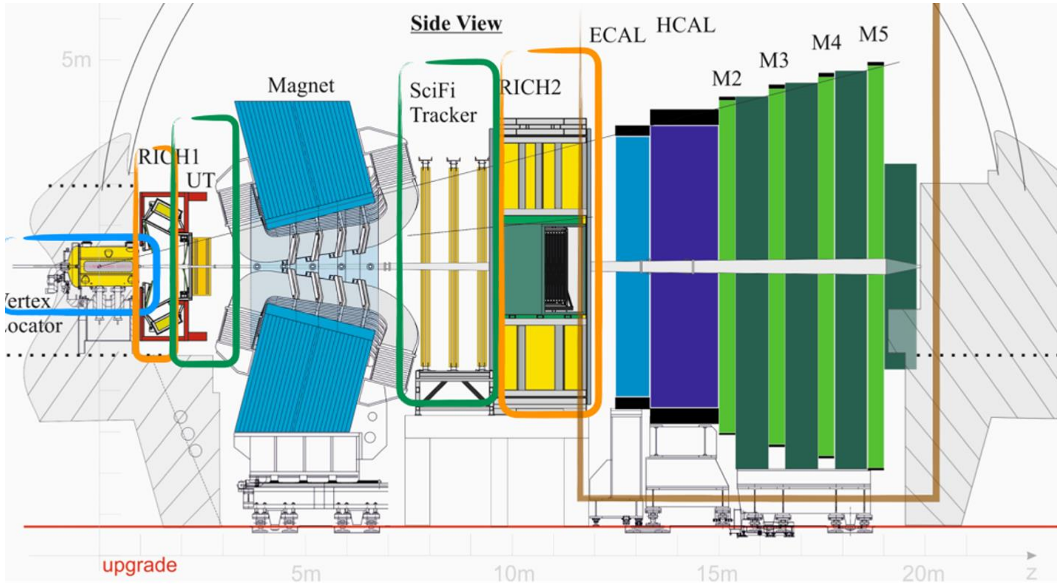
x_F ∝longitudinal momentum

6

Prospects & Conclusions

Prospects of LHCb physics

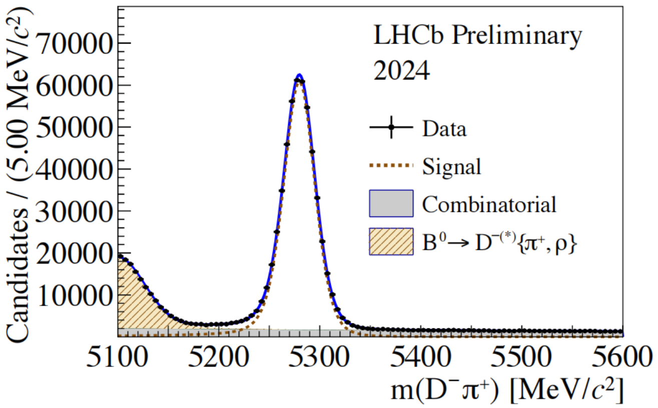
- Run 3 data-taking with Upgrade I LHCb detector ongoing
  - —higher peak luminosity in pp wrt Run 2
  - —Expect to accumulate 23 fb^{-1} data in Run3
- Phase II Upgrade for Run 5 proposed
  - —Huge increase in sample size expected - stay tuned

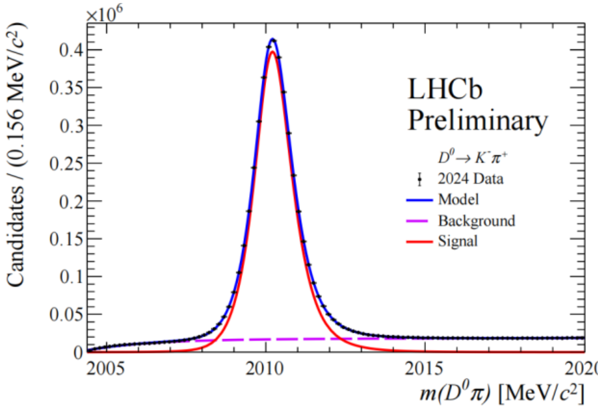


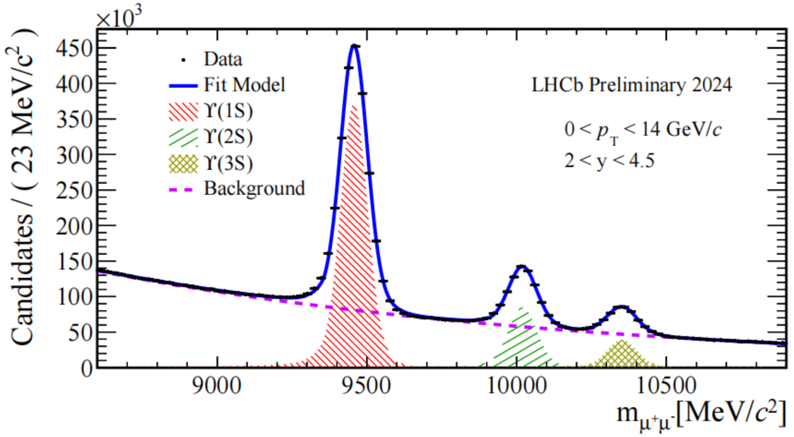
What could be expected after upgrades?

- More data than the expectation luminosity of Run 1 & 2 in 2024!

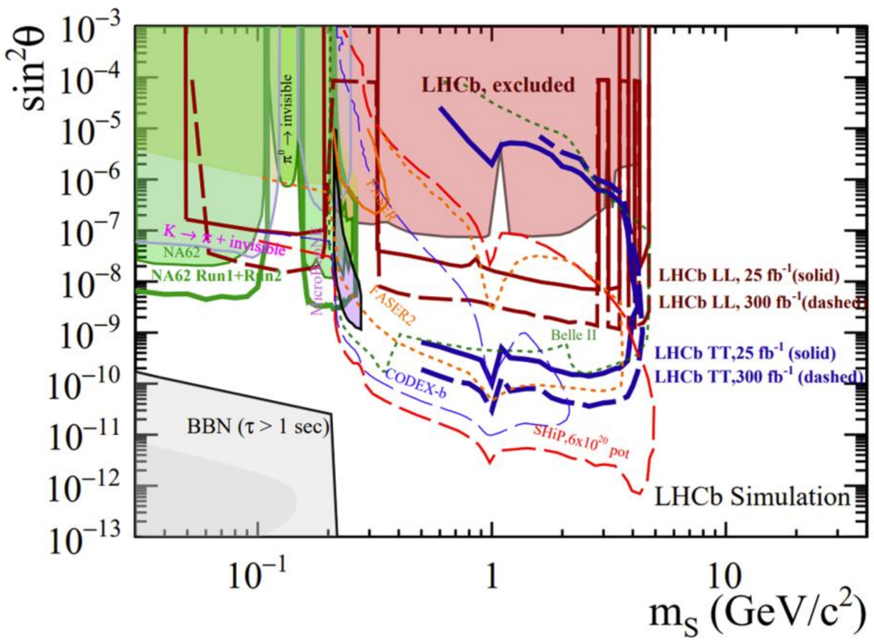
The gain maybe ~2 × due to removal of hardware trigger







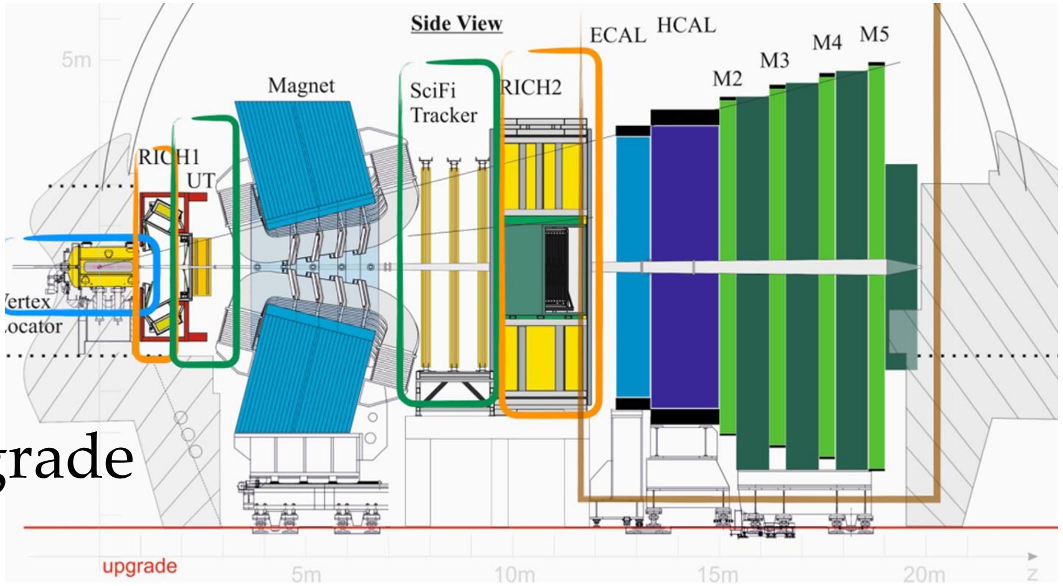
Topic	Comment
Spectroscopy	Enormous yields in gold-plated final states
	e.g. 4M $\Lambda_b^0 \to J\psi pK^-$ decays ('pentaquark' mode)
Higgs	Measure Higgs-charm Yukawa within factor 2 to 3 of SM value
$\sin^2\theta_W$	Uncertainty $< 10^{-4}$, better than LEP/SLD
Proton structure	Precision probes at extremely low and high Bjorken-x values,
	with $Q^2 > 10^5$ GeV^2
Hidden sector	Sensitivity to most of relevant parameter space for dark-photon models



e.g. Replacing TT → SCIFI allow to probe the invisible using SCIFI-only tracking

Conclusion

- First observation of CPV in baryon decays
- World-leading precision measurements of the CKM matrix
- Rich observations in hadron spectroscopy
- Expanding strength in heavy-ion and electroweak measurements
- Comprehensive studies of rare decays and LFU tests
- Promising future with Run 3 and Phase-II Upgrade



BackUp

CPV in $B^+ \to J/\psi\pi^+$ Decays

- $b \to c\bar{c}d$ decay penguin diagrams contribution not negligible wrt to tree-level, expect $\mathcal{O}(1\%)$ direct CP violation. [JHEP 03 (2015) 145 JPG 48, 065002 (2021)]
- Can improve understanding of penguin contribution to transitions (β from $B^0 \to J/\psi K^0$)
- Experimental measure yields asymmetry

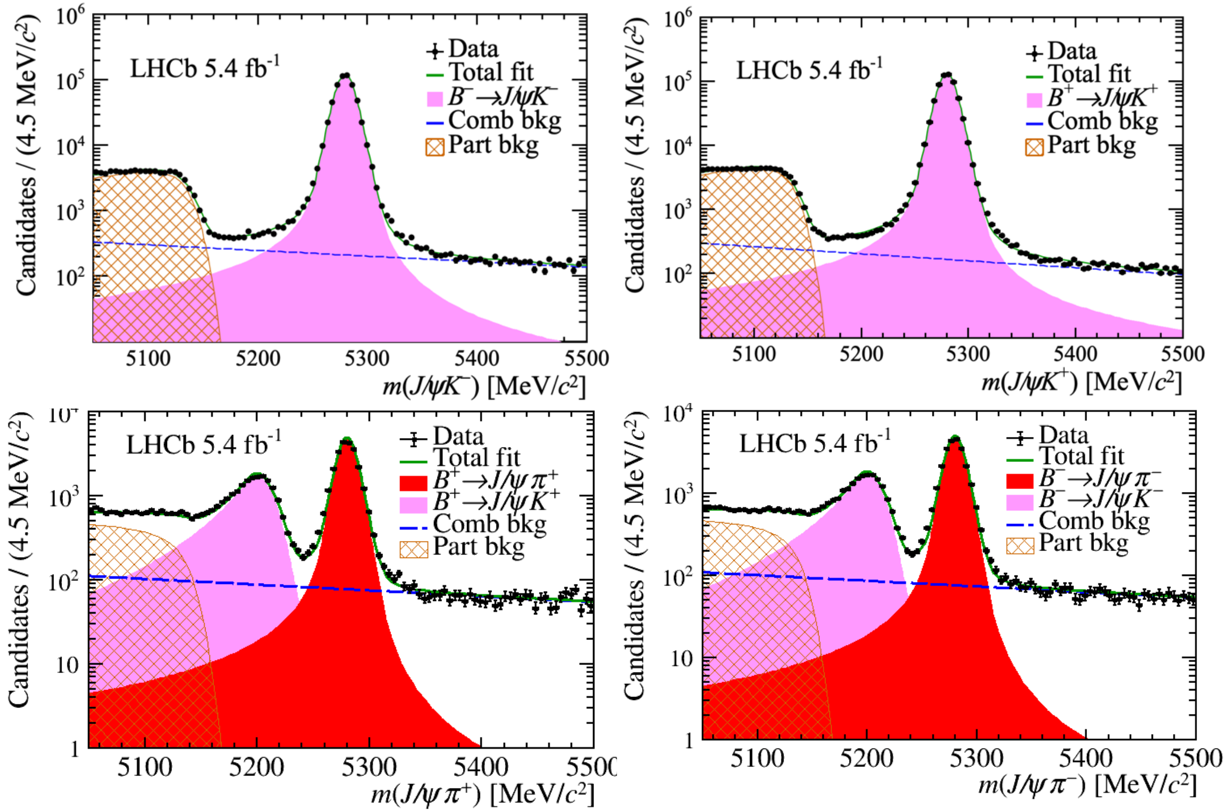
$$A^{raw} = A^{CP} + A^{det} + A^{prod}$$

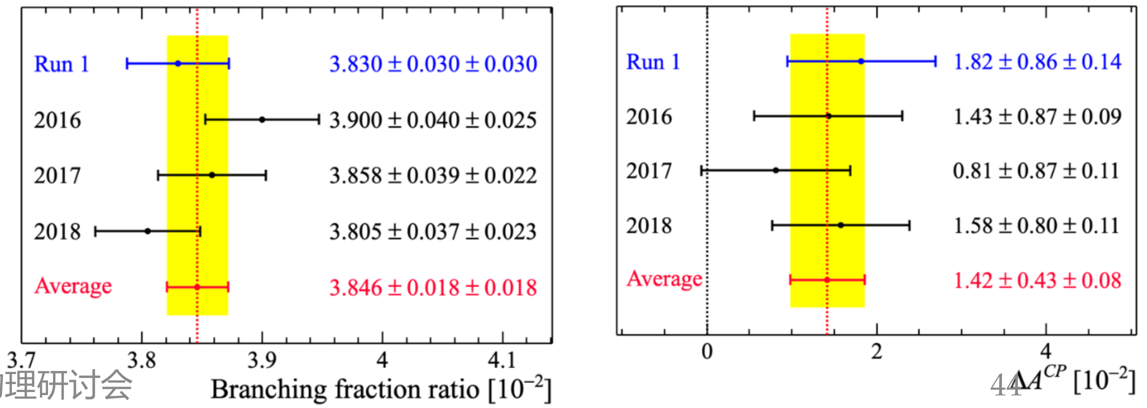
Physical asymmetry	F.S. detection asymmetry	Particle - anti-particle production asymmetry

- Measured relative to control sample of $B^+ \to J/\psi K^+$ decays: cancellation of many systematics

$$\Delta A_{CP} = (1.42 \pm 0.43 \pm 0.08)\ \%$$

First evidence of direct violation in beauty to charmonia decays(3.2σ)



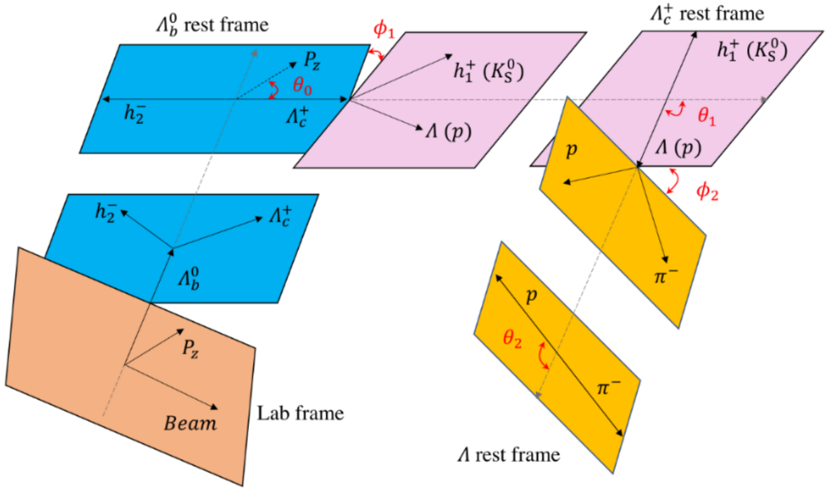


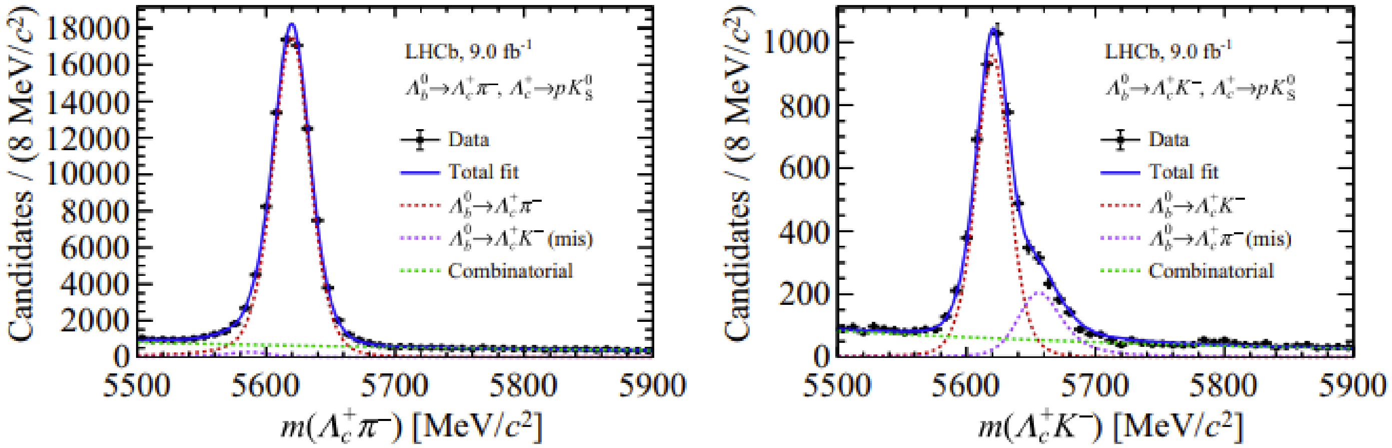
Measurement of Λ_b^0 decay parameters

- Decay parameters have been proposed by Lee and Yang (1957) to study hyperon decays ($\Lambda \to p\pi$)

$$\frac{d\Gamma}{d\cos\theta_1} \propto 1 + \alpha_{\Lambda_b^0}\alpha_{\Lambda_c^+}\cos\theta_1, \qquad \alpha \equiv \frac{2\Re(s^*p)}{|s|^2+|p|^2}, \quad \beta \equiv \frac{2\Im(s^*p)}{|s|^2+|p|^2}, \quad \gamma \equiv \frac{|s|^2-|p|^2}{|s|^2+|p|^2},$$

s and p denote the parity-violating S-wave and parity-conserving P-wave amplitude





Contain S- or P-waves and thus one can study strong and weak phases difference between them and probe CPV inside

Measurement of Λ_b^0 decay parameters

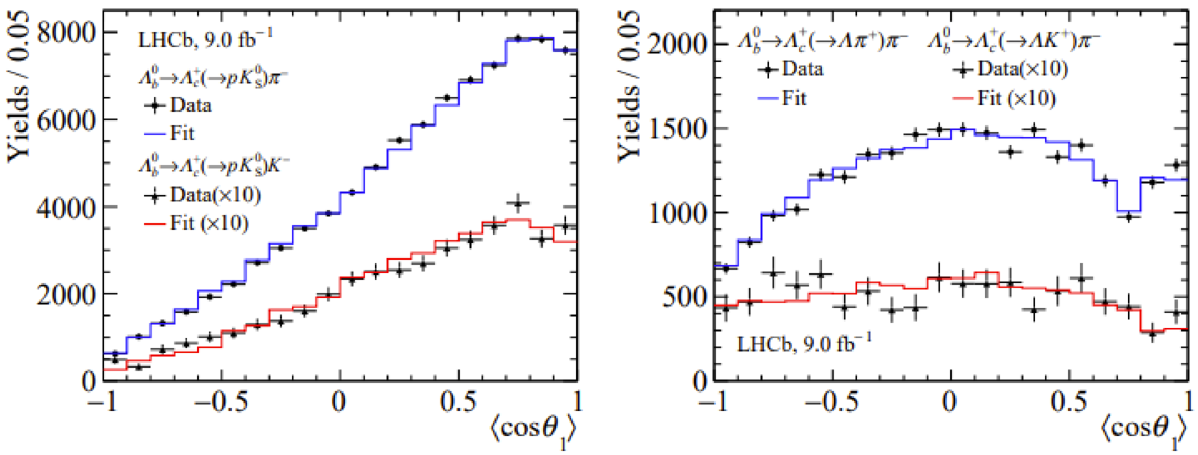
CP violating observables:

$$A_{CP}^{\alpha} \equiv \frac{\alpha(\Lambda) + \alpha(\overline{\Lambda})}{\alpha(\Lambda) - \alpha(\overline{\Lambda})}$$

Decay	α	$\bar{\alpha}$	$\langle\alpha\rangle$	A_α
$\Lambda_b^0 \to \Lambda_c^+\pi^-$	$-1.010 \pm 0.011 \pm 0.003$	$0.996 \pm 0.011 \pm 0.003$	$-1.003 \pm 0.008 \pm 0.005$	$0.007 \pm 0.008 \pm 0.005$
$\Lambda_b^0 \to \Lambda_c^+ K^-$	$-0.933 \pm 0.042 \pm 0.014$	$0.995 \pm 0.036 \pm 0.013$	$-0.964 \pm 0.028 \pm 0.015$	$-0.032 \pm 0.029 \pm 0.006$
$\Lambda_c^+ \to \Lambda\pi^+$	$-0.782 \pm 0.009 \pm 0.004$	$0.787 \pm 0.009 \pm 0.003$	$-0.785 \pm 0.006 \pm 0.003$	$-0.003 \pm 0.008 \pm 0.002$
$\Lambda_c^+ \to \Lambda K^+$	$-0.569 \pm 0.059 \pm 0.028$	$0.464 \pm 0.058 \pm 0.017$	$-0.516 \pm 0.041 \pm 0.021$	$0.102 \pm 0.080 \pm 0.023$
$\Lambda_c^+ \to pK_S^0$	$-0.744 \pm 0.012 \pm 0.009$	$0.765 \pm 0.012 \pm 0.007$	$-0.754 \pm 0.008 \pm 0.006$	$-0.014 \pm 0.011 \pm 0.008$
$\Lambda \to p\pi^-$	$0.717 \pm 0.017 \pm 0.009$	$-0.748 \pm 0.016 \pm 0.007$	$0.733 \pm 0.012 \pm 0.006$	$-0.022 \pm 0.016 \pm 0.007$

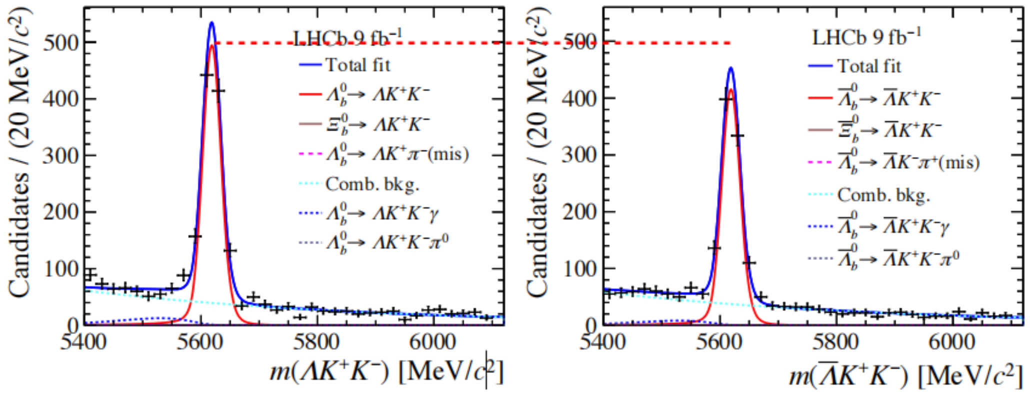
- First measurement of Λ_b^0 decay parameters
- All A_α consistent with zero

No CPV observed



Evidence for CPV in $\Lambda_b^0 \to \Lambda h^+ h^-$

- CP violation in $\Lambda_b^0/\Xi_b^0 \to \Lambda h^+ h^- (h = \pi, K)$ decays
  - similar dynamics $B \to hh'h''$
  - possible CPV enhancement

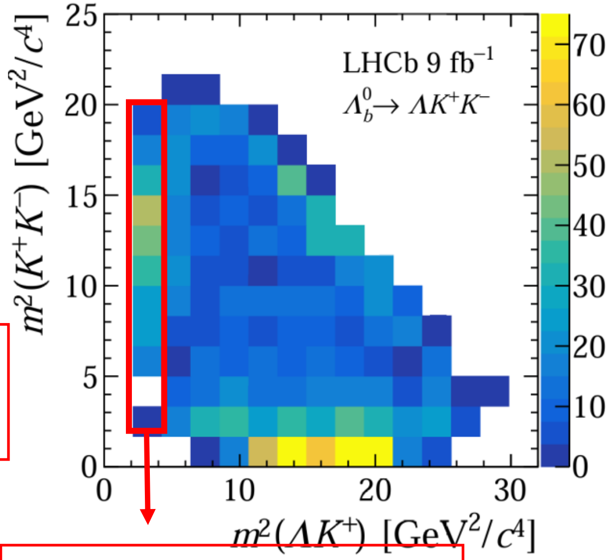


- $\Lambda_b^0/\Xi_b^0 \to \Lambda h^- h'^-$ decays

$$\Delta A^{CP}(\Lambda_b^0 \to \Lambda\pi^+\pi^-) = -0.013 \pm 0.053 \pm 0.018,$$
$$\Delta A^{CP}(\Lambda_b^0 \to \Lambda K^+\pi^-) = -0.118 \pm 0.045 \pm 0.021,$$
$$\Delta A^{CP}(\Lambda_b^0 \to \Lambda K^+K^-) = 0.083 \pm 0.023 \pm 0.016,$$
$$\Delta A^{CP}(\Xi_b^0 \to \Lambda K^-\pi^+) = 0.27 \pm 0.12 \pm 0.05 ,$$

- CP asymmetries measured as difference wrt to control mode $\Lambda_b^0 \to \Lambda_c^+(\to \Lambda\pi^+)\pi^-$(null CPV expected)
- Evidence of direct violation in $\Lambda_b^0/\Xi_b^0 \to \Lambda K^+ K^-$ decays (3.1σ)
- Possible interpretation: enhancement from $N^{*+} \to \Lambda K^+$ (3.2σ) resonance

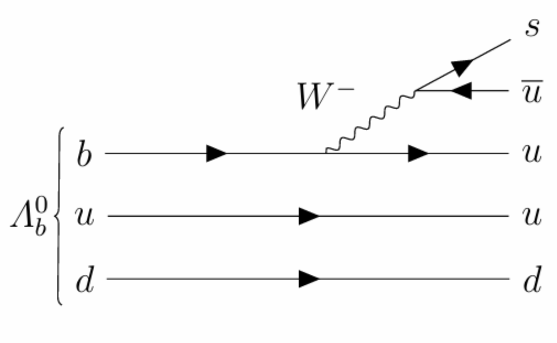
Amplitude analysis needed to clarify

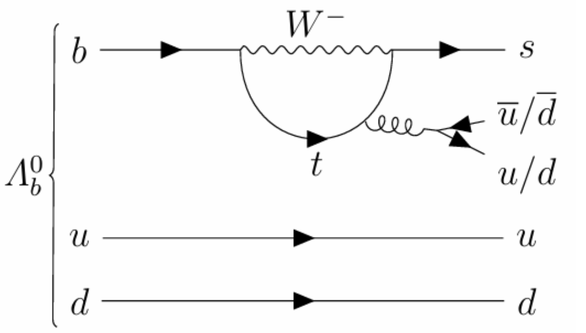


$\Delta A_{CP} = (16.5 \pm 5.1)\%$

Observation of CPV in $\Lambda_b^0 \to pK^-\pi^+\pi^-$ decays

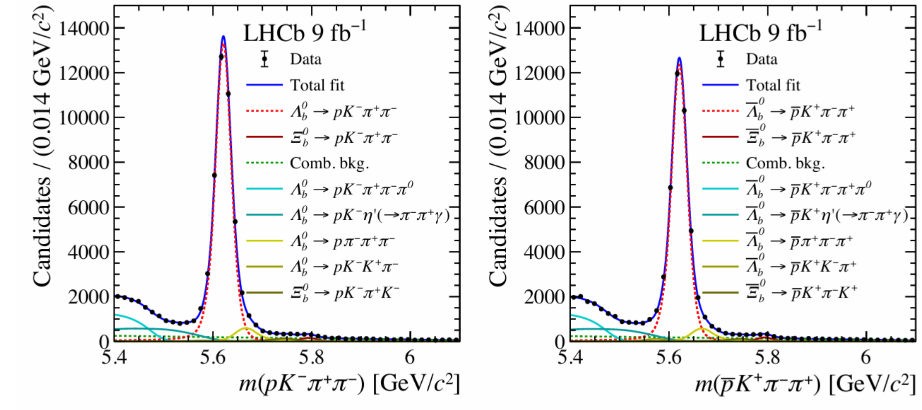
- CPV arises from interference between tree and loop amplitudes
- Resonant structure may enhance CPV across the phase space
- Similar measurement to extract A_{CP}





$$A_{CP} \equiv \frac{N(\Lambda_b^0 \to K^-\pi^+\pi^-) - N(\Lambda_b^0 \to \bar{p}K^+\pi^-\pi^+)}{N(\Lambda_b^0 \to K^-\pi^+\pi^-) + N(\bar{\Lambda}_b^0 \to \bar{p}K^+\pi^-\pi^+)}$$

$$A_{CP} = (2.45 \pm 0.46 \pm 0.10)\ \%$$



- Clean measurement thanks to control sample of $\Lambda_b^0 \to \Lambda_c^+(\to pK^-\pi^+)\pi^-$
- First observation of direct violation in baryon decays (5.2 σ from 0)

Observation of CPV in $\Lambda_b^0 \to pK^-\pi^+\pi^-$ decays

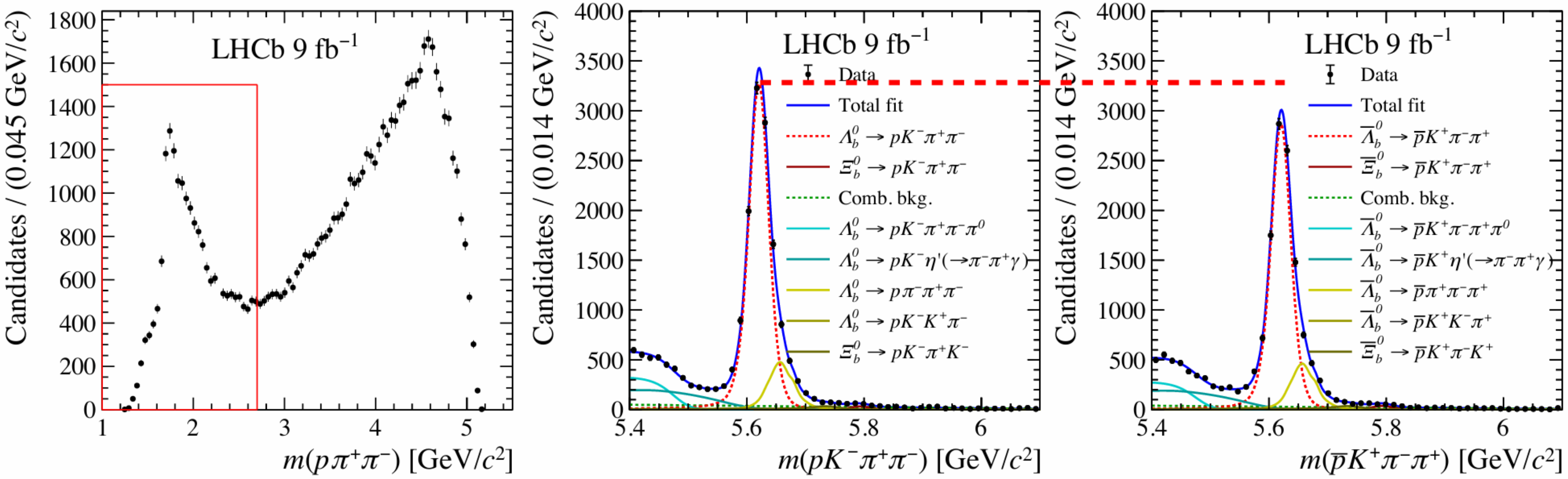
•Search for local violation in selected regions of the phase space

•Measured asymmetries up to (resonances)

•Hadronic effects preventing precise predictions- amplitude structure investigation potentially clarifying scenario

Decay topology	Mass region (GeV/c^2)	$\mathcal{A}_{CP}$	
$\Lambda_b^0 \to R(pK^-)R(\pi^+\pi^-)$	$m_{pK^-} < 2.2$, $m_{\pi^+\pi^-} < 1.1$	$(5.3 \pm 1.3 \pm 0.2)\%$	4σ
$\Lambda_b^0 \to R(p\pi^-)R(K^-\pi^+)$	$m_{p\pi^-} < 1.7$, $0.8 < m_{\pi^+K^-} < 1.0$ or $1.1 < m_{\pi^+K^-} < 1.6$	$(2.7 \pm 0.8 \pm 0.1)\%$	
$\Lambda_b^0 \to R(p\pi^+\pi^-)K^-$	$m_{p\pi^+\pi^-} < 2.7$	$(5.4 \pm 0.9 \pm 0.1)\%$	6σ
$\Lambda_b^0 \to R(K^-\pi^+\pi^-)p$	$m_{K^-\pi^+\pi^-} < 2.0$	$(2.0 \pm 1.2 \pm 0.3)\%$	

Amplitude analysis needed!



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