2026 CEPC workshop

LHCb Flavour highlights and prospects

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On behalf of LHCb collaboration

Oct. 24th 2026 · Shanghai

Outline

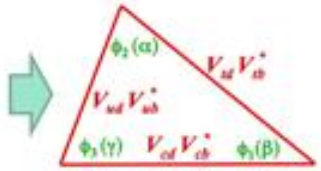
- Flavour physics
- LHCb detector
- Select of recent measurements
  - CKM and CPV
  - FCNC and LFU
  - Heavy flavour spectroscopy
- Prospects of LHCb U2 and CEPC

CKM and CP violation

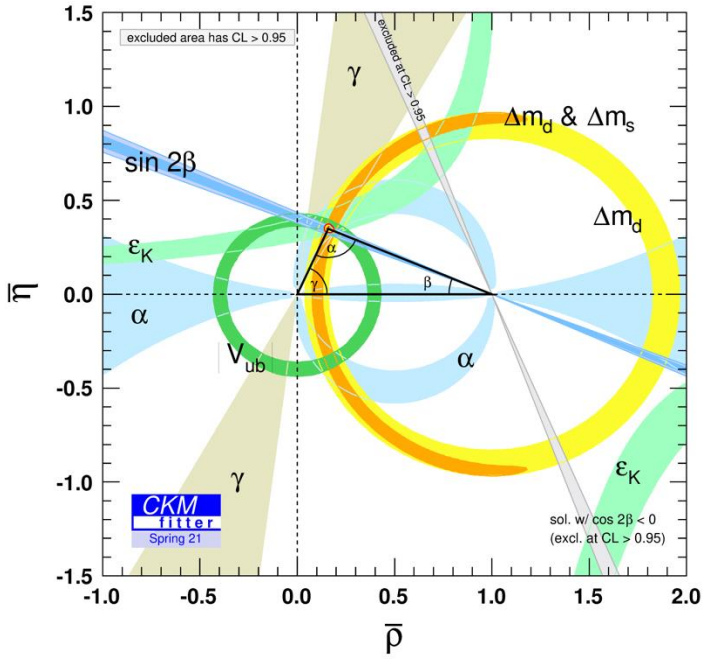
CKM matrix

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

	d	s	b
u	$1-\frac{1}{2}\lambda^2$	λ	$A\lambda^3(\rho-i\eta)$
c	$-\lambda$	$1-\frac{1}{2}\lambda^2$	$A\lambda^2$
t	$A\lambda^3(1-\rho-i\eta)$	$-A\lambda^2$	1



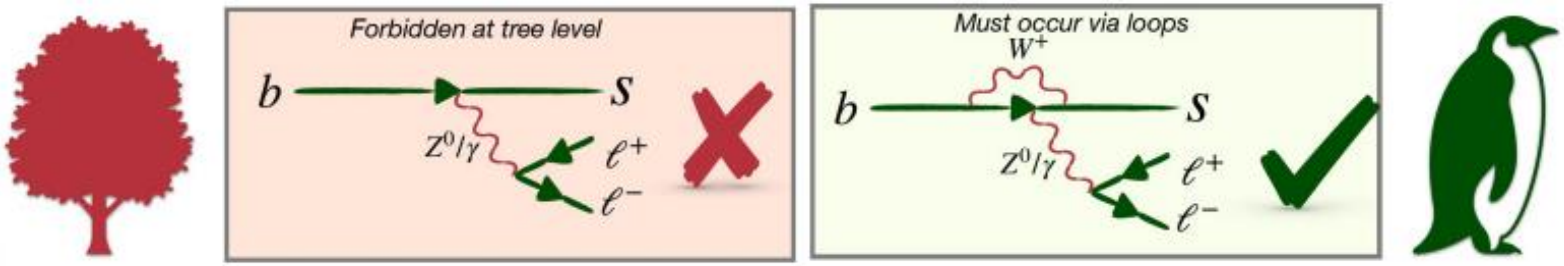
$\eta \neq 0$ ➔ **CP violation**



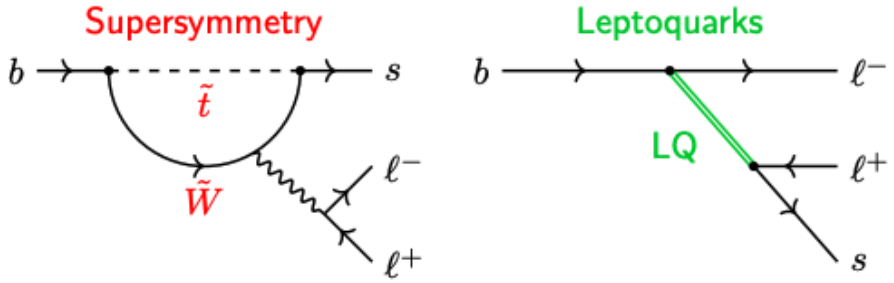
- Flavour : precise measurement of the CKM matrix is a **strict test of the SM**
- Key question: **is CKM matrix the only source of CP violation?**
- Overall strategy :
  - Precision measurement of CKM matrix
  - Searching for new phenomena in CP violation

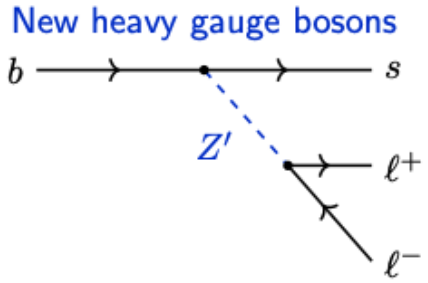
FCNC decays as sensitive probes for New Physics

In the Standard Model



Possible contributions from NP





Look for deviations from SM predictions

- FCNC forbidden at tree level in the SM
- FCNC decays heavily (loop) suppressed in the SM
- Flavour probes new physics energy scales >> 1 TeV via loop-mediated processes
- New heavy particles can significantly contribute and affect branching fractions, angular distributions, and rate asymmetries

$b \to s\ell\ell$ Observables

Increasing precision of SM prediction

The LHCb detector @ Run1+2

- A single-arm forward spectrometer covering $2 < \eta < 5$

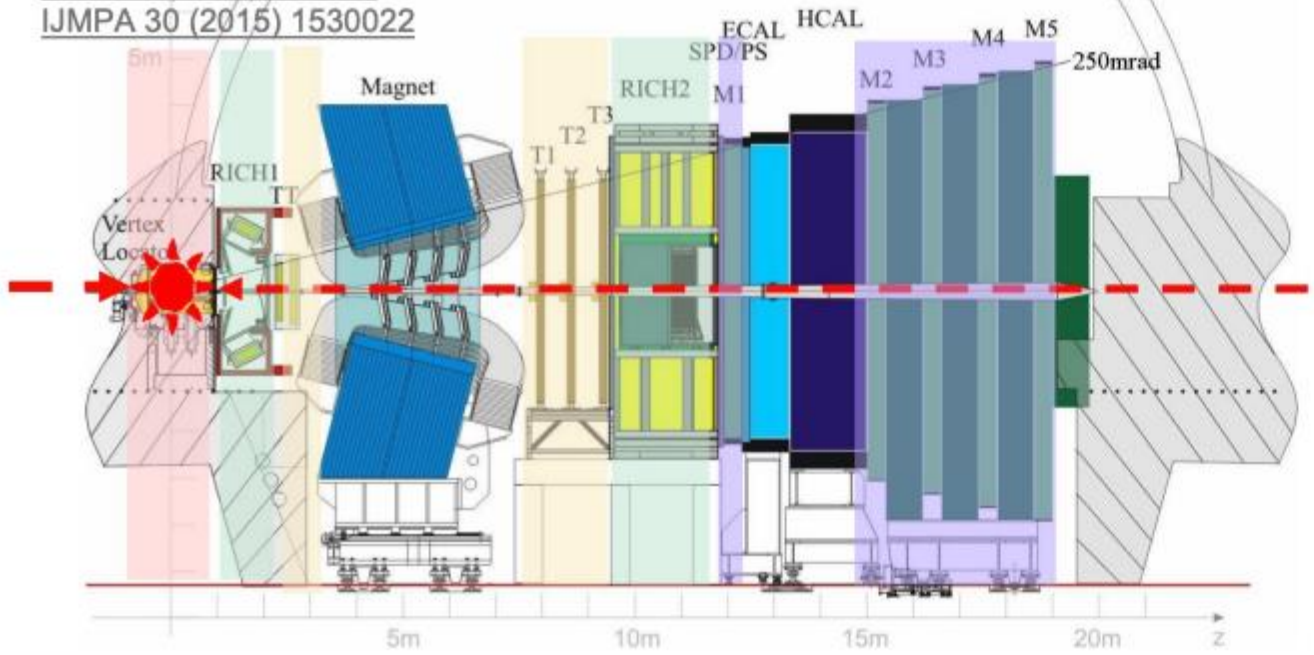
Vertex Locator
$\sigma_{IP} \sim 15 + 29/p_T$ μm
$\sigma_\tau \sim 45$ fs

Tracking system
$\epsilon_{tracking} \sim 96\%$
$\sigma_p/p \sim 0.5\% - 1\%$ $(5 - 200$ GeV$)$

RICHs
$\epsilon(K \to K) \sim 95\%$
mis-ID $\epsilon(\pi \to K) \sim 5\%$

Muon system
$\epsilon(\mu \to \mu) \sim 97\%$
mis-ID $\epsilon(\pi \to \mu) \sim 1 - 3\%$

JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022

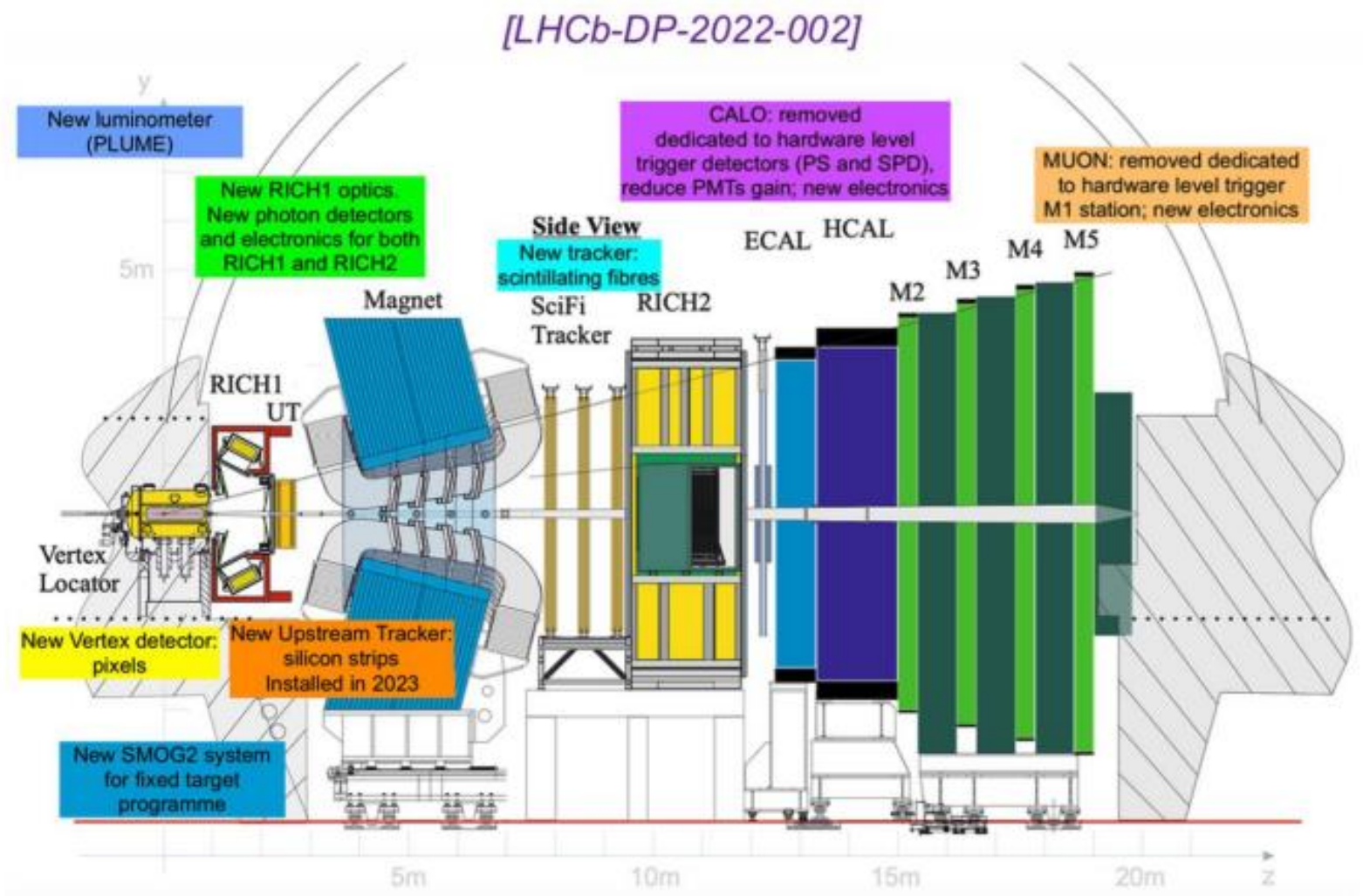


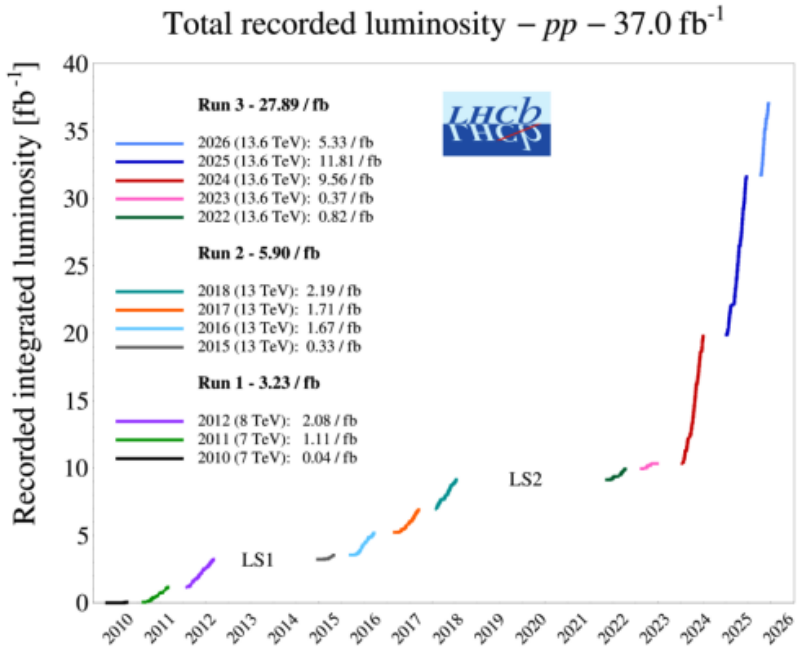
LHC: heavy hadron factory
LHCb:
- precise vertex resolution
- good momentum and mass resolution
- powerful particle identification

LHCb is highly competitive in heavy flavour spectroscopy

Designed for precision study of heavy flavour physics and CP violation

The upgraded LHCb detector in Run 3



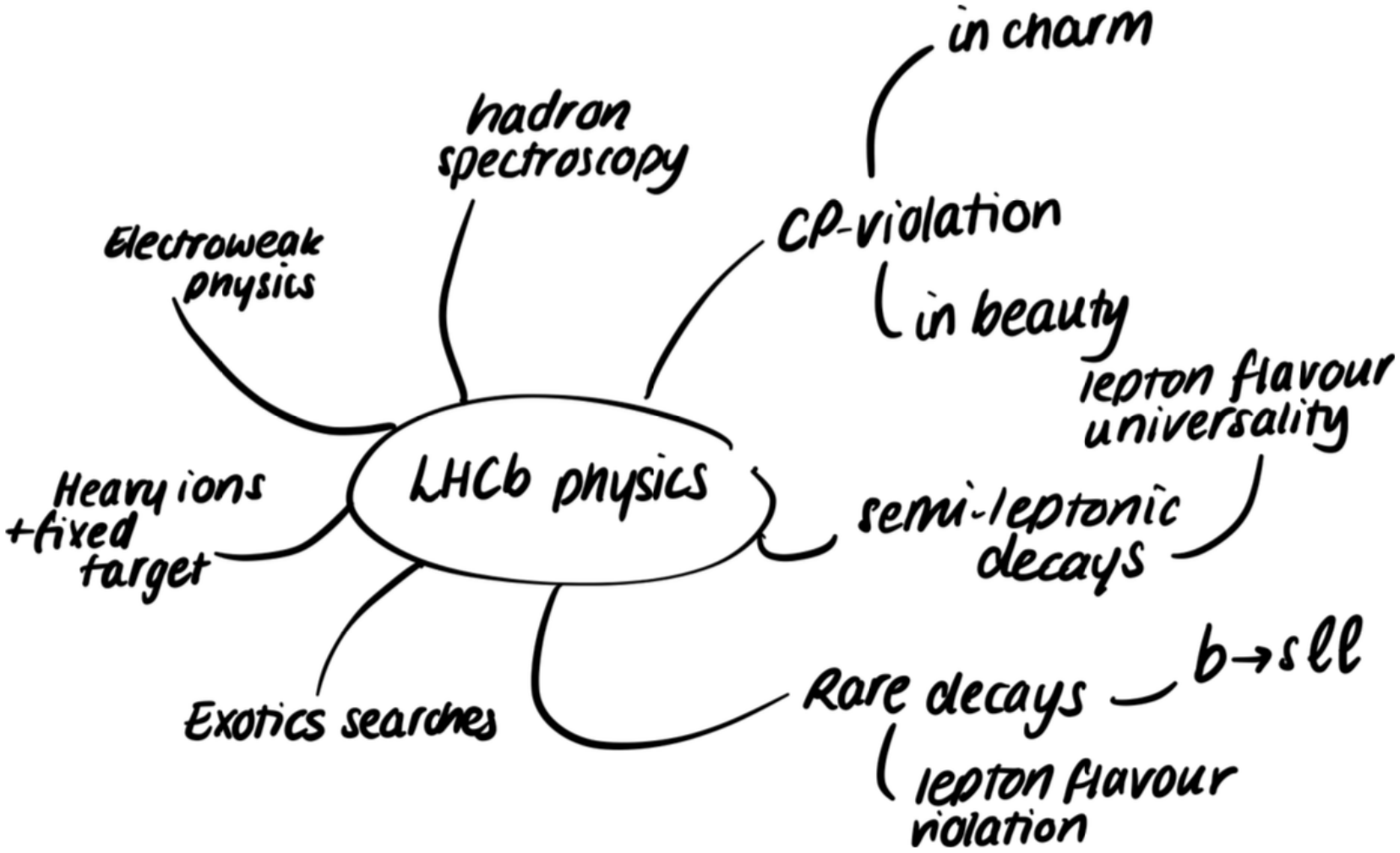


pp Collision data :

- 9 fb^{-1} in Run 1-2
- 28 fb^{-1} in Run 3

Running at 5 × higher luminosity, with great potential in flavour and beyond

LHCb physics programme

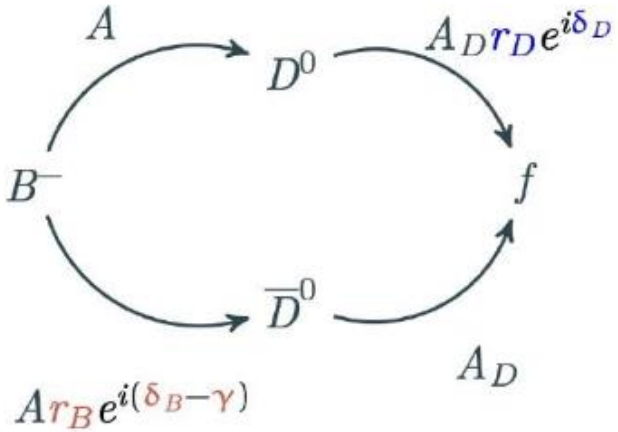


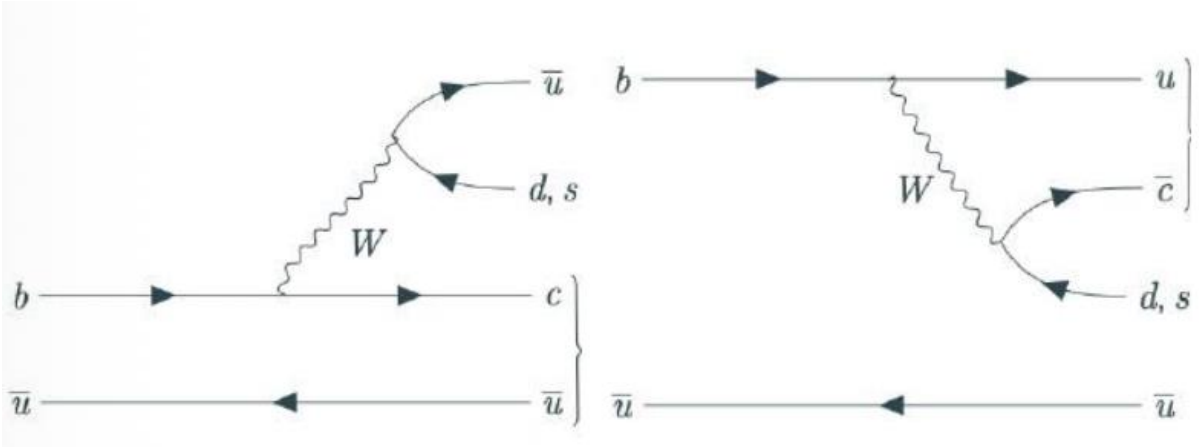
Expanded from heavy-flavour to spectroscopy, electroweak, ions, and beyond

CKM matrix and CPV

CKM angle γ

- Tree-level decays, theoretically clean ($\delta\gamma \sim 10^{-7}$)
- At LHCb, benefit from large statistics using tree-dominated processes
- Final states accessible to both D and $\overline{D}$ to examine interference between $b \to c$ and $b \to u$ transitions
- Multi-body D decays are used in combination with input on strong phases from independent measurements (BESIII, CLEO3)





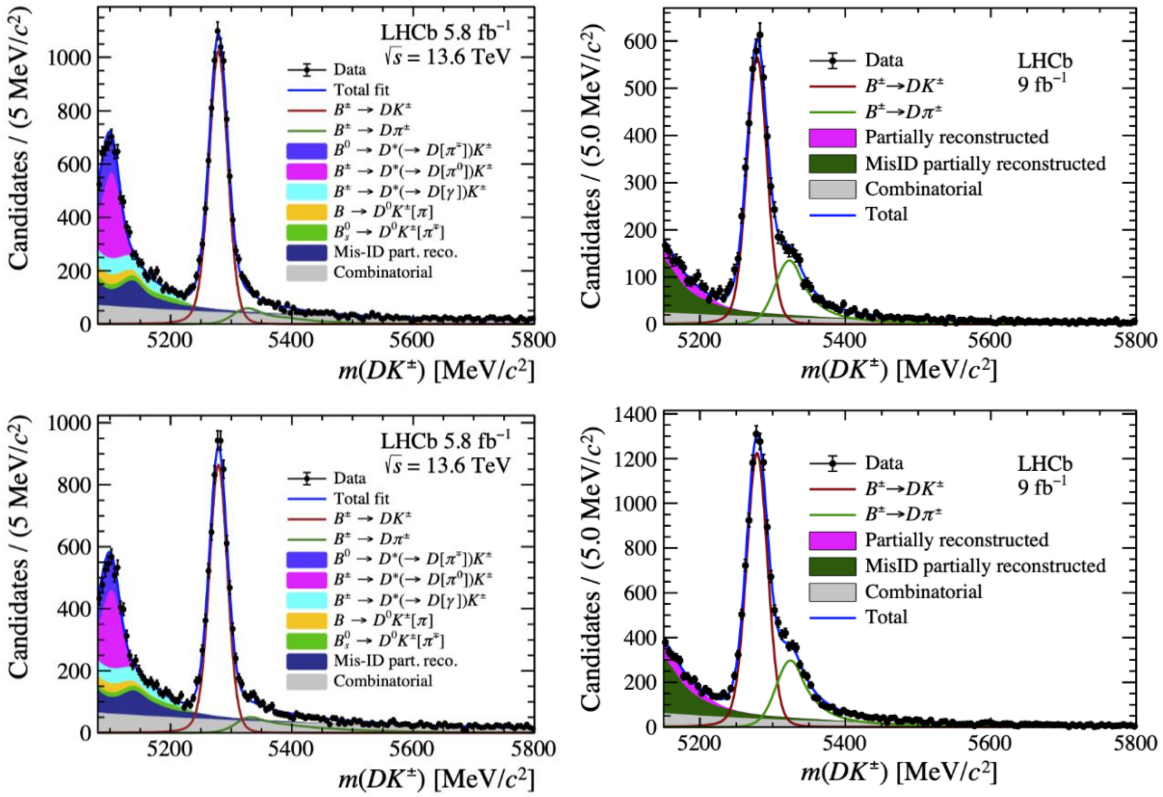
$$|A(B^-)|^2 \propto A_D^2 + r_B^2 A_{\overline{D}}^2 + 2A_D A_{\overline{D}} r_B \cos(\delta_B - \gamma)$$

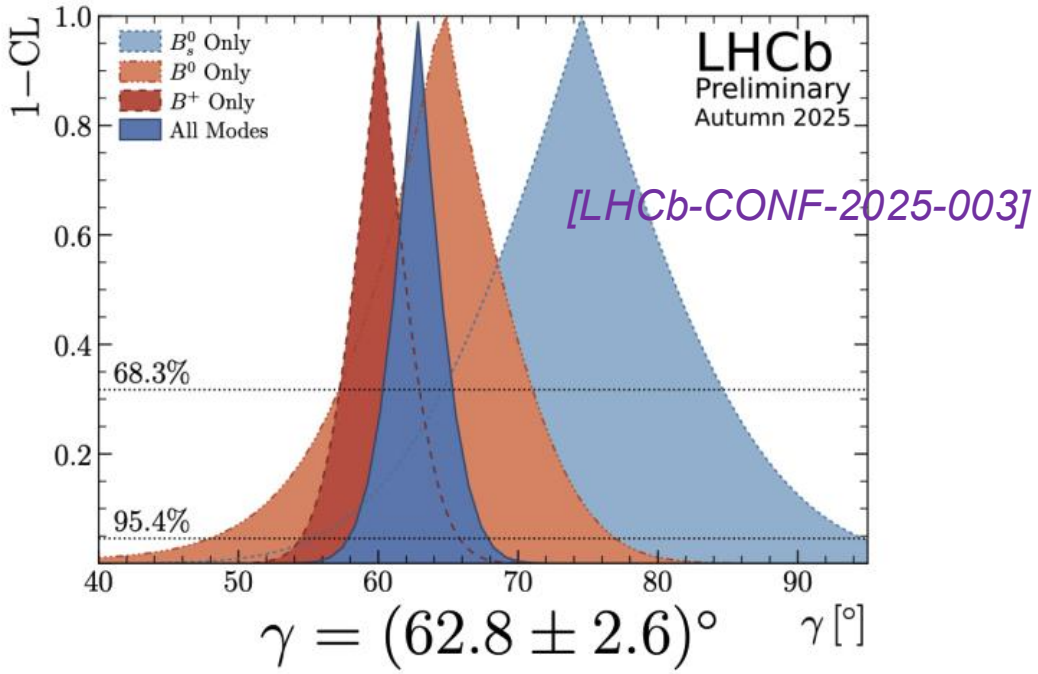
$$|A(B^+)|^2 \propto A_D^2 + r_B^2 A_{\overline{D}}^2 + 2A_D A_{\overline{D}} r_B \cos(\delta_B + \gamma)$$

Latest CKM angle γ combination

- 5.8 fb^{-1} data in 2024 *[LHCb-PAPER-2026-010]*

2024 Run 1+ Run 2





[LHCb-CONF-2025-003]

2024 LHCb average: $\gamma = (64.6 \pm 2.8)°$

2025 LHCb average: $\gamma = (62.8 \pm 2.6)°$

Precision brought to below 3°, most precision measurement in single experiment

Unbinned measurement of CKM angle γ

- Joint analysis between BESIII and LHCb experiment

[LHCb-PAPER-2025-063]
[LHCb-PAPER-2025-064]

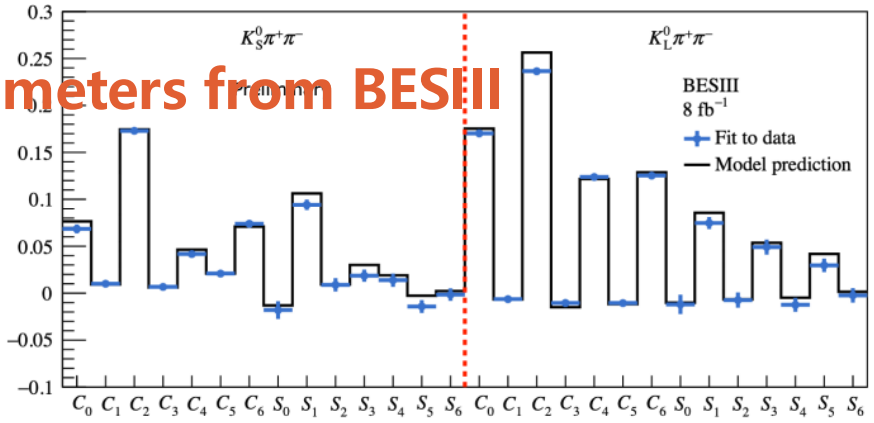
- In $B^{\pm} \to D(\to K_S^0 hh)h^{\pm}$ decay:

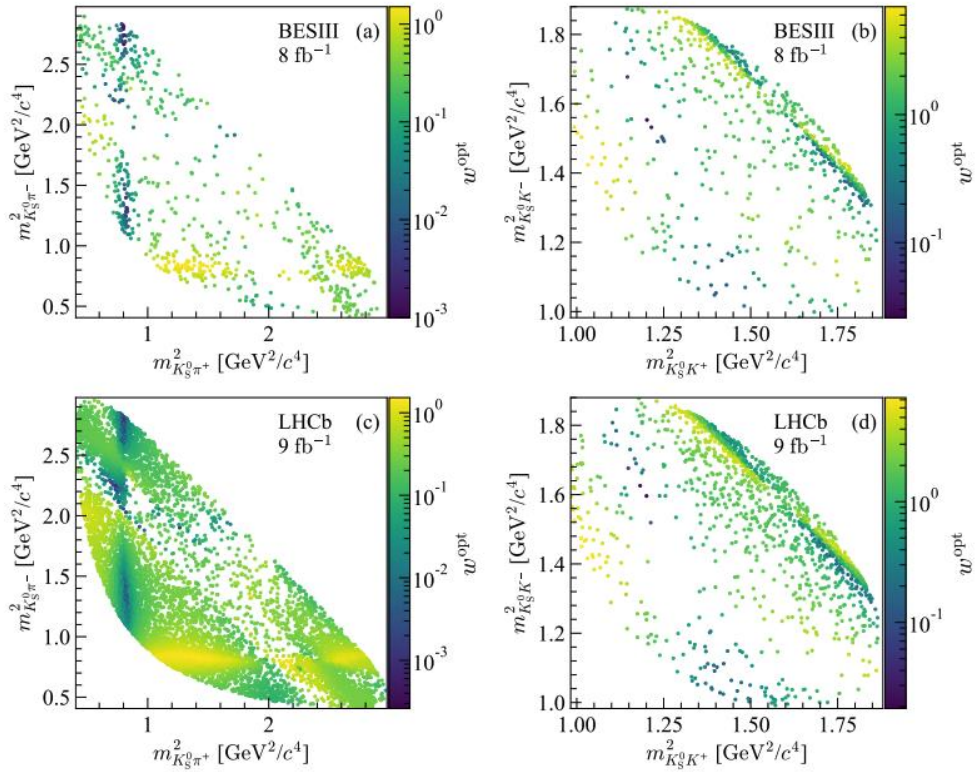
$$B^-: p_B(\mathbf{z}) \propto p_D(\mathbf{z}) + (x_-^2 + y_-^2)\bar{p}_D(\mathbf{z}) + 2[x_- \mathcal{C}(\mathbf{z}) + y_- \mathcal{S}(\mathbf{z})]$$
$$B^+: \bar{p}_B(\mathbf{z}) \propto \bar{p}_D(\mathbf{z}) + (x_+^2 + y_+^2)p_D(\mathbf{z}) + 2[x_+ \mathcal{C}(\mathbf{z}) - y_+ \mathcal{S}(\mathbf{z})]$$

$D^0/\bar{D}^0 \to K_S^0 h^+ h^-$ decay density

$\{\mathcal{C}, \mathcal{S}\} = \sqrt{p_D \bar{p}_D}\{\cos, \sin\}(\phi)$

Strong Phase parameters from BESIII



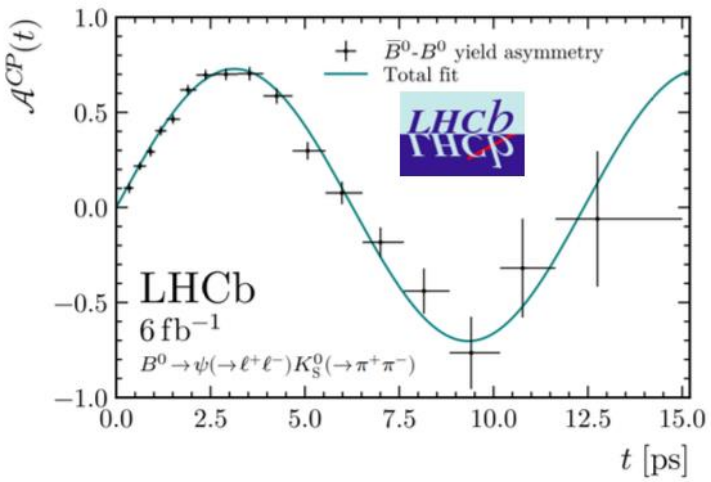


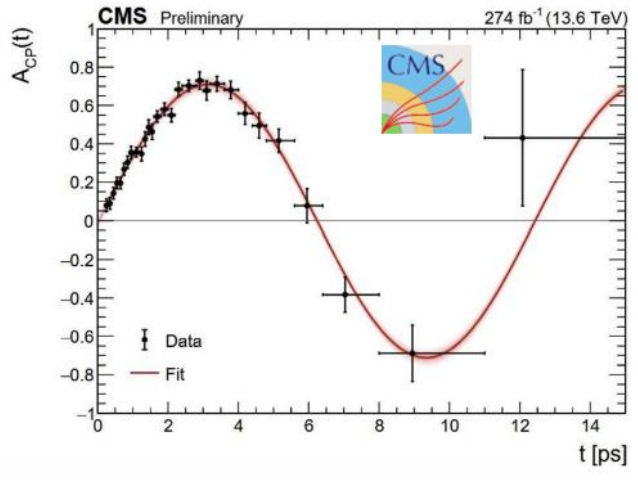
- Unbinned Fourier (novel):
  - Improved statistical precision than binned methods (~5% improvement)

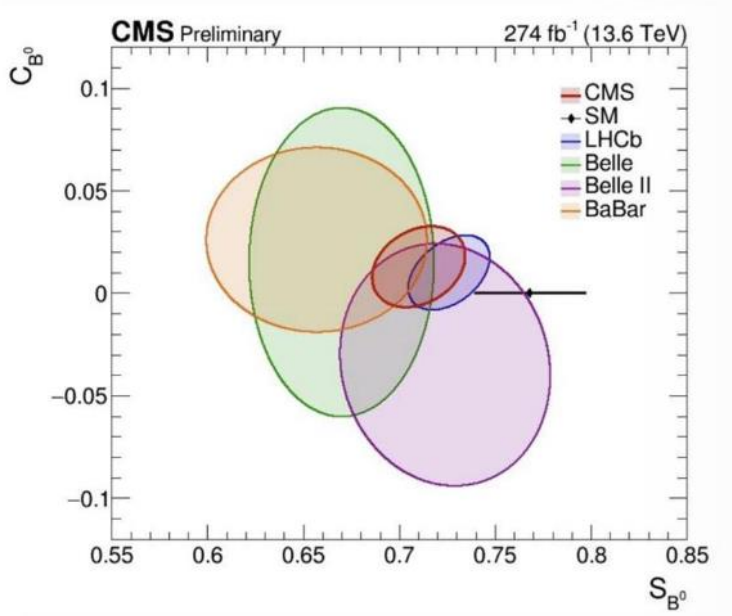
CKM phase β

- Measured in tree-dominating $b \to ccs$ processes, mainly $B^0 \to J/\psi K_S^0$

$$A^{CP}(t) \approx \sin 2\beta \sin(\Delta m_d t)$$







PRL 132 (2024) 021801

LHCb Run 1+2

$\sin 2\beta = 0.724 \pm 0.014$

CMS-PAS-BPH-26-005

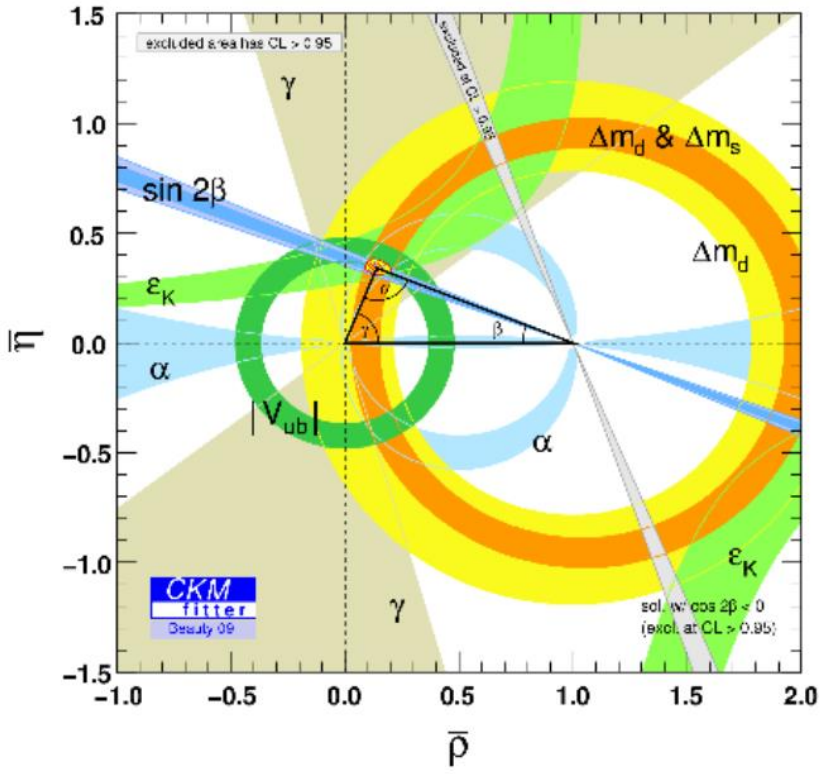
CMS Run 3 (2022-2025)

$\sin 2\beta = 0.710 \pm 0.013 \pm 0.009$

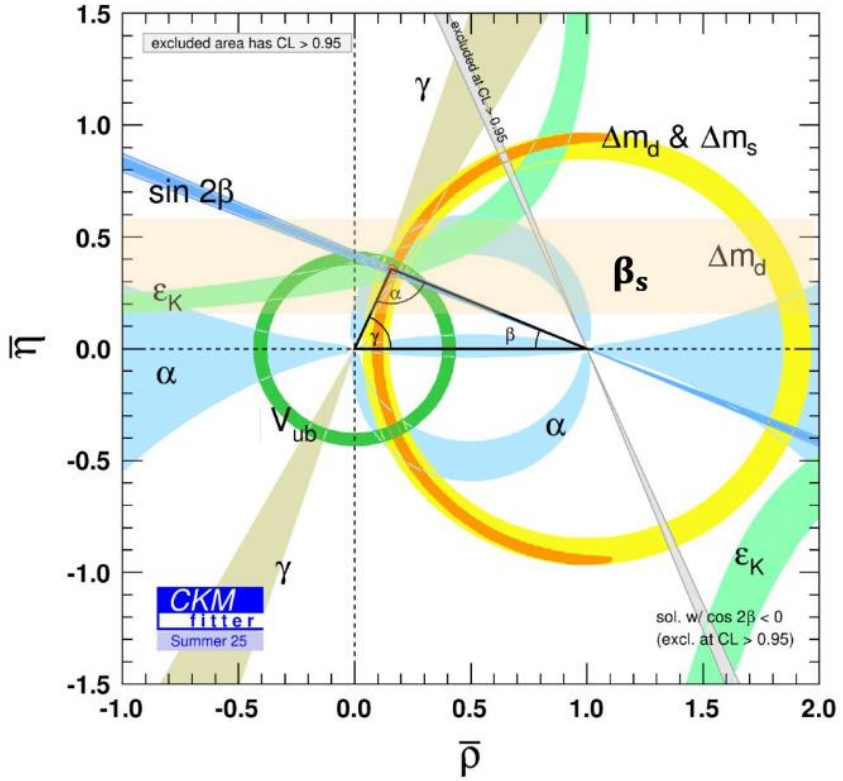
All measurements consistent with SM expectation

CKM global fit

Before LHC started（2009）



2025 summer



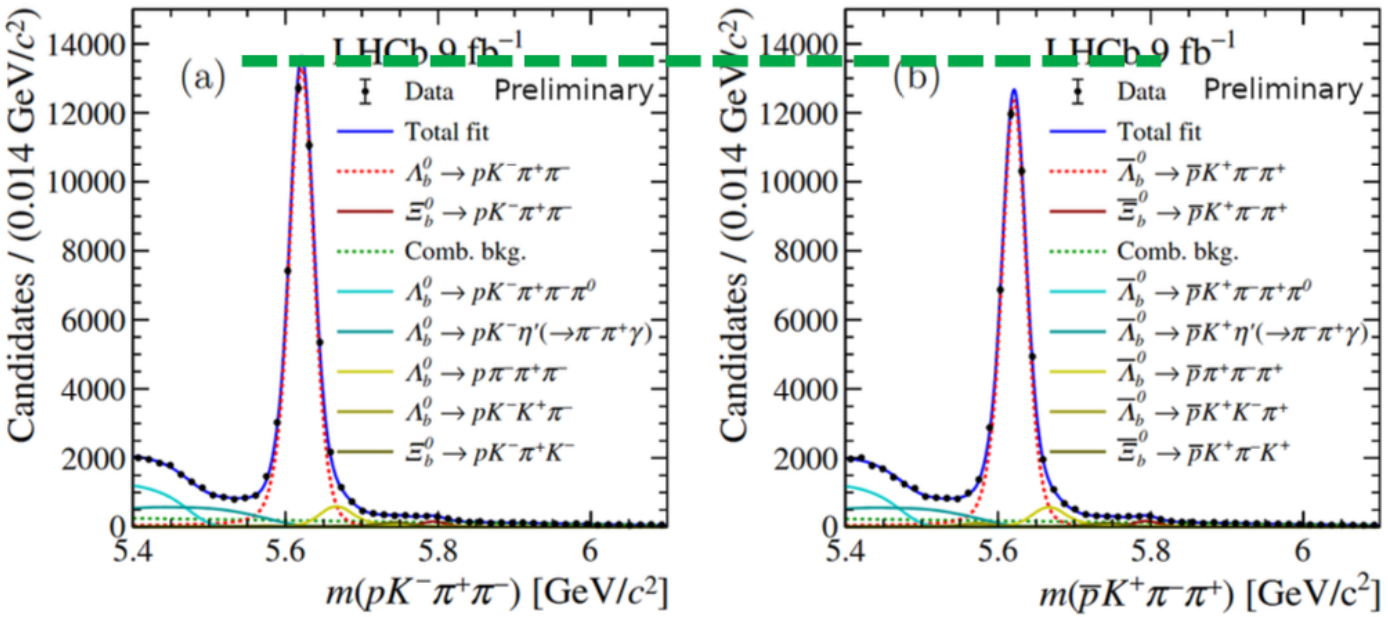
With significantly improved β, β_s, γ and $\delta m_{s/d}$, everything still matches

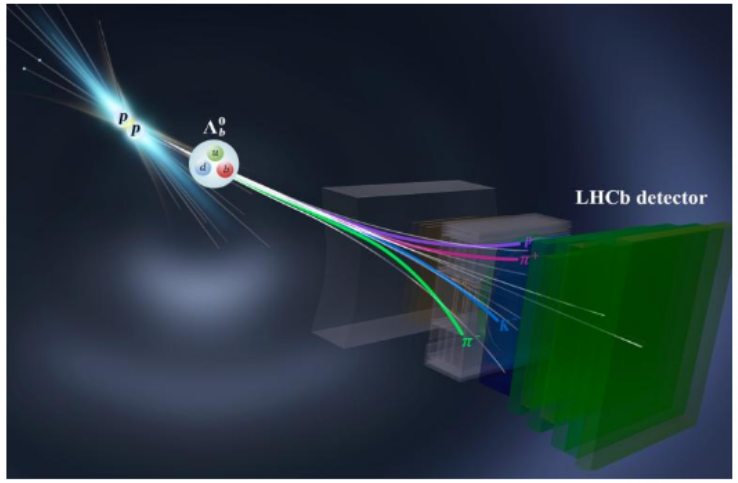
Hunting for CPV in baryons

- Expect baryons to behave similarly to mesons in quark level weak transitions
- LHCb performed a long list of searches for CPV in b-baryon decays
- No CP violation in baryon decays was observed until 2025

Decay	Methods	Data	References
$\Lambda_b^0 \to pK_S^0\pi^-$	A_{CP}	1 fb^{-1}	JHEP 04 (2014) 087
$\Lambda_b^0 \to \Lambda hh'$	A_{CP}	3 fb^{-1}	JHEP 05 (2016) 081
$\Lambda_b^0 \to p\pi^-\pi^+\pi^-$	TPA, energy test	3 fb^{-1} 6.6 fb^{-1}	Nature Physics 13 (2017) 391 PRD 102 (2020) 051101
$\Lambda_b^0 \to pK^-\mu^+\mu^-$	A_{CP}	3 fb^{-1}	JHEP 06 (2017) 108
$\Lambda_c^+ \to ph^-h^+$	A_{CP}	3 fb^{-1}	JHEP 03 (2018) 182
$\Lambda_b^0 \to pK^-/p\pi^-$	A_{CP}	3 fb^{-1}	PLB 787 (2018) 124
$\Lambda_b^0 \to ph^-h^+h^-$	TPA	3 fb^{-1}	JHEP 08 (2018) 039
$\Lambda_b^0 \to ph^-h^+h^-$	A_{CP}	3 fb^{-1}	EPJC 79 (2019) 745
$\Xi_b^- \to pK^-K^-$	Amplitude	5 fb^{-1}	PRD 104 (2020) 052010
$\Xi_c^+ \to pK^-\pi^+$	kNN	3 fb^{-1}	EPJC 80 (2020) 986
$\Lambda_b^0 \to pD^0K^-$	Miranda S_{CP}^i	9 fb^{-1}	PRD104 (2021) 112008
$\Lambda_b^0 \to \Lambda\gamma$	photon polarization	3 fb^{-1}	PRD105 (2022) L051104
$\Lambda_b^0 \to \Lambda_c^+h^-$	Decay parameter	9 fb^{-1}	PRL 133 (2024) 261804
$\Lambda_b^0 \to ph^-$	A_{CP}	9 fb^{-1}	PRD 111(2025) 092004
$\Lambda_b^0 \to \Lambda hh'$	A_{CP}	9 fb^{-1}	PRL 134 (2025) 101802
$\Lambda_b^0 \to pK^-\pi^+\pi^-$	A_{CP}	9 fb^{-1}	Nature 643 (2025) 1223
$\Lambda_b^0, \Xi_b^0 \to pK_S^0h^-$	A_{CP}	9 fb^{-1}	JHEP 10 (2025) 169
$\Lambda_b^0 \to J/\psi ph^-$	A_{CP}, TPA	6 fb^{-1}	LHCb-PAPER-2025-021

Observation of CPV in baryons





$$\Delta A^{CP} = (2.45 \pm 0.46 \pm 0.10)\%$$

using $\Lambda_b^0 \to \Lambda_c^+(pK^-\pi^+)\pi^-$ as a control channel

Nature 643 (2025) 1223

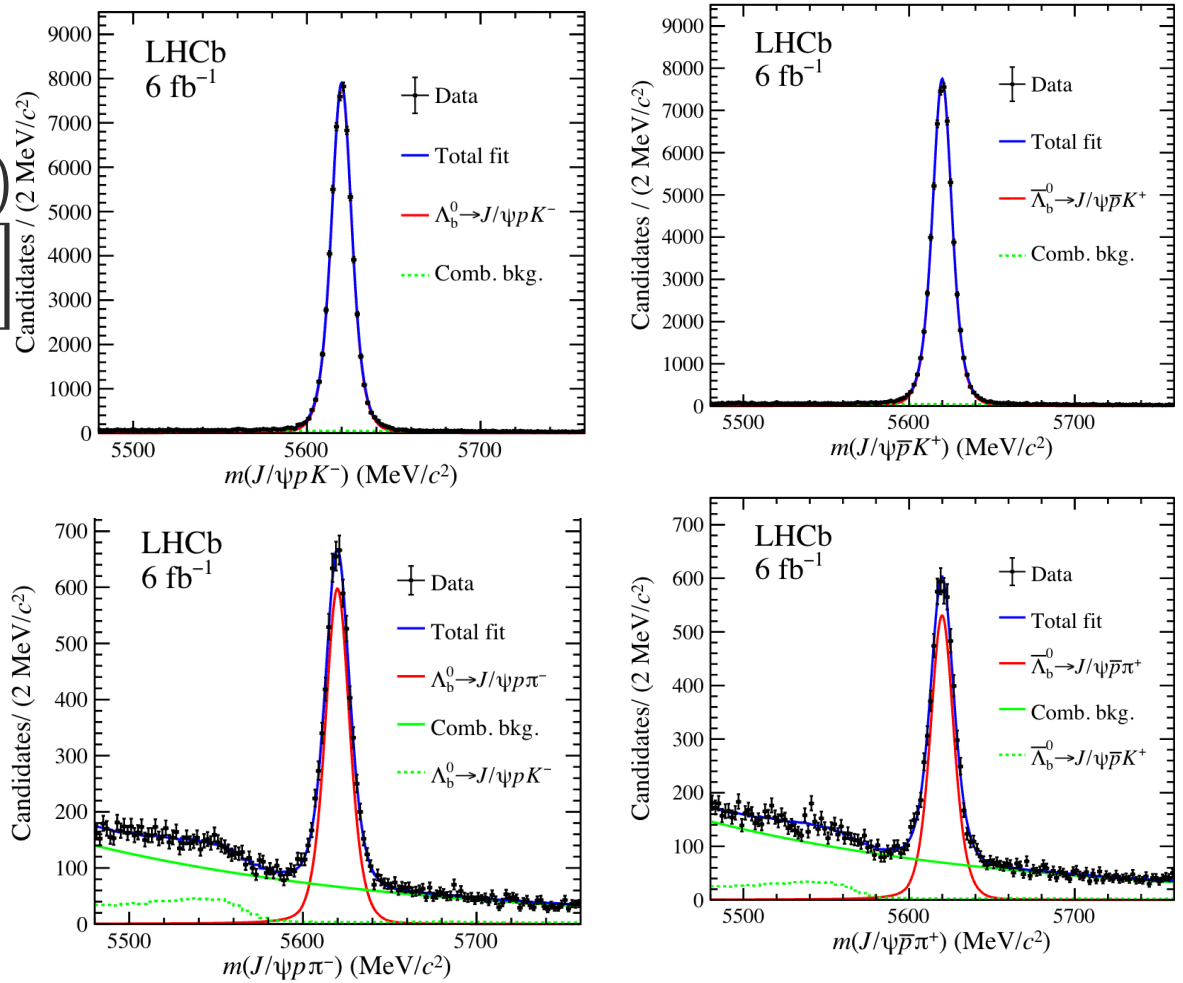
5.2σ from zero, discovery of CP violation in baryon decays!

CPV in *b* baryon to charmonium decays

- Penguin contributions expected to enhance asymmetry in $\Lambda_b^0 \to J/\psi p\pi^-$
- Observable:
  - $\Delta A_{CP} \equiv A_{CP}\left(\Lambda_b^0 \to J/\psi p\pi^-\right) - A_{CP}\left(\Lambda_b^0 \to J/\psi pK^-\right)$
  - $A_{\tilde{T}}-\text{odd} \equiv \frac{1}{2}\left[\frac{N(C_{\tilde{T}}>0)-N(C_{\tilde{T}}\leq 0)}{N(C_{\tilde{T}}>0)+N(C_{\tilde{T}}\leq 0)} - \frac{N(-C_{\tilde{T}}>0)-N(-C_{\tilde{T}}\leq 0)}{N(-C_{\tilde{T}}>0)+N(-C_{\tilde{T}}\leq 0)}\right]$
- Run 2 results $\Delta A_{CP} = (4.03 \pm 1.18 \pm 0.23)\%$
- Combined with previous LHCb result:

$\Delta A_{CP} = (4.31 \pm 1.06 \pm 0.28)\% \Rightarrow 3.9\sigma$ First

[Science Bulletin 71 (2026) 547]

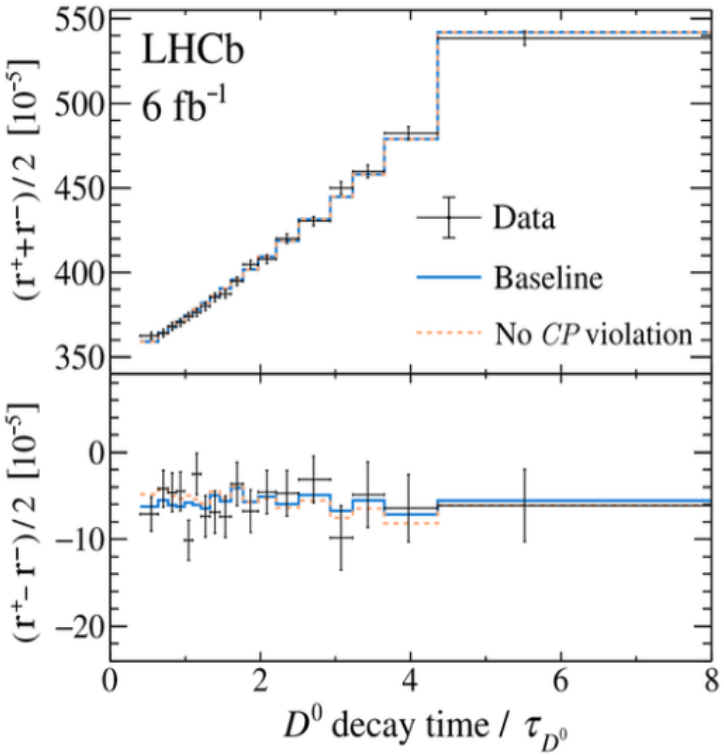


Mixing and CPV in charm sector

- First observation of direct CPV in charm sector at LHCb in 2019
- Mixing and CPV parameters with right and wrong sign

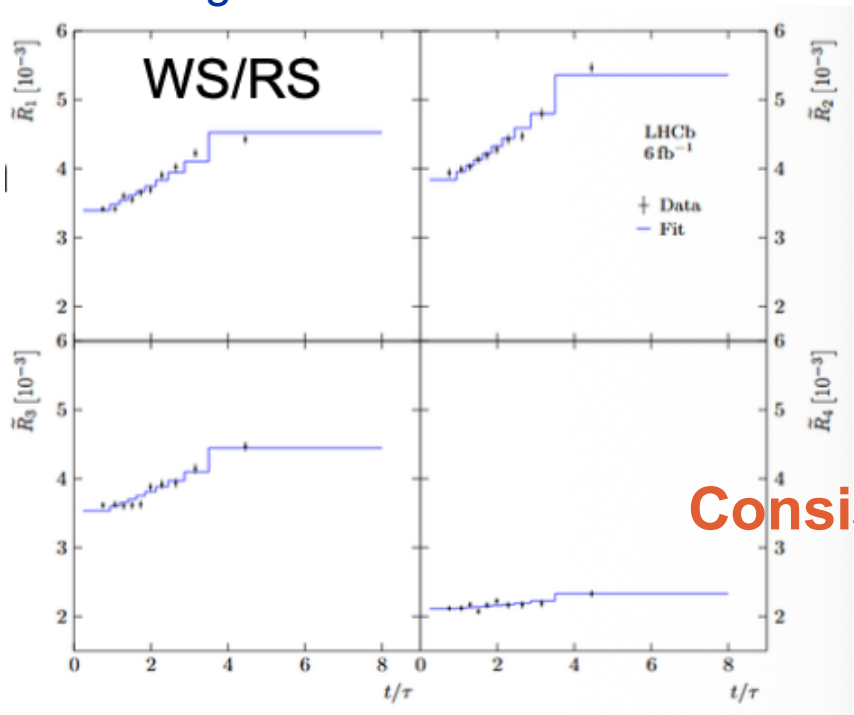
  $D^0 \to K^+\pi^-$ decays tagged with prompt D^* decays

Mixing and CPV in $D^0 \to K\pi$

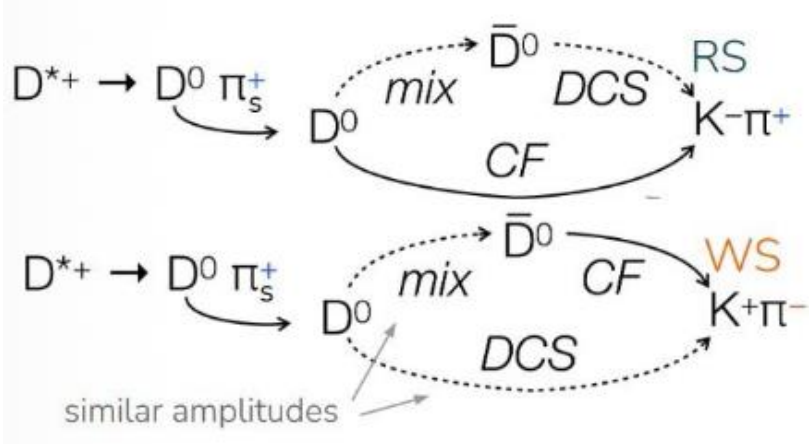


[PRD 111 (2025) 012001]

Mixing and CPV in $D^0 \to K\pi\pi\pi$



[JHEP 12 (2025) 153]



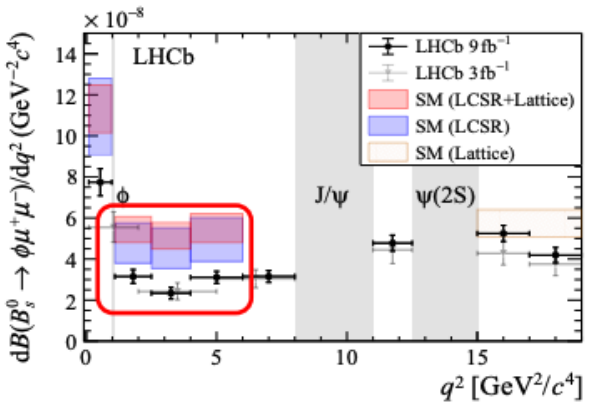
Consistent with CP symmetry

FCNC & LFU

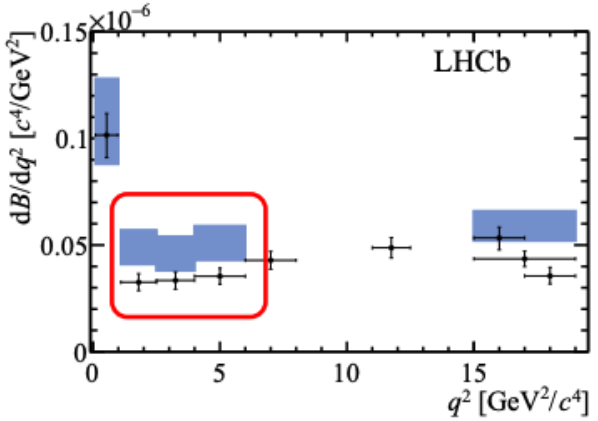
Consistently low $\mathfrak{P}$ found in $b \to s\mu\mu$

Branching fractions

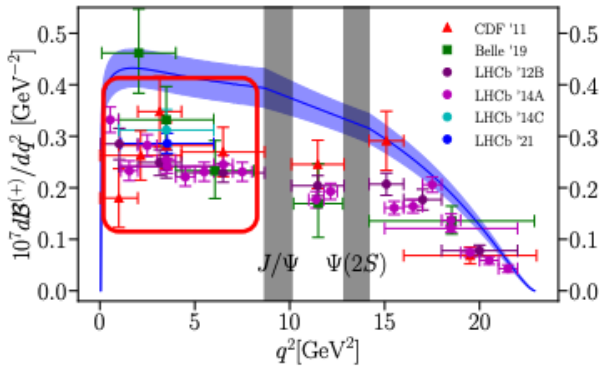
LHCb $B_s^0 \to \phi\mu^+\mu^-$ [PRL 127 (2021) 151801]



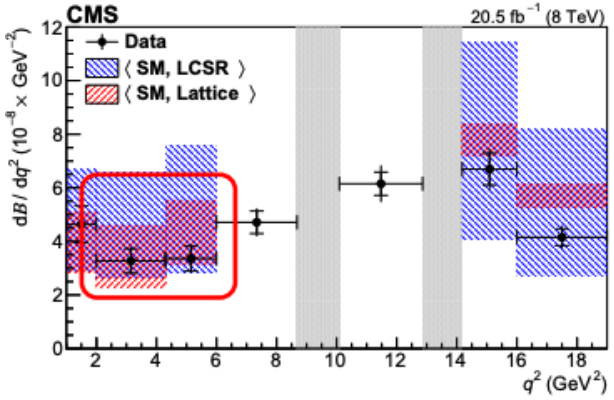
LHCb $B^0 \to K^{*0}\mu^+\mu^-$ [JHEP 11 (2016) 047]



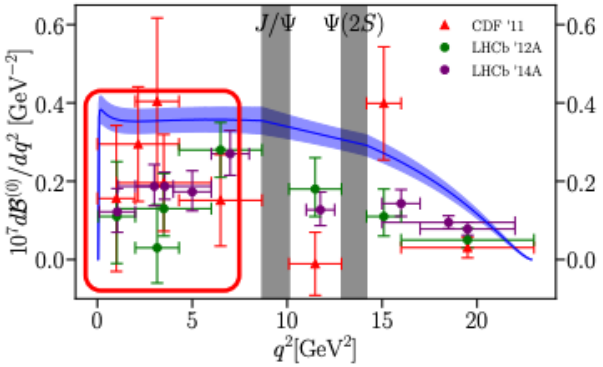
$B^+ \to K^+\mu^+\mu^-$ [HPQCD, PRD 107 (2023) 1]



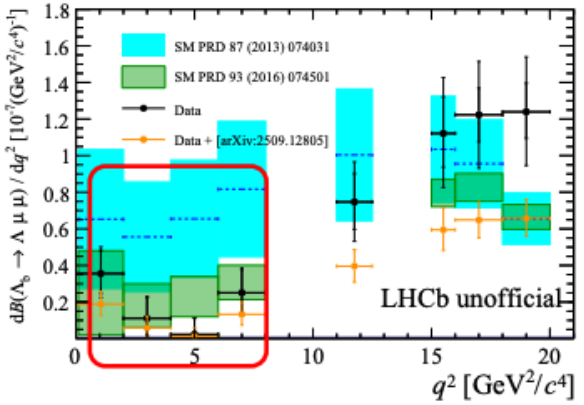
CMS $B^0 \to K^{*0}\mu^+\mu^-$ [PLB 753 (2016) 424]



$B^0 \to K^0\mu^+\mu^-$ [HPQCD, PRD 107 (2023) 1]



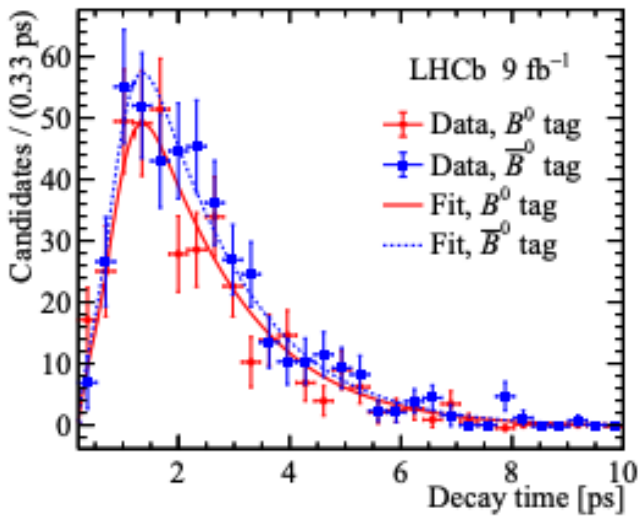
LHCb $\Lambda_b^0 \to \Lambda\mu^+\mu^-$ [JHEP 06 (2015) 115]

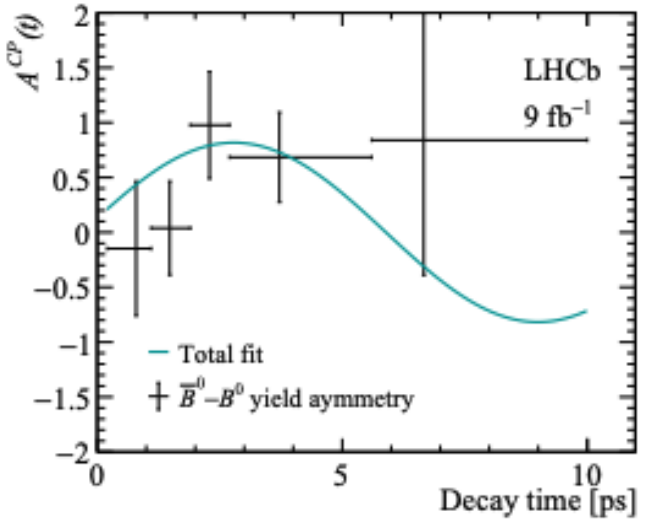


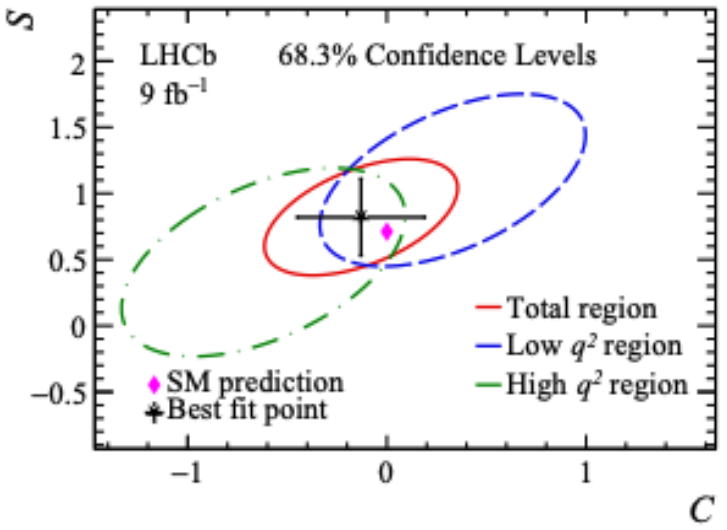
- Consistently below SM, tensions at $1-3\sigma$ level (significant hadronic uncertainties)
- $B^+ \to \bar{\Lambda}p\mu^+\mu^-$ explored recently, in agreement with the SM *[PRL 137 (2026) 051801]*

Time-dependent CP-asymmetry in $B^0 \to K^0_S \mu\mu$

Rate asymmetries







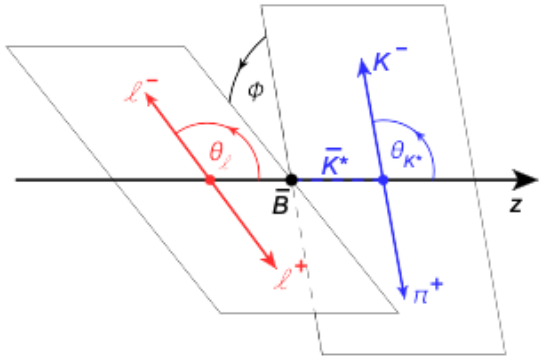
- First time-dep. measurement of CPV in $b \to sll$ processes using Run 1+2
- Legacy Time-dep. CP-asymmetry $A_{CP} = S \times sin(\Delta m_d t) - C \times cos(\Delta m_d t)$
- Resulting in $S = +0.32 \pm 0.29 \pm 0.05$ and $C = +0.13 \pm 0.32 \pm 0.04$; in good agreement with SM prediction

[PRL 136 (2026) 231904]

Angular analysis of $B \to K^{*0}[\to K\pi]\mu^+\mu^-$

Angular distribution

- Fit of 5D PDF to determine CP-symmetries S_i and CP-asymmetries A_i

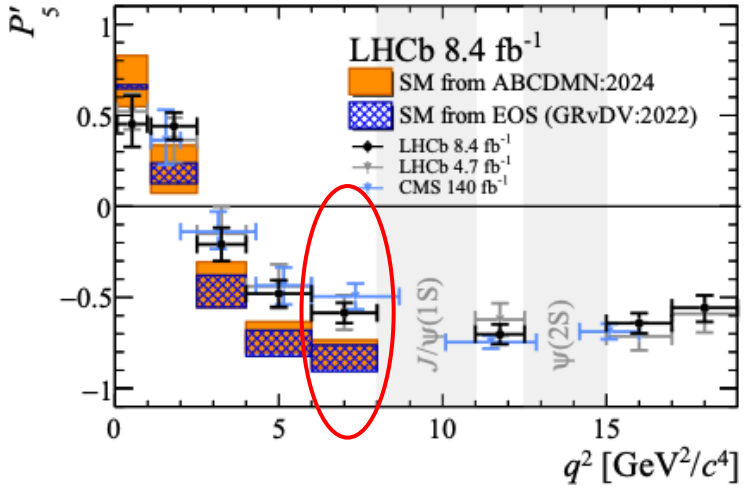


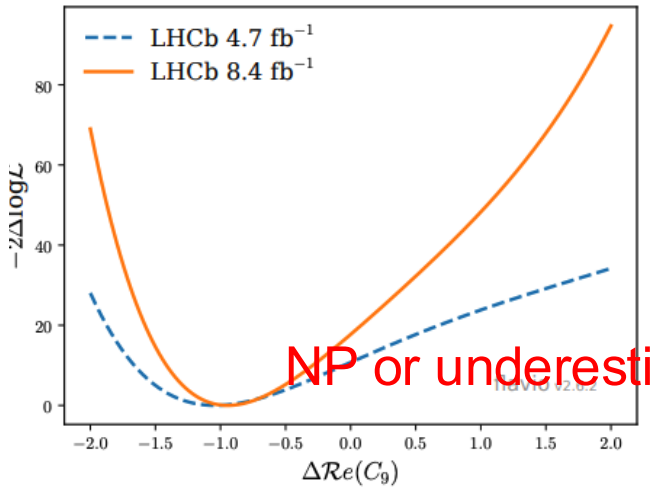
$$\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}^5\overleftrightarrow{\Gamma}}{\mathrm{d}q^2\mathrm{d}m_{K\pi}\mathrm{d}\vec{\Omega}} = (1-\hat{F}_S)\frac{9}{64\pi}\sum_i (S_i \pm A_i) f_i(\vec{\Omega})|\mathcal{BW}_P(m_{K\pi})|^2 \quad \text{P-wave}$$

$$+\frac{1}{8\pi}\sum_j (\tilde{S}_j \pm \tilde{A}_j) f_j(\vec{\Omega}) F(m_{K\pi}) \quad \text{S-wave+interference}$$

$$P_5' = \frac{S_5}{\sqrt{F_L(1-F_L)}}$$

Optimized angular





Wilson coefficients

$$\Delta\mathcal{R}eC_9 = -0.93^{+0.18}_{-0.16}$$

Significance $4.1\,\sigma$

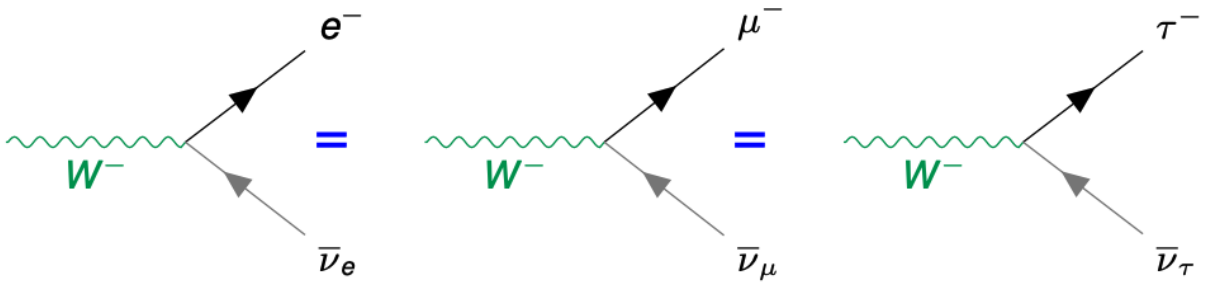
NP or underestimated hadronic effect?

- Local deviations 3.1 (2.7) σ in [6, 8] GeV for EOS(ABCDMN)
- Legacy analysis of $B \to K^{*0}\mu^+\mu^-$ sees tension of around 4σ

[PRL 137 (2026) 021802]

Lepton flavour universality (LFU)

- In the SM, weak interactions towards three generations of leptons are identical



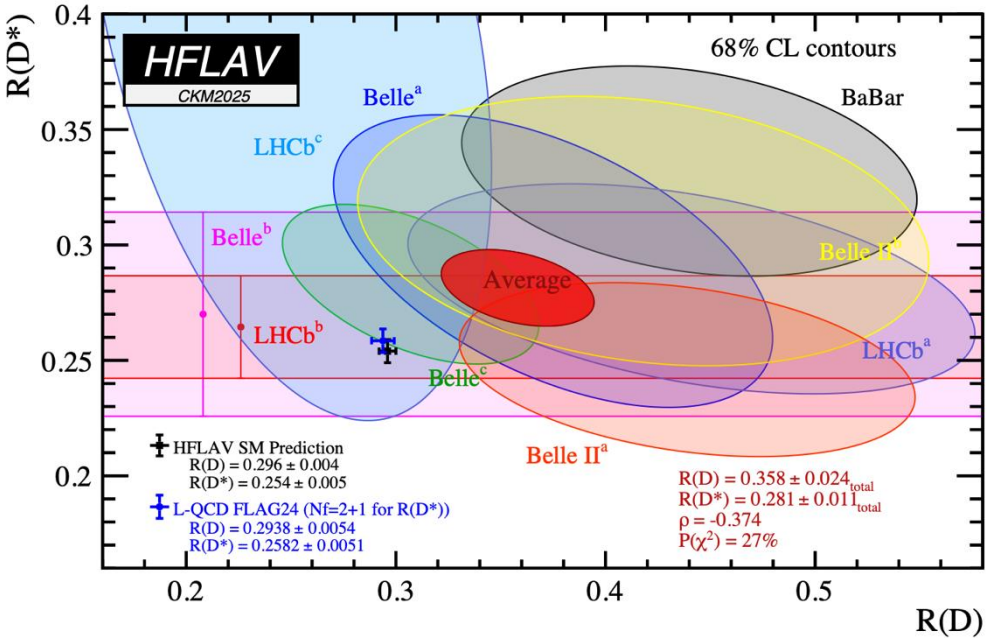
- Interesting measurement: $\mathcal{R}(X_c) \equiv \frac{\mathcal{B}(X_b \to X_c \tau^+ \nu_\tau)}{\mathcal{B}(X_b \to X_c \ell^+ \nu_\ell)}$

- Recent LHCb results using Run 2 data:

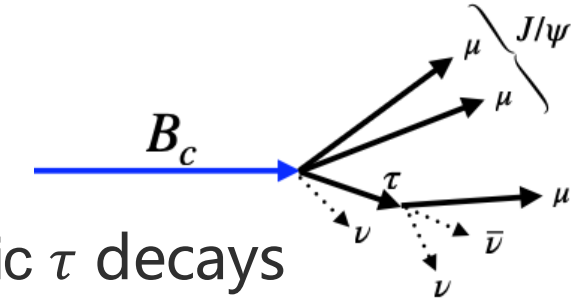
Muonic: $R(D^{*+}) = 0.402 \pm 0.081 \pm 0.085,$

Hadronic: $\mathcal{R}(D^{*-}) = 0.260 \pm 0.015 \pm 0.016 \pm 0.012\,,$

- Recent 3.8σ in $R(D^*)$ measurements HFLAV 2025

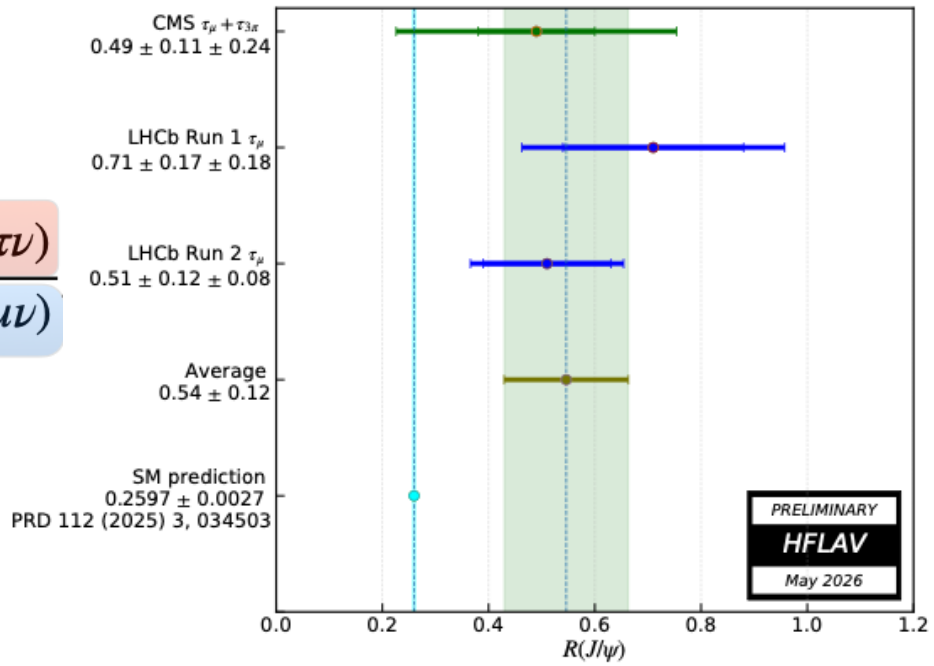


$R(J/\psi)$ measurement



Muonic τ decays

$$\frac{\mathcal{B}(B_c \to J/\psi\tau\nu)}{\mathcal{B}(B_c \to J/\psi\mu\nu)}$$



Final value: 0.51 ± 0.12**(stat)** ± 0.08**(syst)**

1.8σ **compatibility with Standard Model** (0.26)

- World leading Result!
- Consistent with world average
- Statistically limited

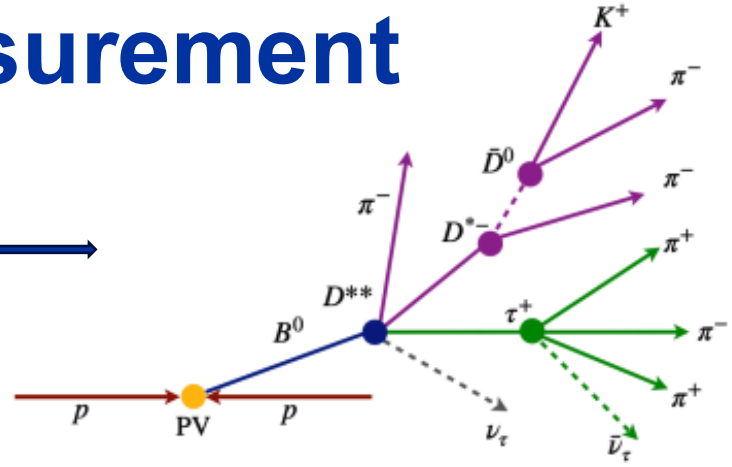
Source of uncertainty on $\mathcal{R}(J/\psi)$	Value ($\times 10^{-2}$)
Simulation statistical uncertainty	5.9
$B_c^+ \to \psi(2S)\ell^+\nu$ modeling	2.6
MisID composition estimation	2.5
Simulation corrections	2.0
$B_c^+ \to J/\psi\,\ell^+\,\nu$ form factors	1.8
$B_c^+ \to \chi_c\,\mu^+\nu$ scaling	1.5
Efficiency ratio	1.3
Fragmentation background modeling	1.3
MisID decay-in-flight correction	1.1
$(J/\psi + \mu^+)$ combinatorial modeling	0.6
MisID decay-in-flight smearing	0.3
$B_c^+ \to \psi(2S)\,\ell^+\nu$ scaling	0.3
$\mathcal{B}(\tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau)$	0.2
Trimuon effect	0.1
Systematic uncertainty	7.9
Statistical uncertainty	11.9
Total uncertainty	14.3

[PRev 137 (2026) 141801]

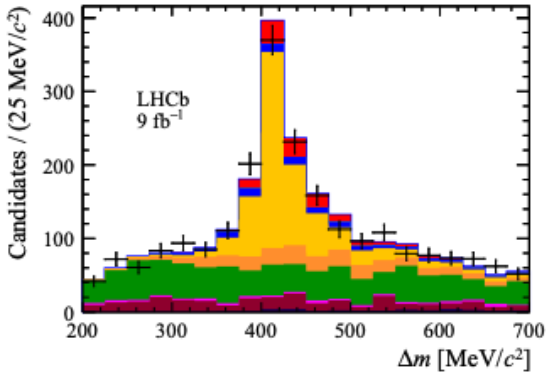
$B^- \to D^{**0}\tau^-\bar{\nu}_\tau$ decay measurement

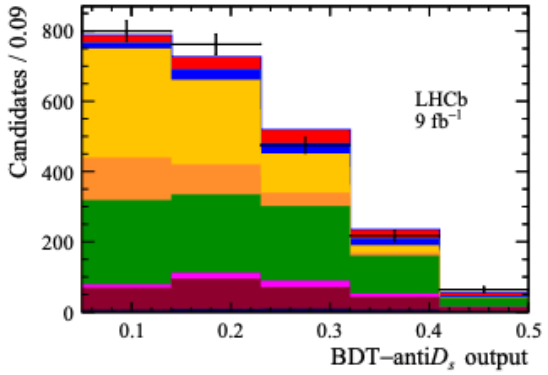
$$\mathcal{R}(D^{**0}_{1,2}) = \frac{\mathcal{B}(B^- \to D^{**0}_{1,2}\tau^-\bar{\nu}_\tau)}{\mathcal{B}(B^- \to D^{**0}_{1,2}\mu^-\bar{\nu}_\mu)}$$

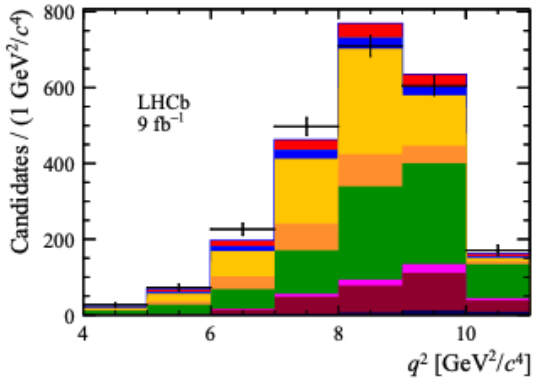
Searching

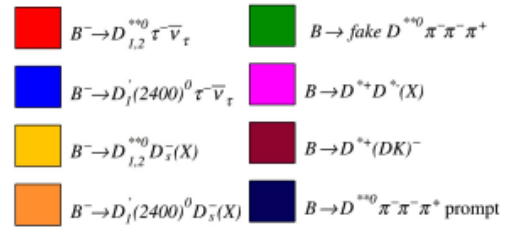


- Signal extracted from binned fit to: $\Delta m = m(D^{*-}\pi^+) - m(D^{*-})$, anti-$D_s$ BDT, $q^2 = (p_B - p_{D^{**}})^2$









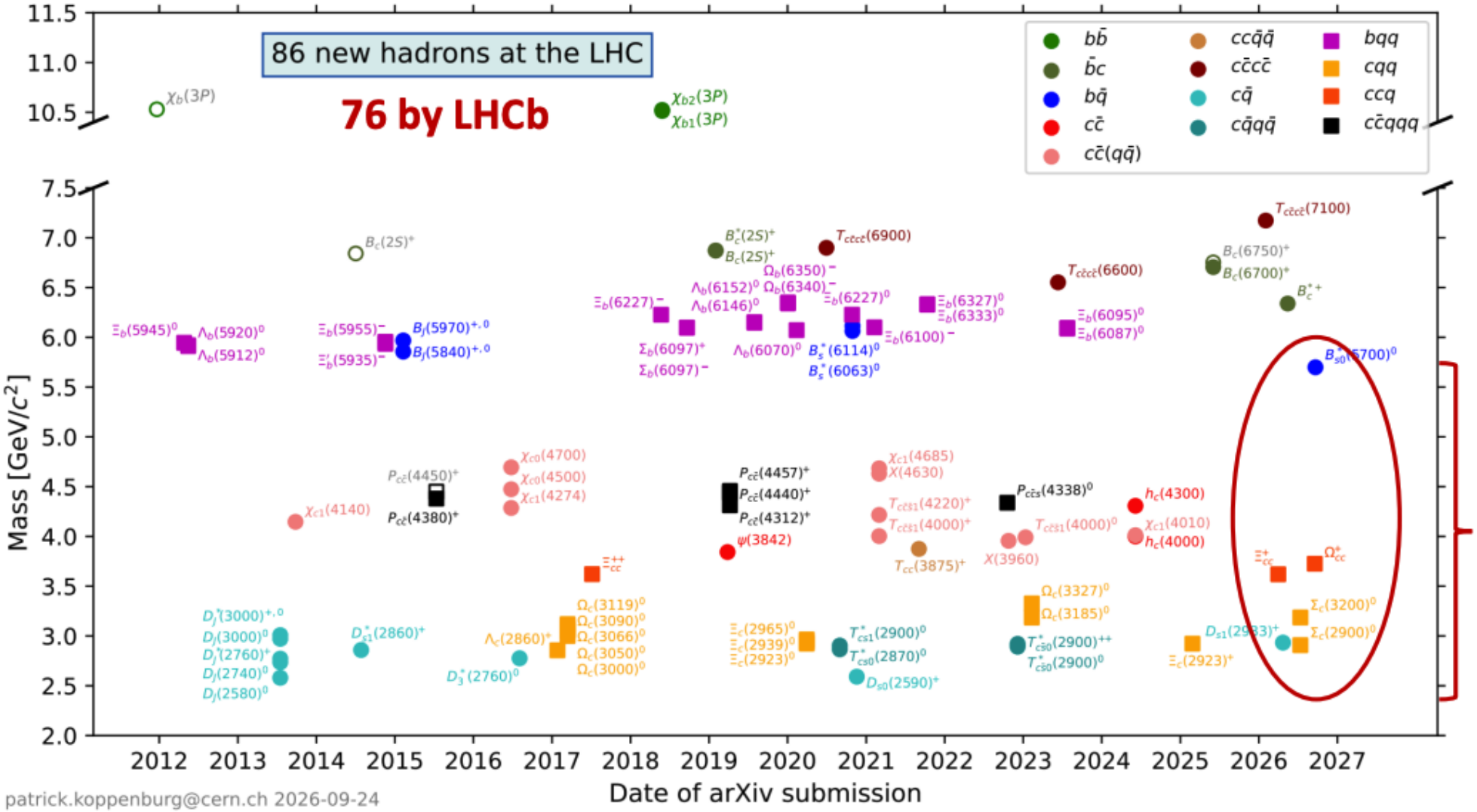
$$\mathcal{R}(D^{**0}_{1,2}) = \frac{\mathcal{B}(B^- \to D^{**0}_{1,2}\tau^-\bar{\nu}_\tau)}{\mathcal{B}(B^- \to D^{**0}_{1,2}\mu^-\bar{\nu}_\mu)} = 0.13 \pm 0.04$$

[PRL 135 (2025) 021802]

- In agreement with SM prediction 0.09 ± 0.02 [PRD 97 (2018) 075011]

Spectroscopy

New hadrons observed at LHCb

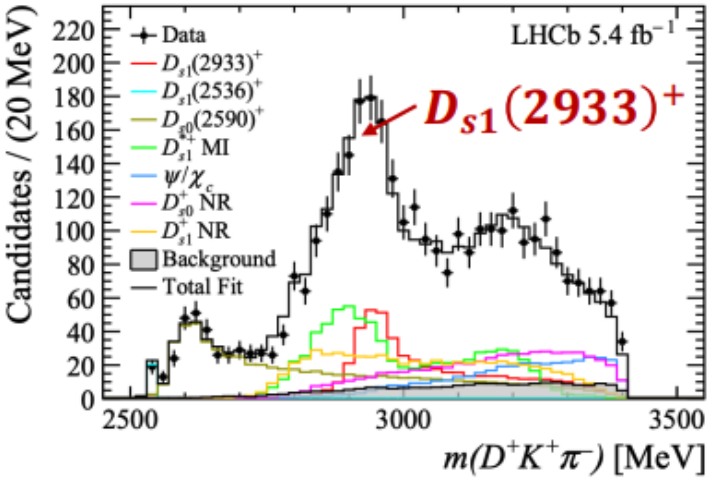


Six new hadrons observed by LHCb in 2026

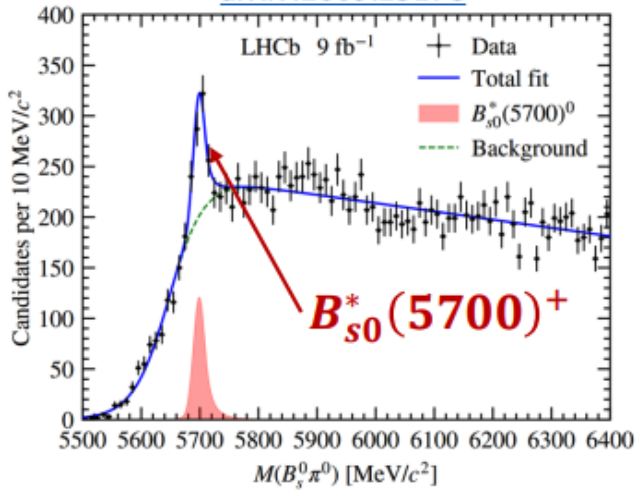
[Patrick's webpage]

Six new hadrons observed by LHCb in 2026

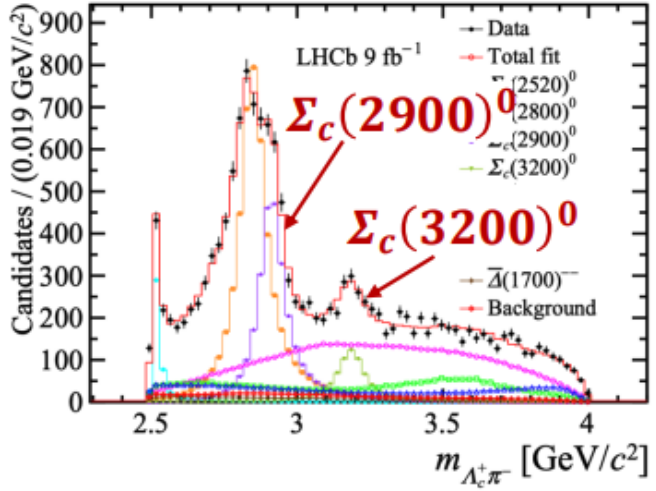
arXiv:2604.21257

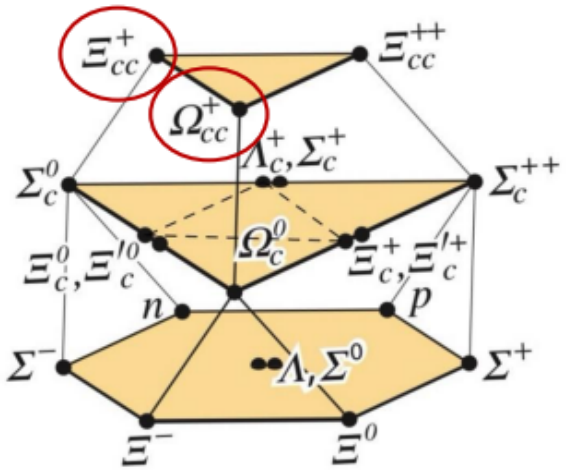


arXiv:2609.25178

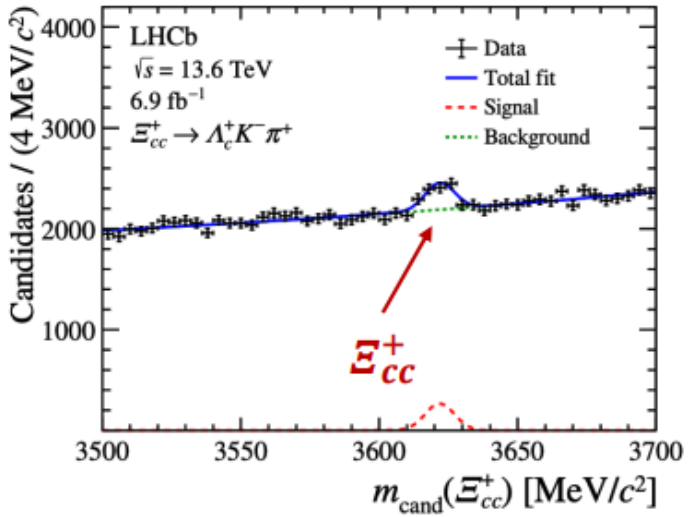


arXiv:2607.10595

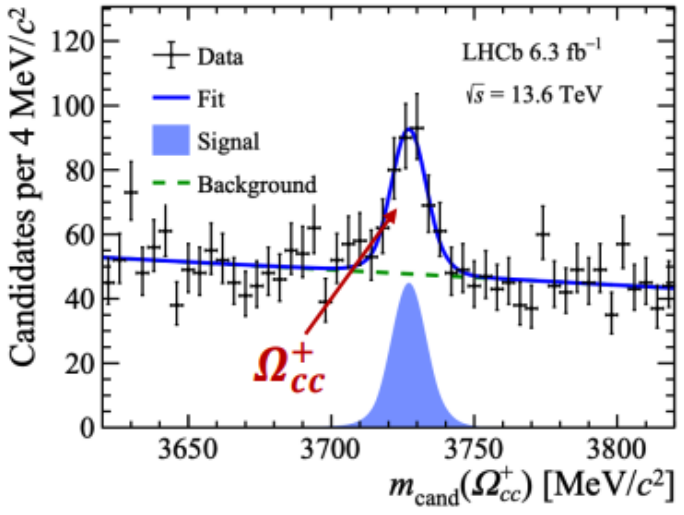




PRL 137 (2026) 021902

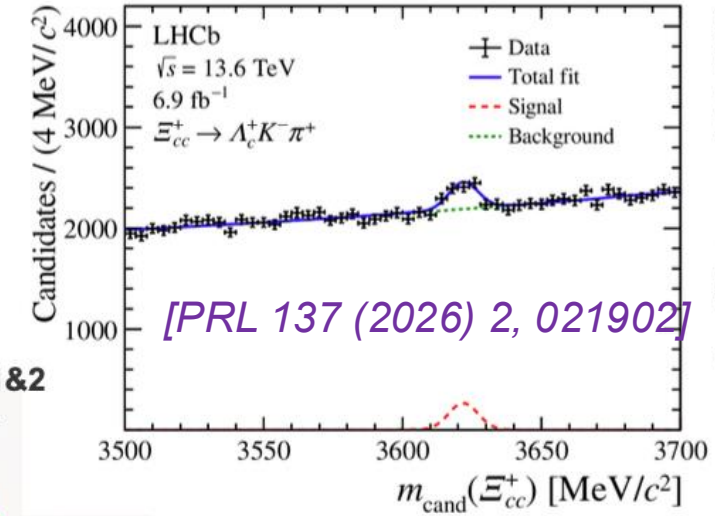


arXiv:2609.21921

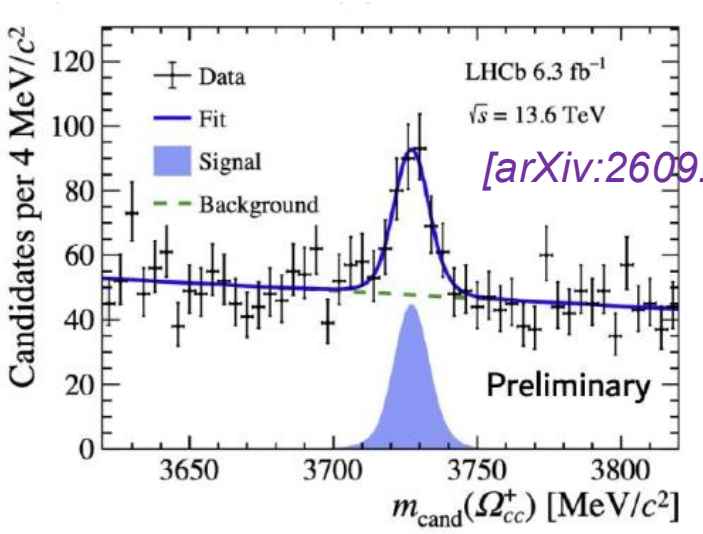


New doubly charmed baryon

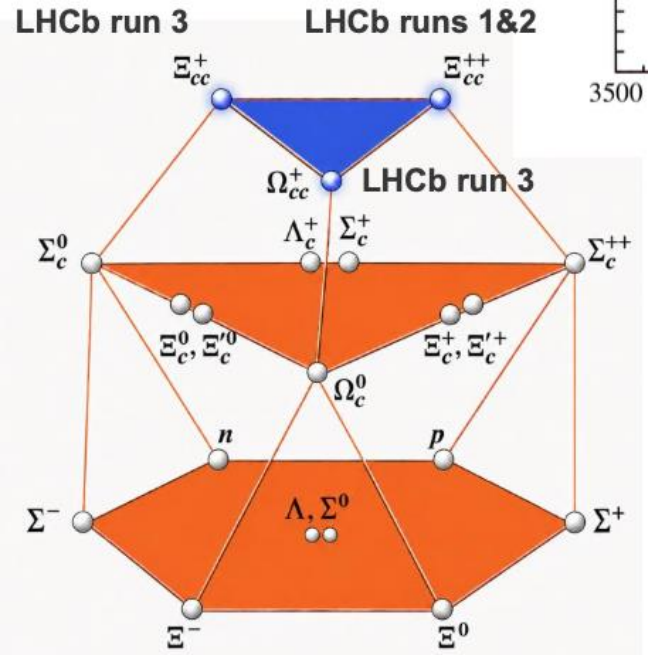
- Observed in $\Xi_{cc}^{+} \to \Lambda_c^+ K^- \pi^+$ and $\Omega_{cc}^{++} \to \Omega_c^0 (\to pKK\pi)\, \pi^+$
- Yield per fb^{-1} improved factor ~4 thanks to improved fully-software trigger



[PRL 137 (2026) 2, 021902]



[arXiv:2609.21921]



$$M(\Xi_{cc}^+) = 3619.97 \pm 0.83 \pm 0.26\, ^{+1.90}_{-1.30}\ \mathrm{MeV}/c^2$$

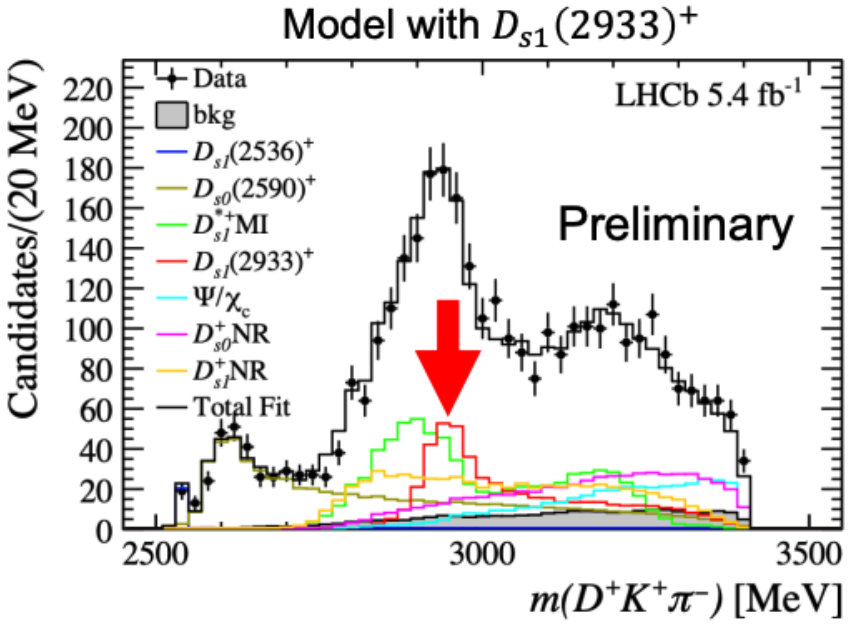
- ❑ All members of the spin-1/2 20-plet of ground-state baryons established
- ❑ Future interesting probes of charm hadronization

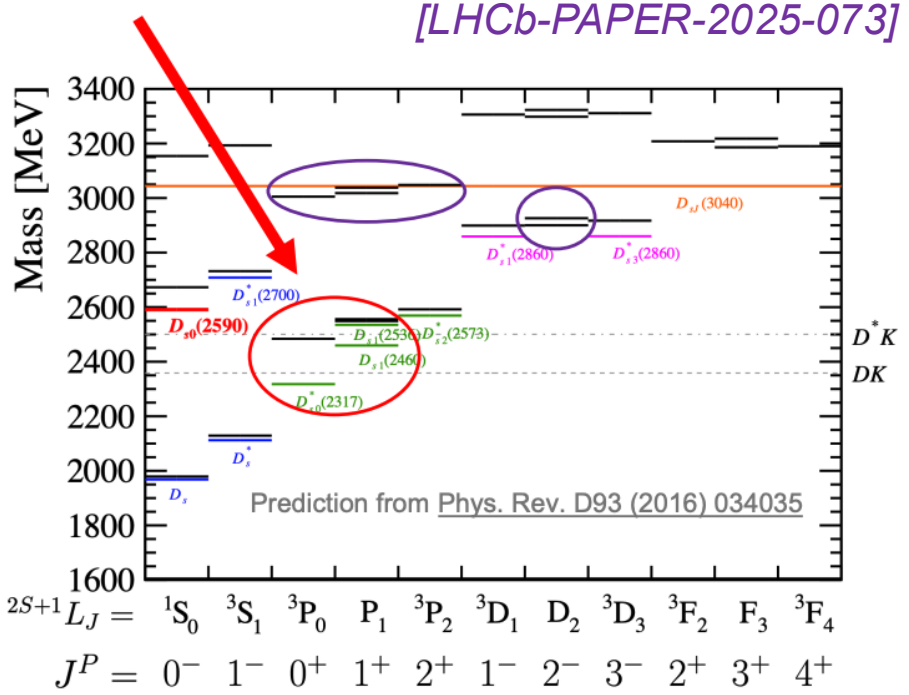
New excited charm-strange meson $D_{s1}(2933)^+$

- A long-standing puzzle about the nature of $D_{s0}^*(2317)^+$ and $D_{s1}(2460)^+$
  - ~100 MeV below quark-model predictions for P-wave states

[LHCb-PAPER-2025-073]

- Search for excited D_s^+ in $B^0 \to D^+D^-K^+\pi^-$

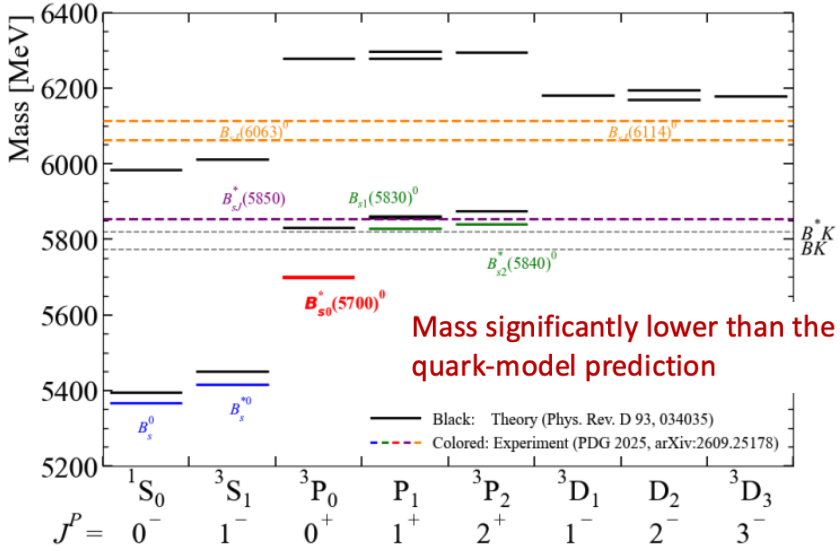




- Mass and width: $\mathrm{M} = 2933^{+6}_{-5}(\mathrm{stat.})^{+4}_{-3}(\mathrm{syst.})$ MeV; $\Gamma = 72^{+18}_{-12}(\mathrm{stat.})^{+7}_{-10}(\mathrm{syst.})$ MeV
- Spin-parity: $J^P = 1^+$, other J^P hypotheses rejected at $> 5\sigma$

A narrow beauty-strange state

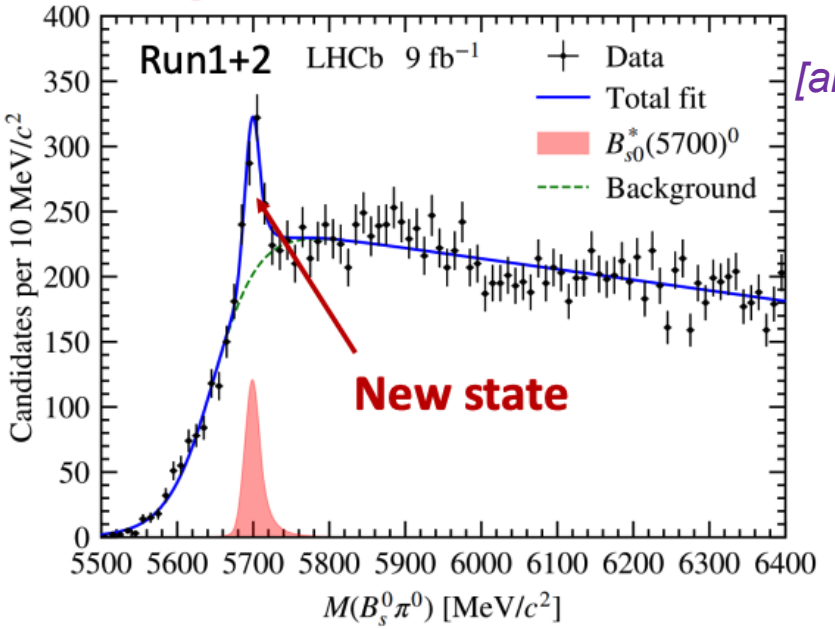
- $B_s^0 \to D_s^- \pi^+, J/\psi\phi, D_s^- 3\pi$;



Mass significantly lower than the quark-model prediction

Similar pattern to that of $D_{s1}(2460)^+$ under the $J^P = 1^+$ interpretation

$N_{\rm sig} = 343^{+44}_{-41}$ $\quad > 7\sigma$



[arXiv: 2608.10826]

- Two interpretations:

$$B_{s0}^* \to B_s^0 \pi^0 \qquad m = 5698.9 \pm 1.5\,(\text{stat}) \pm 0.6\,(\text{syst})\ \text{MeV}$$
$$\Gamma < 11.8\ \text{MeV} \quad (95\%\ \text{CL})$$

$$B_{s1} \to B_s^{*0} \pi^0 \qquad m = 5748.3 \pm 1.5\,(\text{stat}) \pm 0.6\,(\text{syst})\ \text{MeV}$$
$$\Gamma < 11.8\ \text{MeV} \quad (95\%\ \text{CL})$$

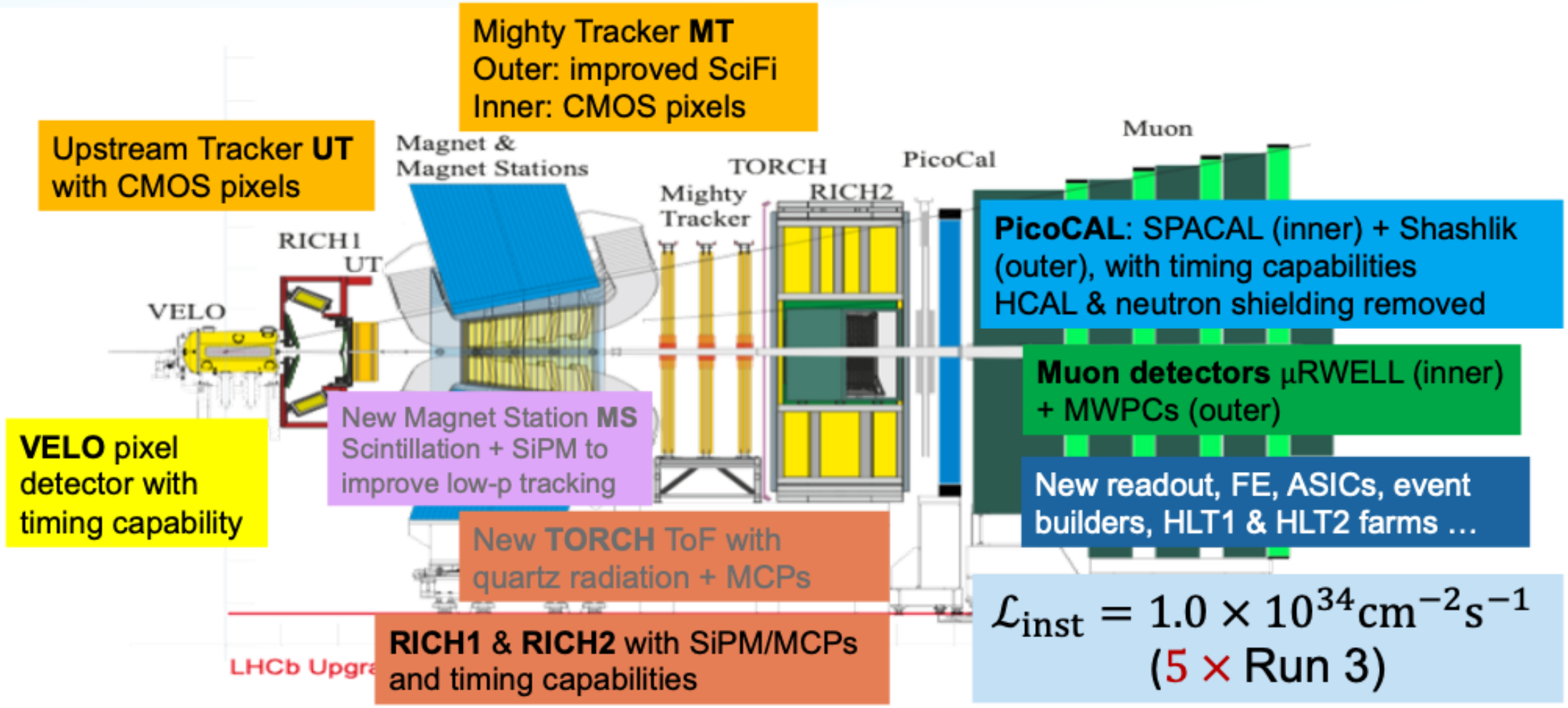
- Similar mass splitting as $D_{s0}^*(2317)^+$
  - the same heavy-flavour independent mechanism?

$$m(D_{s0}^*(2317)) - m(D_s) = 349.5\ \text{MeV}$$

$$m(B_{s0}^*(5700)) - m(B_s) = 332.0\ \text{MeV}$$

Exotic nature?

LHCb Upgrade II

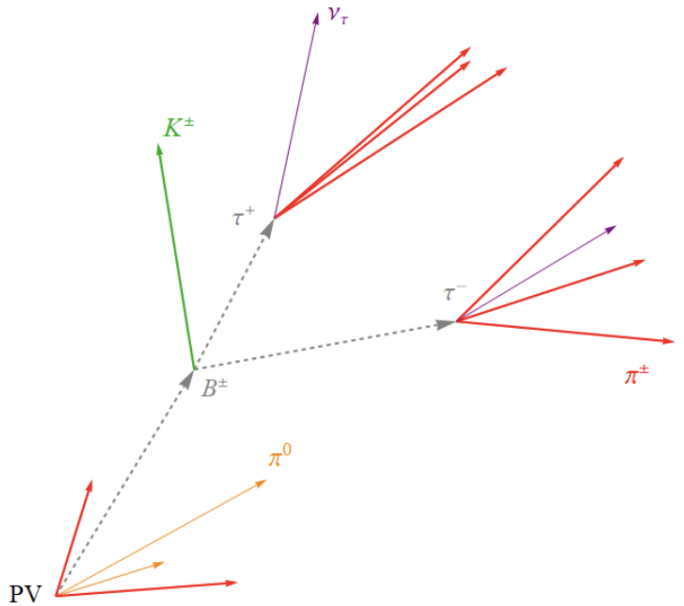


Precise flavour measurements in high-lumi era with higher statistics

Flavour Physics Prospects at CEPC

Statistics alone are not enough !

- LHCb : FCNC and LFU in decays with neutrinos in the final state are challenging to study
- CEPC : Clean e^+e^- events enable stronger kinematic constraints and missing momentum reconstruction



HIGH-VALUE CHANNELS:

$b \to s\tau\tau$

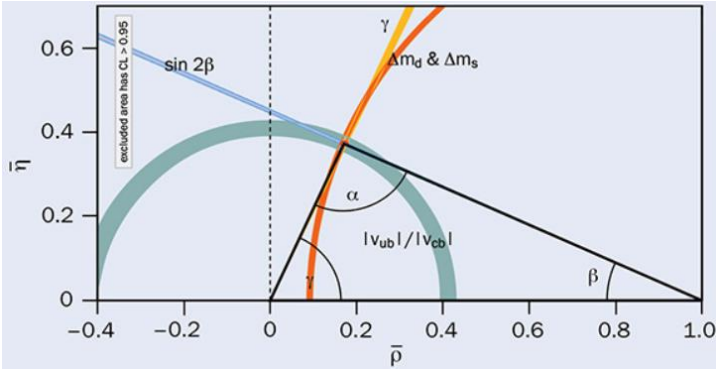
Selected modes: 10^{-7}~ 10^{-6} absolute branching-fraction precision

$b \to s\nu\nu$

$B_s \to \phi\nu\nu$: projected relative precision ≤ 2%

Summary

- LHCb:
  - World-leading precision in CKM matrix measurements
  - CPV in both beauty and charm sectors at LHCb
  - Latest $b \to sll$ and $b \to clv$ in good agreement with SM prediction at LHCb



$300\ \text{fb}^{-1}$

- LHCb U2: larger statistics ➔ more precision



CEPC provides an excellent additional opportunity for flavour physics

Thank you for your attention!