CP violation in *b*-hadrons

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ATLAS EXPERIMENT

CMS Compact Muon Solenoid

LHCb

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Contents

Introduction

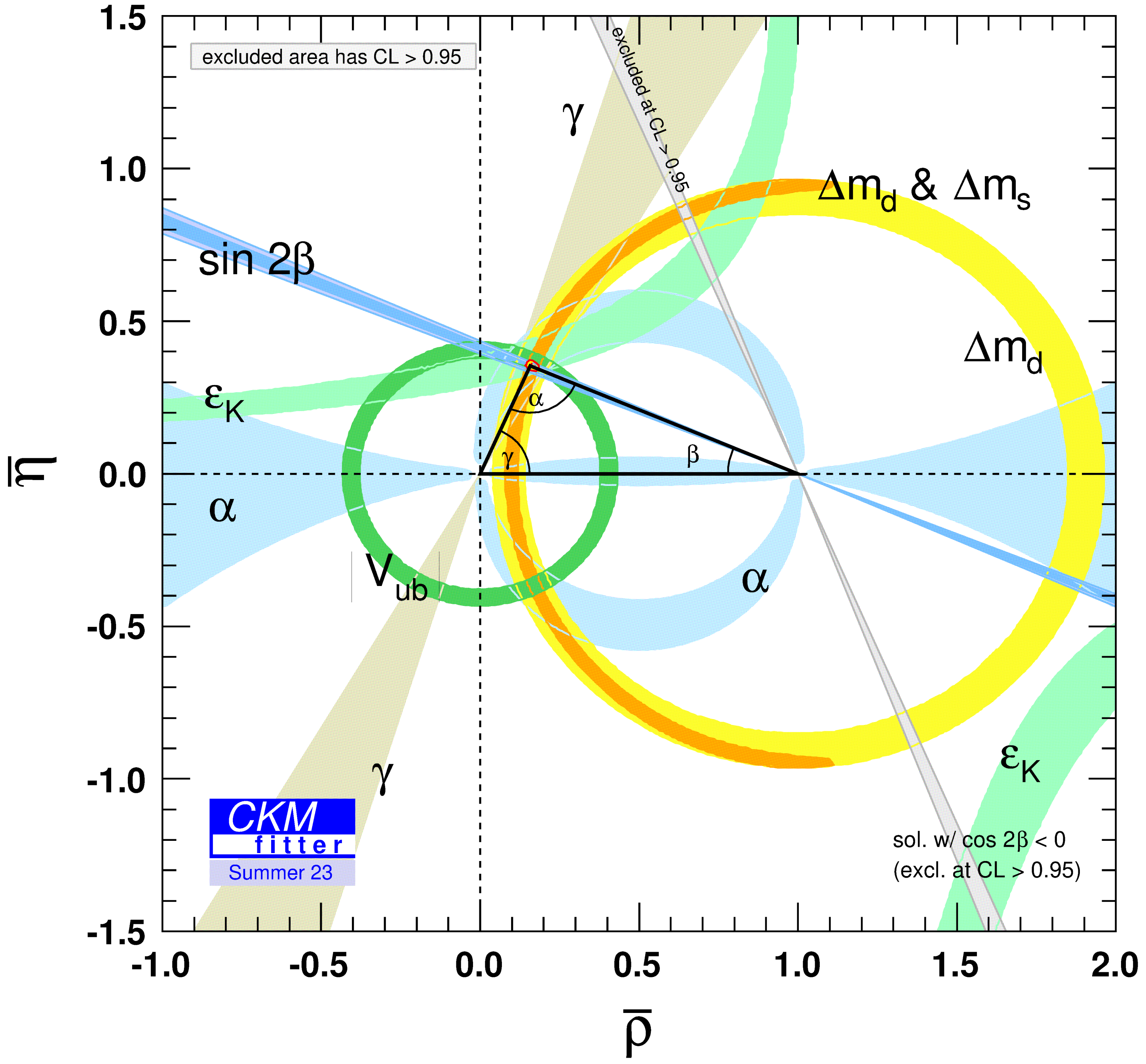
[Bigi & Sanda]

- *CP* violation arises from the presence of a complex phase in the CKM quark-mixing matrix

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

- The unitarity condition $V^\dagger V = \mathrm{I}$ defines triangles in the complex plane

- Measuring the properties of the UT allows for precision tests of the SM assumptions

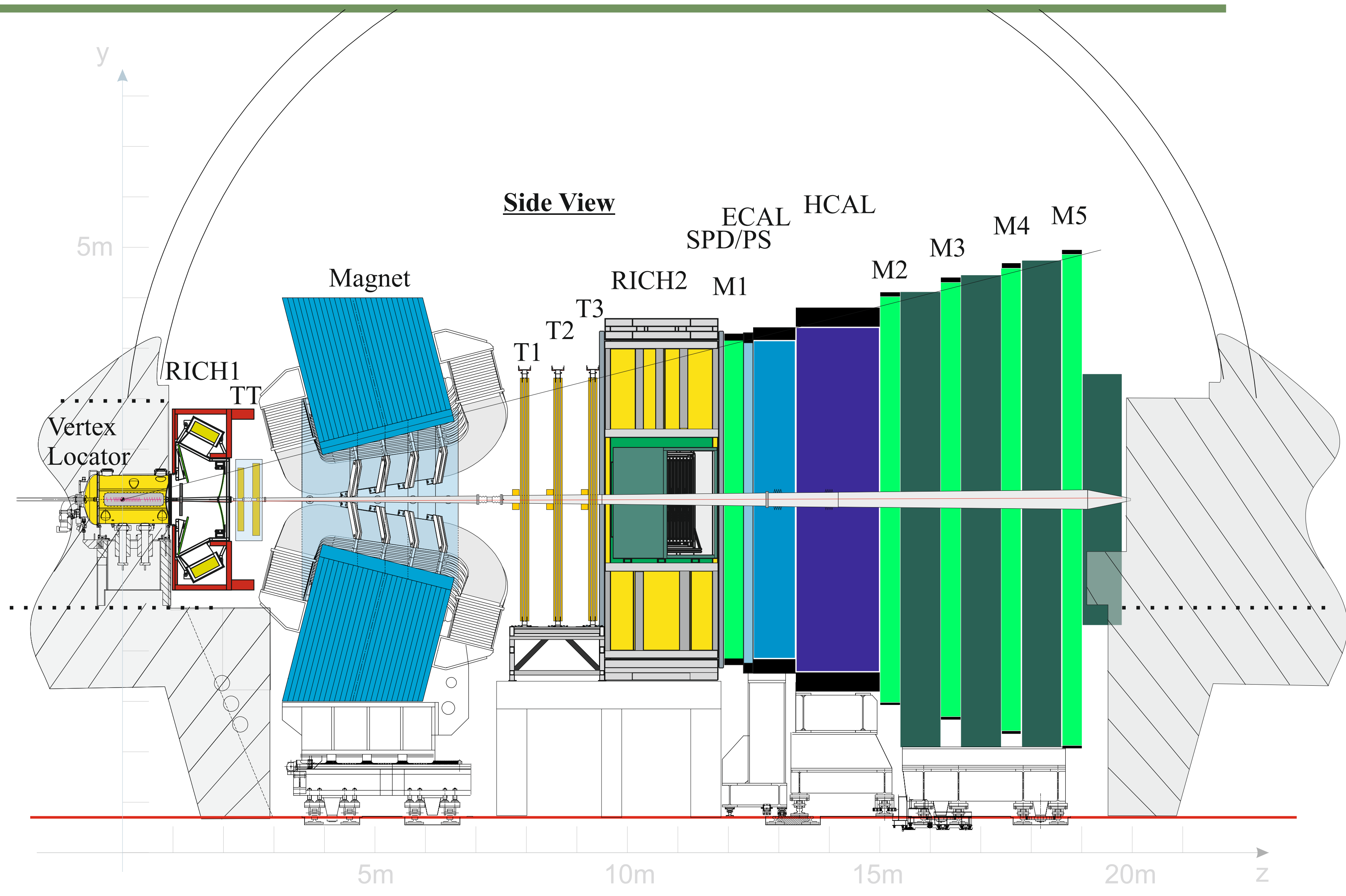


- Amount of CPV observed so far cannot explain the matter-antimatter asymmetry of the Universe

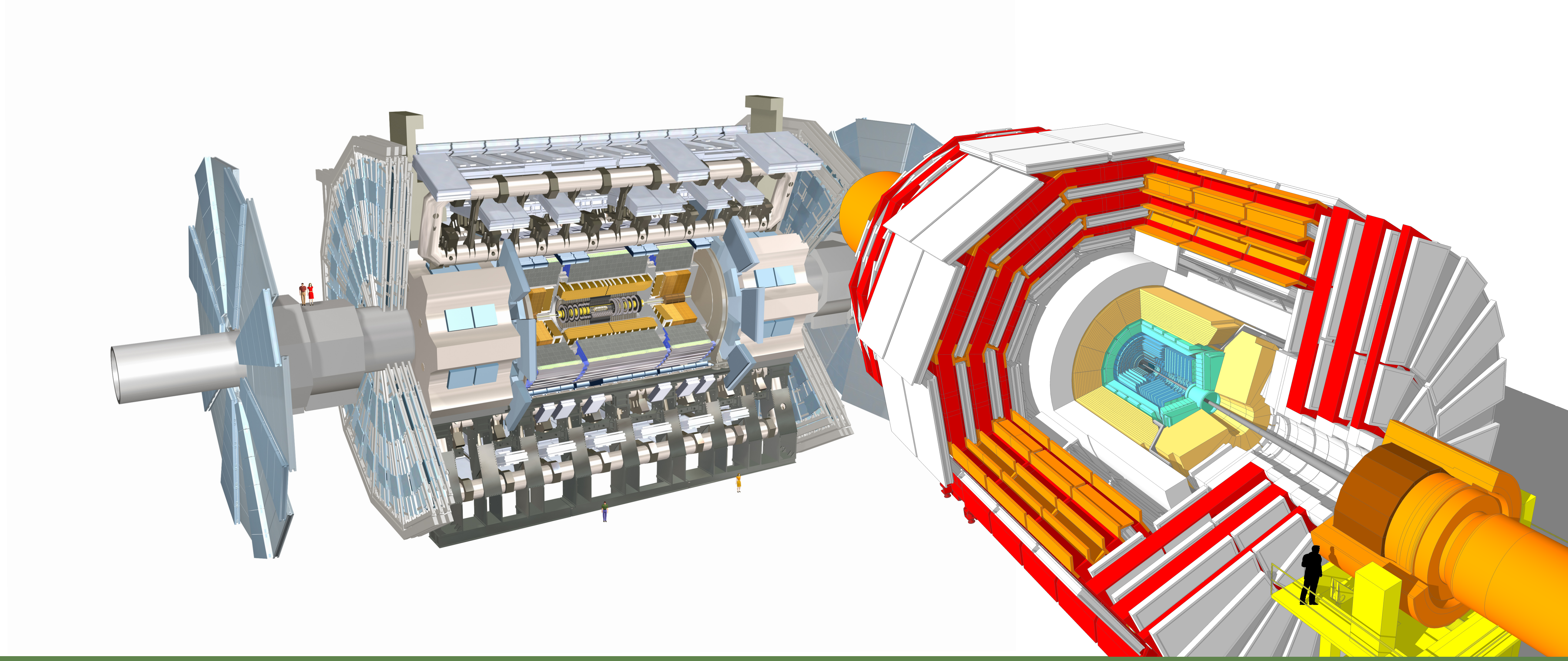
- Additional sources needed, within or beyond the SM

LHC detectors

- LHCb [JINST 3 (2008)]
  - Designed to exploit the huge $b\bar{b}$ production cross section in the forward region ($2 < \eta < 5$)
  - Excellent vertex resolution: 10-40 μm in x/y, 500-300 μm in z
  - Momentum resolution $\leq 1\,\%$ up to 100 GeV/c
  - PID: ~97% efficiency for e/μ with ~3% pion misID
    Good discrimination between π, K, p



- ATLAS/CMS [JINST 3 (2008)] [JINST 3 (2008)]
  - Hermetic design
  - Precise tracking and vertexing
    $|\eta| < 2.5$, complementary to LHCb
  - Excellent performance of calorimeter and muon detectors
  - Higher luminosity compensates for the lower b-hadron production in acceptance



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CP asymmetry of $B^+ \to J/\psi\pi^+$ decays (LHCb) [PRL 134 (2025)]

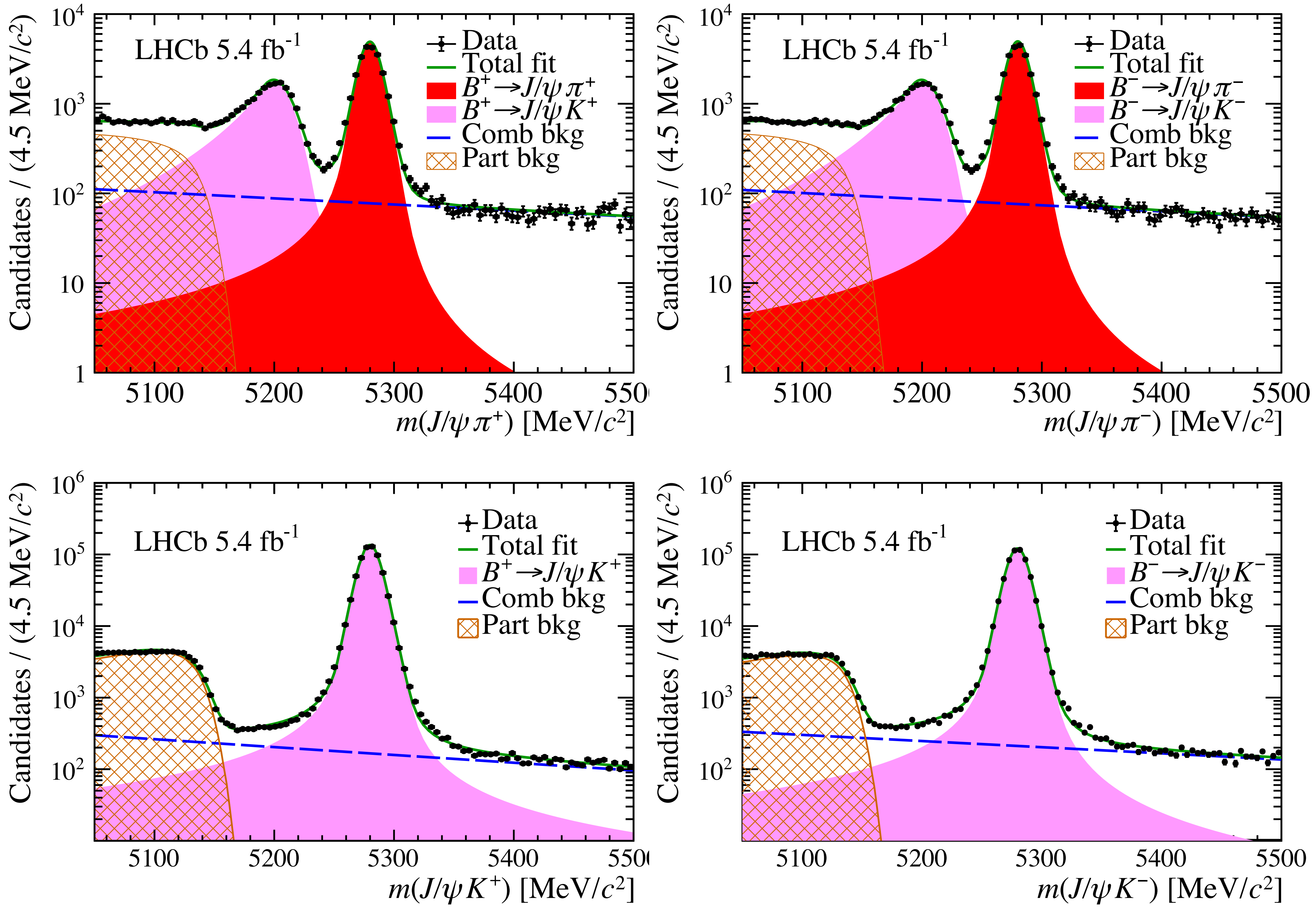
- $b \to c\bar{c}d$ decay → penguin diagrams contribution not negligible wrt to tree-level (*CPV* enhancement from interference?)

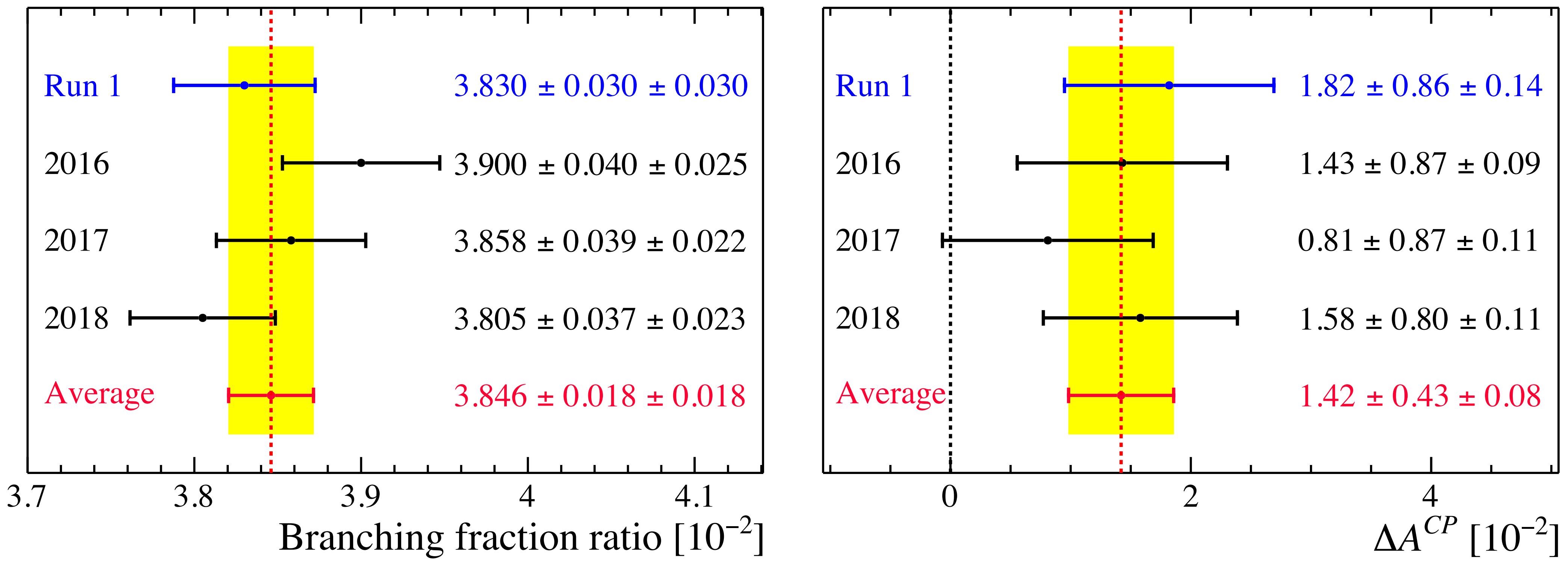
- Can improve understanding of penguin contribution to $b \to c\bar{c}s$ transitions (β from $B^0 \to J/\psi K^0$)

- 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 *CP* violation in beauty to charmonia decays (3.2σ)





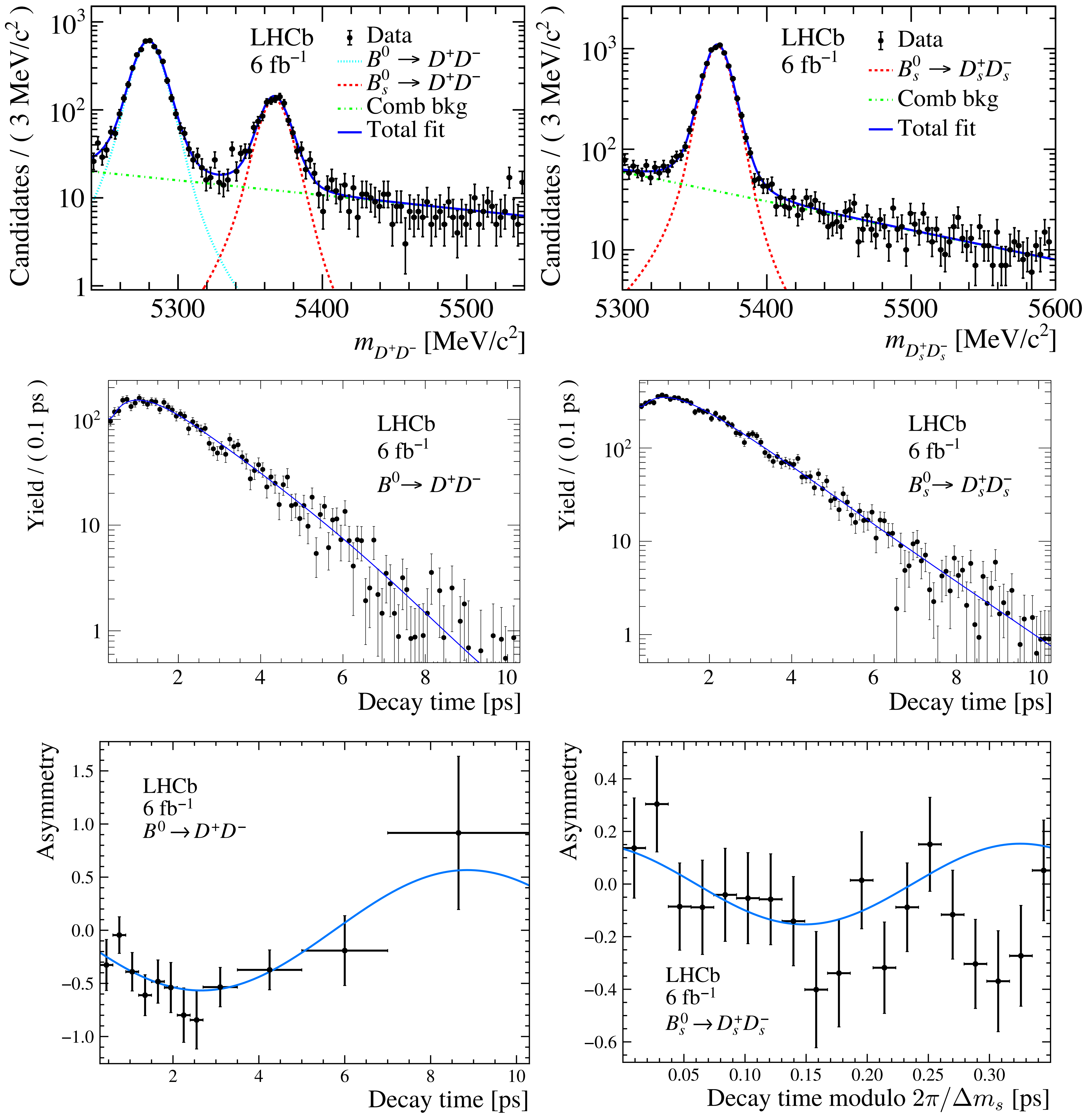
TD-CPV in $B^0_{(s)} \to D^+_{(s)} D^-_{(s)}$ (LHCb)

[JHEP 01 (2025)]

- 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 contribution of loop transitions to the measured values of $\beta_{(s)}$
- Time-dependent flavour-tagged analysis
- 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 at $> 6\sigma$
- For $B^0_s \to D^+_s D^-_s$ compatible with CP conservation



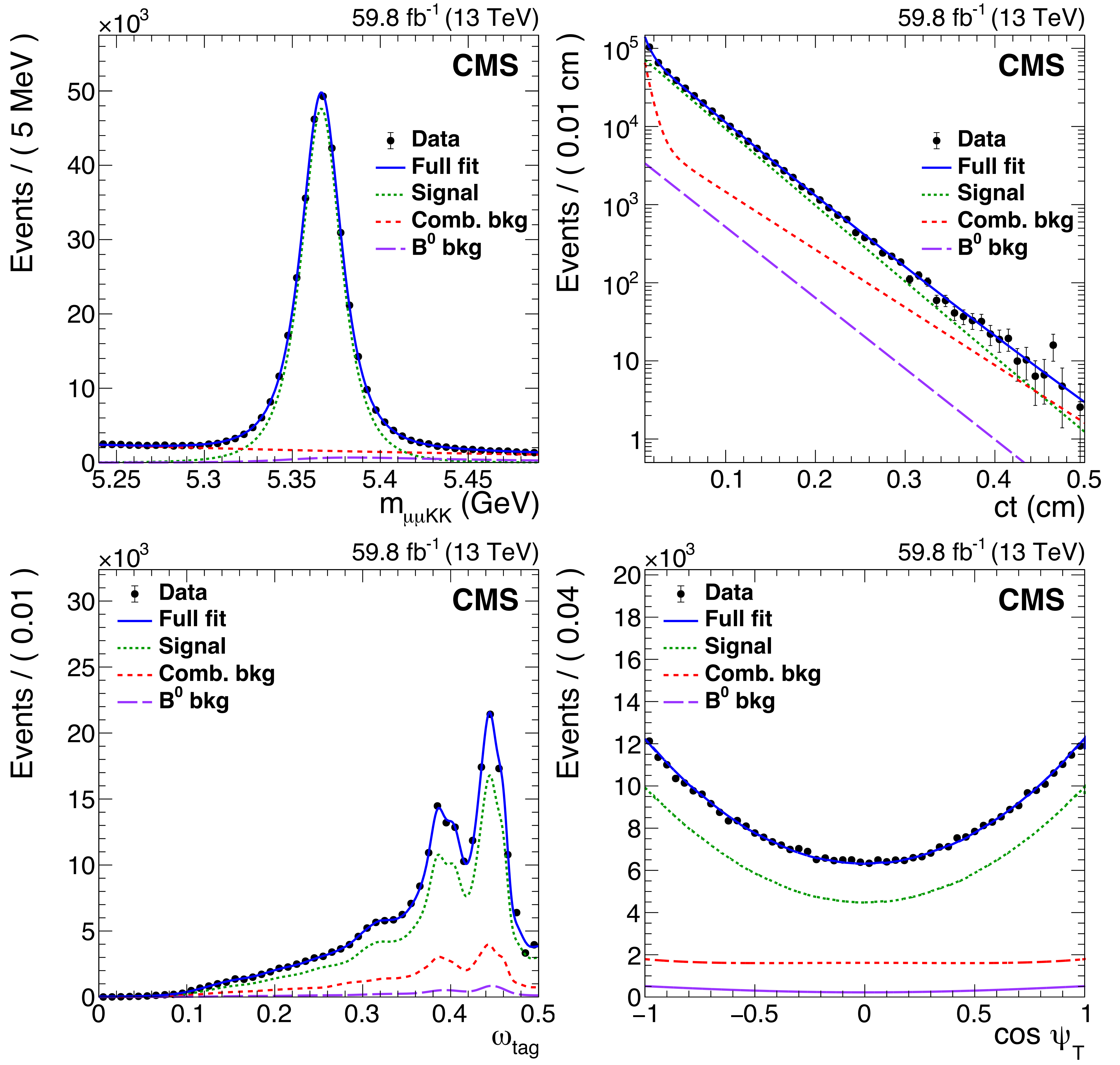
TD-CPV in $B_s^0 \to J/\psi\phi$ (CMS)

[arXiv:2412.19952]
Submitted to PRL

- Measurement of the weak phase $\phi_s \approx -2\beta_s$ arising from interference between direct CPV and $B_s^0 - \overline{B}_s^0$ mixing ($\phi_s^{SM} = -37 \pm 1$ mrad)

- Novel flavour-tagging algorithm + additional trigger paths → largest effective sample of tagged signals ever collected

- Simultaneous fit to mass $m_{\mu\mu KK}$, decay-time and error (ct, σ_{ct}), helicity angles ($\cos\theta_T$, $\cos\psi_T$, ϕ_t), and flavour tagging response ω_{tag}



TD-CPV in $B_s^0 \to J/\psi\phi$ (CMS)

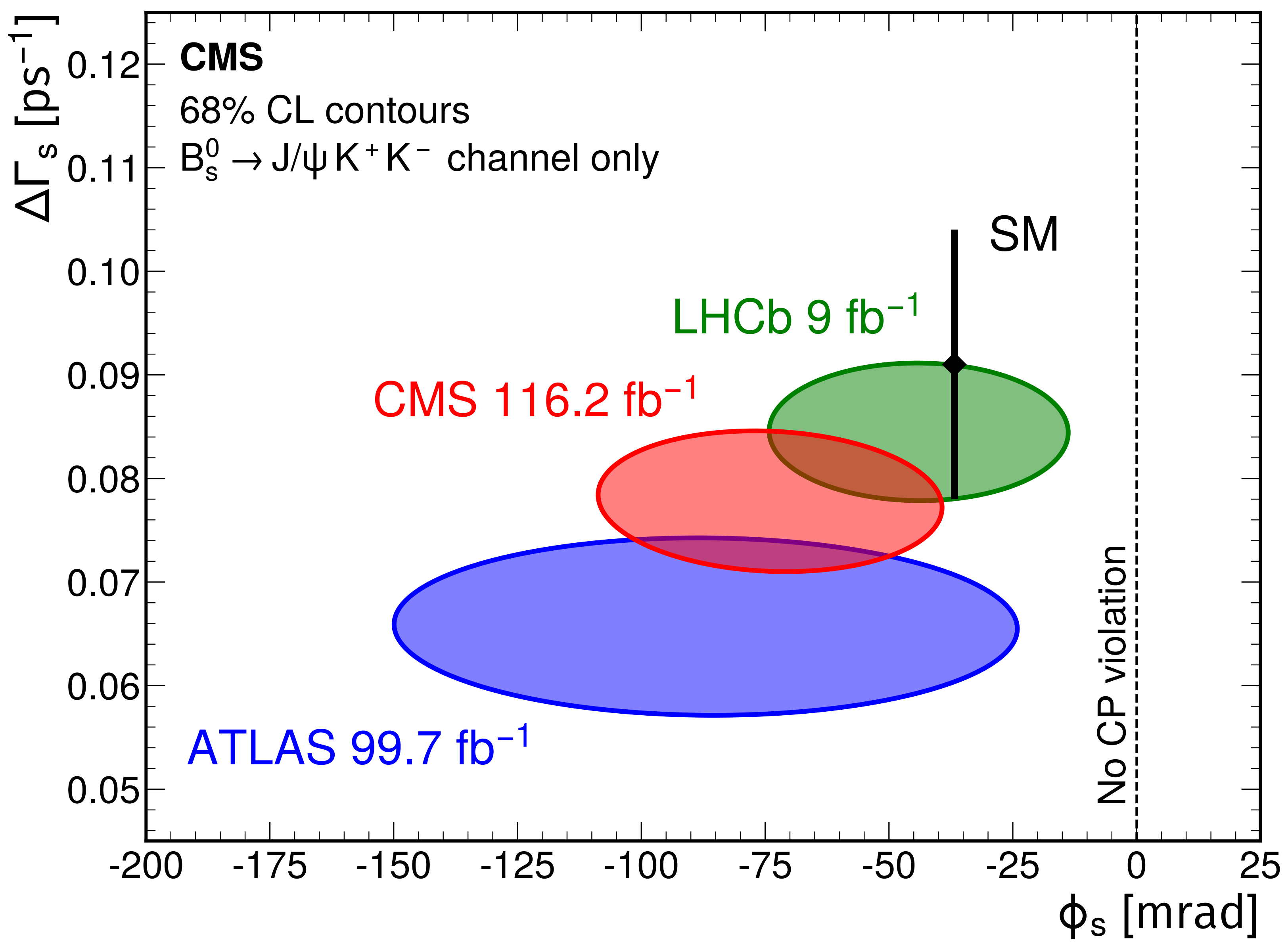
[arXiv:2412.19952]
Submitted to PRL

Parameter	Fit value	Stat. unc.	Syst. unc.
ϕ_s [mrad]	-73	$\pm$ 23	$\pm$ 7
$\Delta\Gamma_s$ [ps^{-1}]	0.0761	$\pm$ 0.0043	$\pm$ 0.0019
Γ_s [ps^{-1}]	0.6613	$\pm$ 0.0015	$\pm$ 0.0028
Δm_s [$\hbar$ ps^{-1}]	17.757	$\pm$ 0.035	$\pm$ 0.017
$\lvert\lambda\rvert$	1.011	$\pm$ 0.014	$\pm$ 0.012
$\lvert A_0\rvert^2$	0.5300	$^{+0.0016}_{-0.0014}$	$\pm$ 0.0044
$\lvert A_\perp\rvert^2$	0.2409	$\pm$ 0.0021	$\pm$ 0.0030
$\lvert A_S\rvert^2$	0.0067	$\pm$ 0.0033	$\pm$ 0.0009
$\delta_\parallel$ [rad]	3.145	$\pm$ 0.089	$\pm$ 0.025
$\delta_\perp$ [rad]	2.931	$\pm$ 0.089	$\pm$ 0.050
$\delta_{S\perp}$ [rad]	0.48	$\pm$ 0.15	$\pm$ 0.05

- Combined tagging power $P_{tag} = (5.59 \pm 0.02)$ %
- All values compatible with SM expectations
- Once combined with previous CMS results [PLB 757 (2016)] they yield

$$\phi_s = (-74 \pm 23)\ \text{mrad}$$

- First evidence of indirect CP violation in $B_s^0 \to J/\psi\phi$ decays



TD-CPV in $B_s^0 \to J/\psi\phi$ (ATLAS, CMS, LHCb)

[EPJC 81 (2021)] [arXiv:2412.19952] [PRL 132 (2024)]

- Combination of ATLAS results:

$$\phi_s = -0.087 \pm 0.036 \pm 0.021 \text{ rad}$$
$$\Delta\Gamma_s = +0.0657 \pm 0.0043 \pm 0.0037 \text{ ps}^{-1}$$

- Combination of LHCb results:

$$\phi_s = -0.033 \pm 0.018 \text{ rad}$$
$$\Delta\Gamma_s = +0.085 \pm 0.004 \text{ ps}^{-1}$$

- Combination of CMS results:

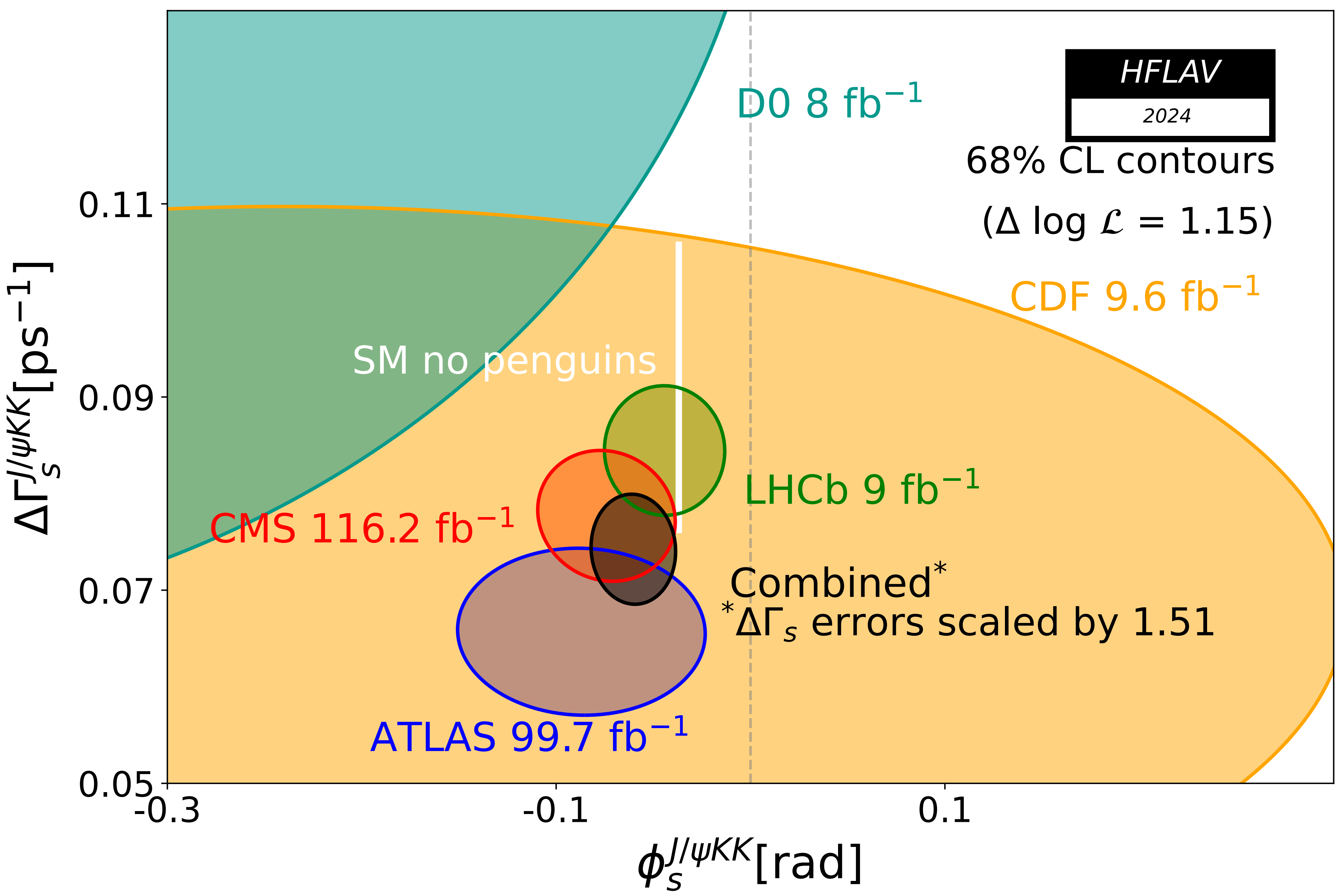
$$\phi_s = -0.074 \pm 0.023 \text{ rad}$$
$$\Delta\Gamma_s = +0.078 \pm 0.004 \text{ ps}^{-1}$$

- Latest combination by HFLAV including all LHC results

$$\phi_s = -0.052 \pm 0.013 \text{ rad}$$
$$\Delta\Gamma_s = +0.076 \pm 0.004 \text{ ps}^{-1}$$

- N.B. errors scaled to account for tensions between values of $\Delta\Gamma_s$

[arXiv:2411.18639]



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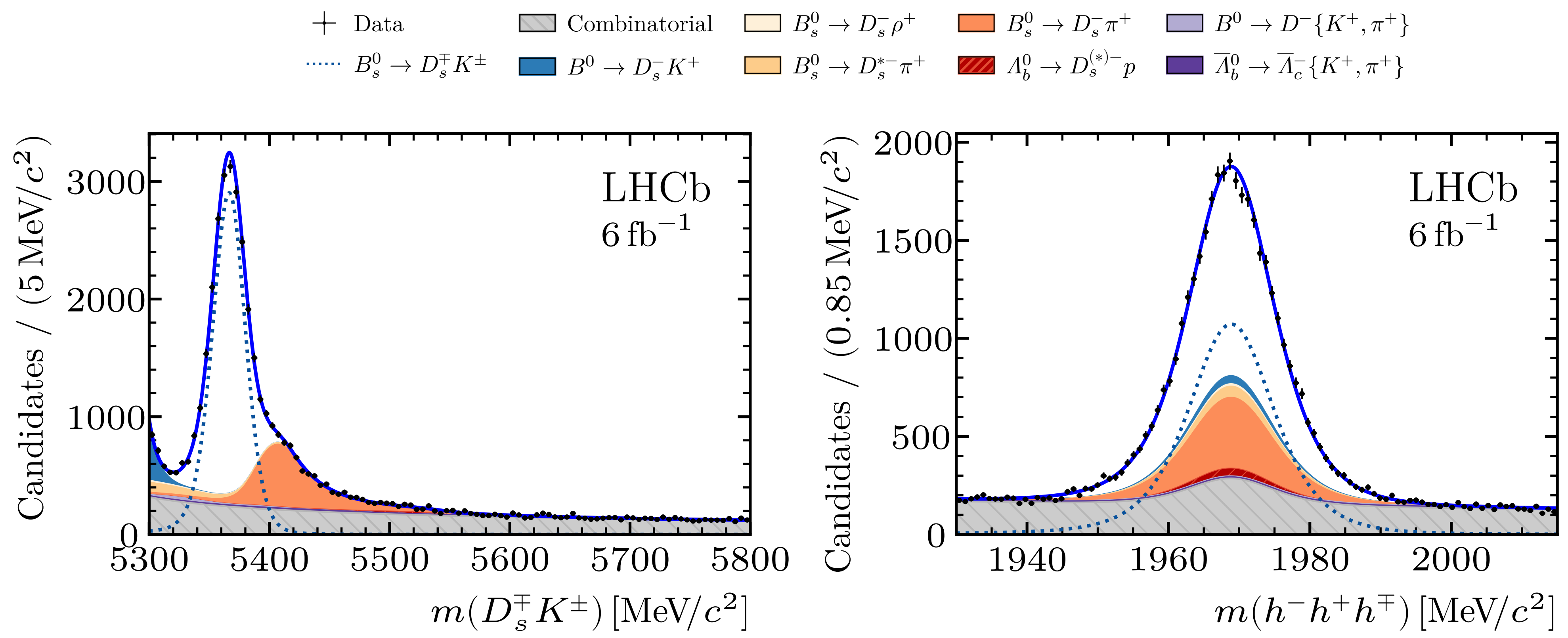
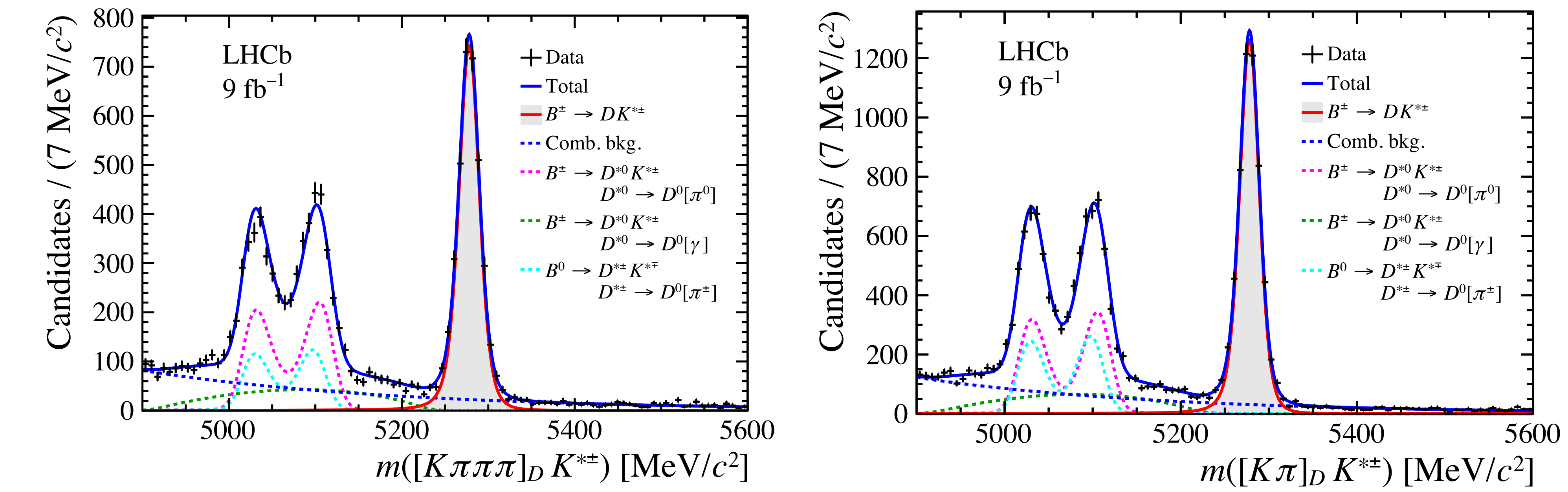
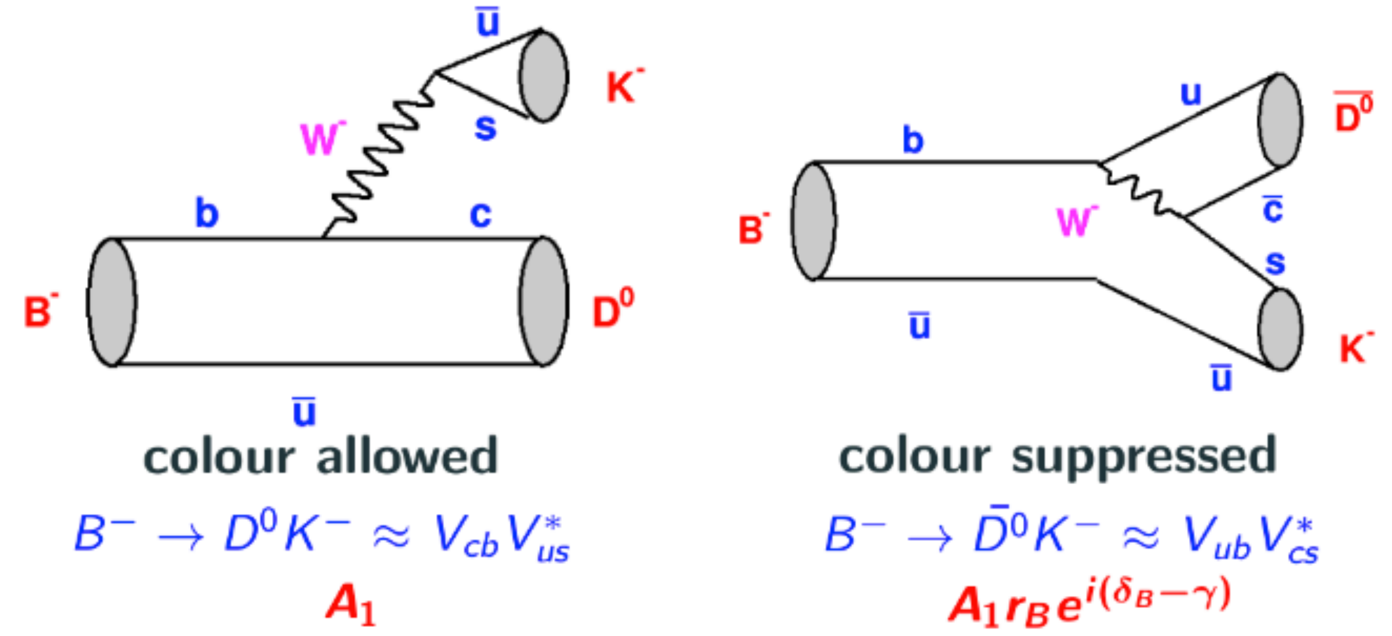
- Introduction
- Detector overview
- Integrated and time-dependent CPV (ATLAS & CMS & LHCb)
- Latest measurements of γ (LHCb)
- CPV in baryon decays (LHCb)
- Future prospects
- Conclusions

Measurements of CPV parameters and γ (LHCb) [JHEP 02 (2025)] [JHEP 03 (2025)]

- γ is the only angle of the UT that can be measured directly with tree-level decays
- Latest LHCb combination $\gamma_{direct} = (66.4 \pm 2.8)^{\circ}$ [LHCb-CONF-2024-004]
- Comparison with indirect determinations from global fits provides stringent tests of the SM consistency
  - $\gamma_{indirect} = (65.1 \pm 1.3)^{\circ}$ [UTfit 2023]
  - $\gamma_{indirect} = (66.23^{+0.60}_{-1.43})^{\circ}$ [CKMfitter 2023]
  - More precise than direct measurements → further studies critically needed
- Two new analyses:
  - $B_s^0 \to D_s^{\mp}K^{\pm}$, high sensitivity to γ thanks to large ratio of interfering amplitudes $\left|\frac{A(\overline{B}_s^0 \to D_s^- K^+)}{A(B_s^0 \to D_s^- K^+)}\right| \approx 0.4$
  - $B^{\pm} \to DK^{*\pm}$, similar BF as golden channel $B^{\pm} \to DK^{\pm}$, worse reco. eff. but less background
- γ measured from the interference between $b \to c\bar{u}s$ and $b \to u\bar{c}s$ tree-level diagrams





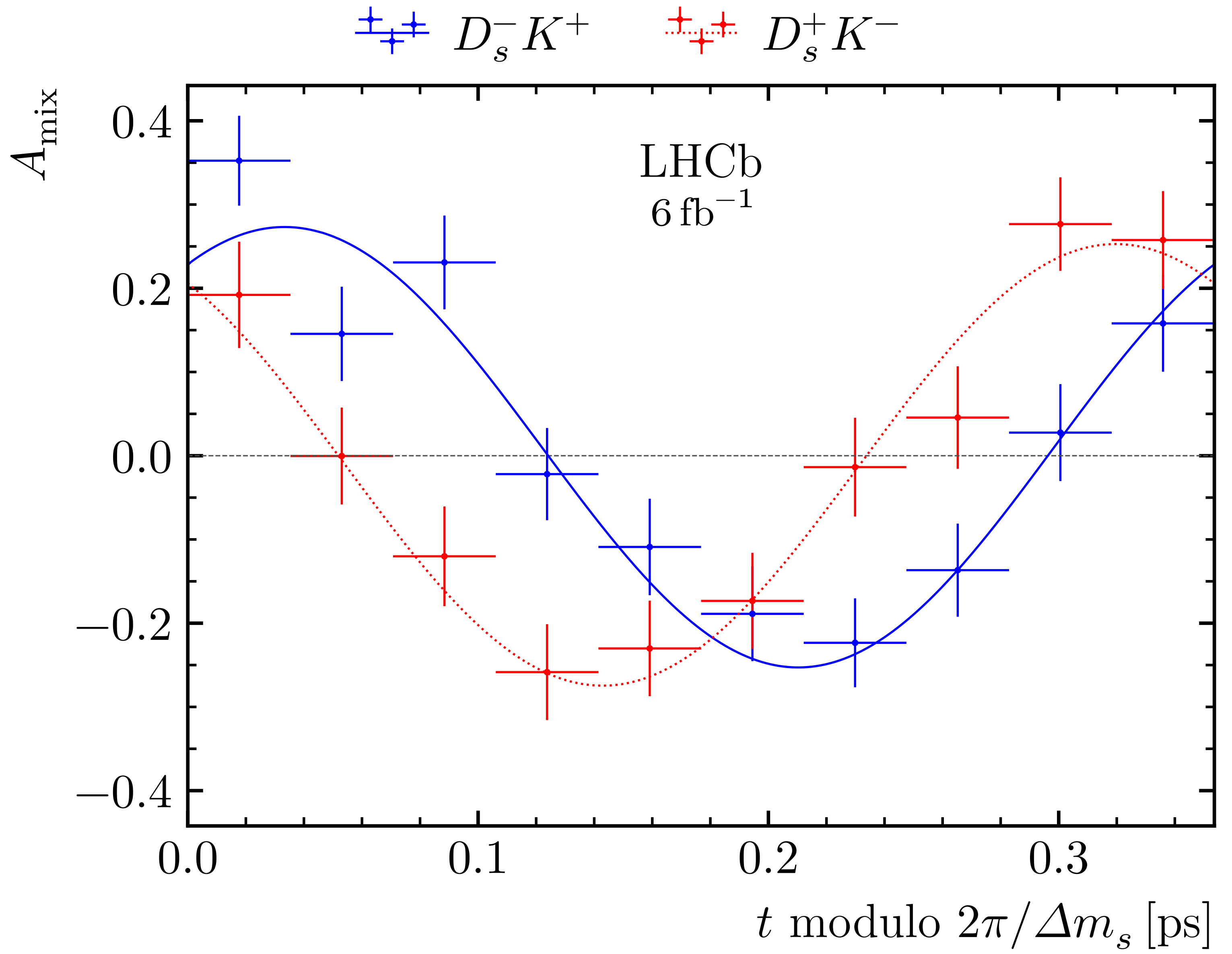


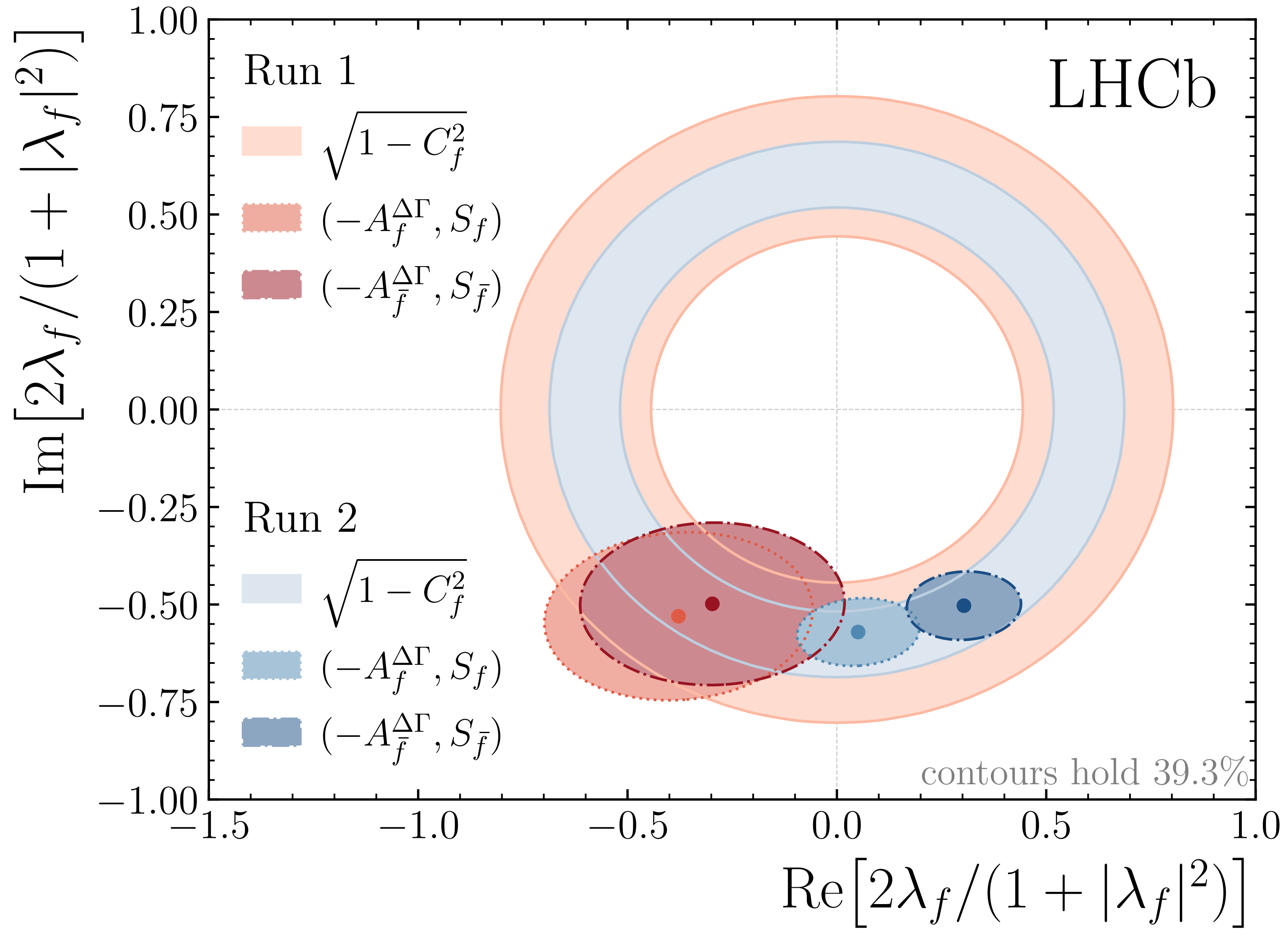
Measurements of CPV parameters and γ (LHCb) [JHEP 03 (2025)]

- $B_s^0 \to D_s^{\mp}(\to h^+h^-h^{\mp})K^{\pm}$, full Run 2 dataset
- The *CP*-violating parameters are measured with a decay-time fit

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

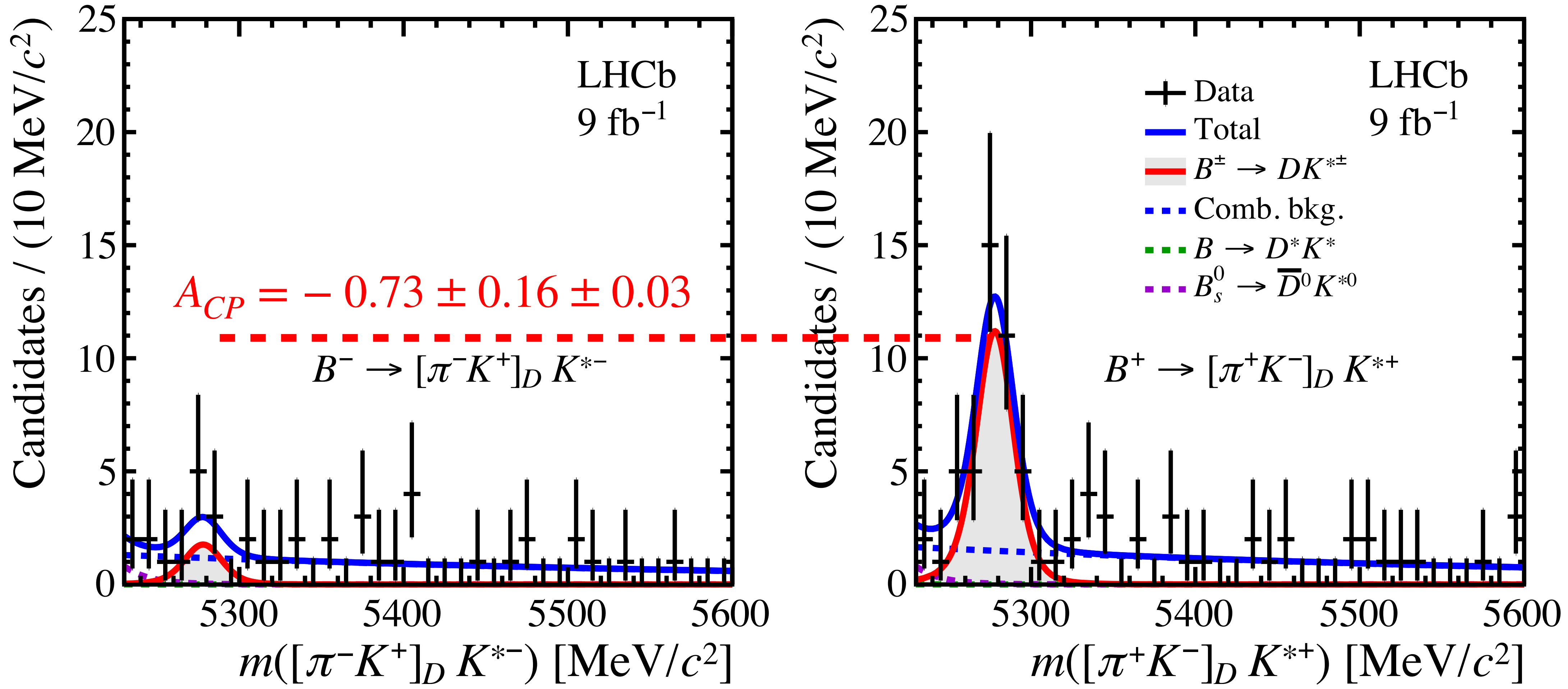
- *CP* violated with 8.6σ significance in interference between $B_s^0 - \overline{B}_s^0$ mixing and $B_s^0 \to D_s^{\mp}K^{\pm}$ decay ($S_f \neq -S_{\bar{f}}$)
- Can be interpreted to obtain an estimate of γ, the strong-phase difference δ and the amplitude ratio r_{D_sK}

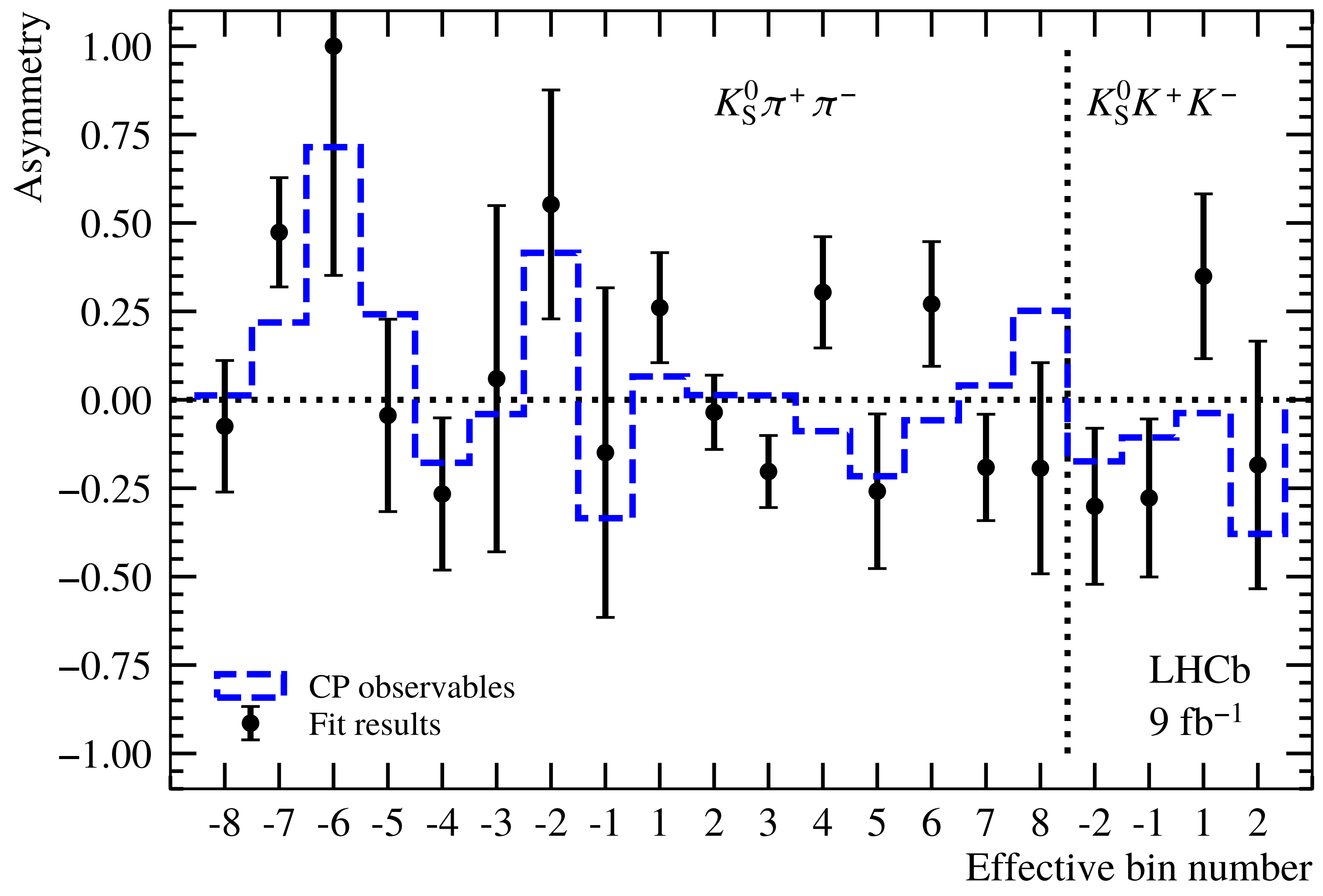


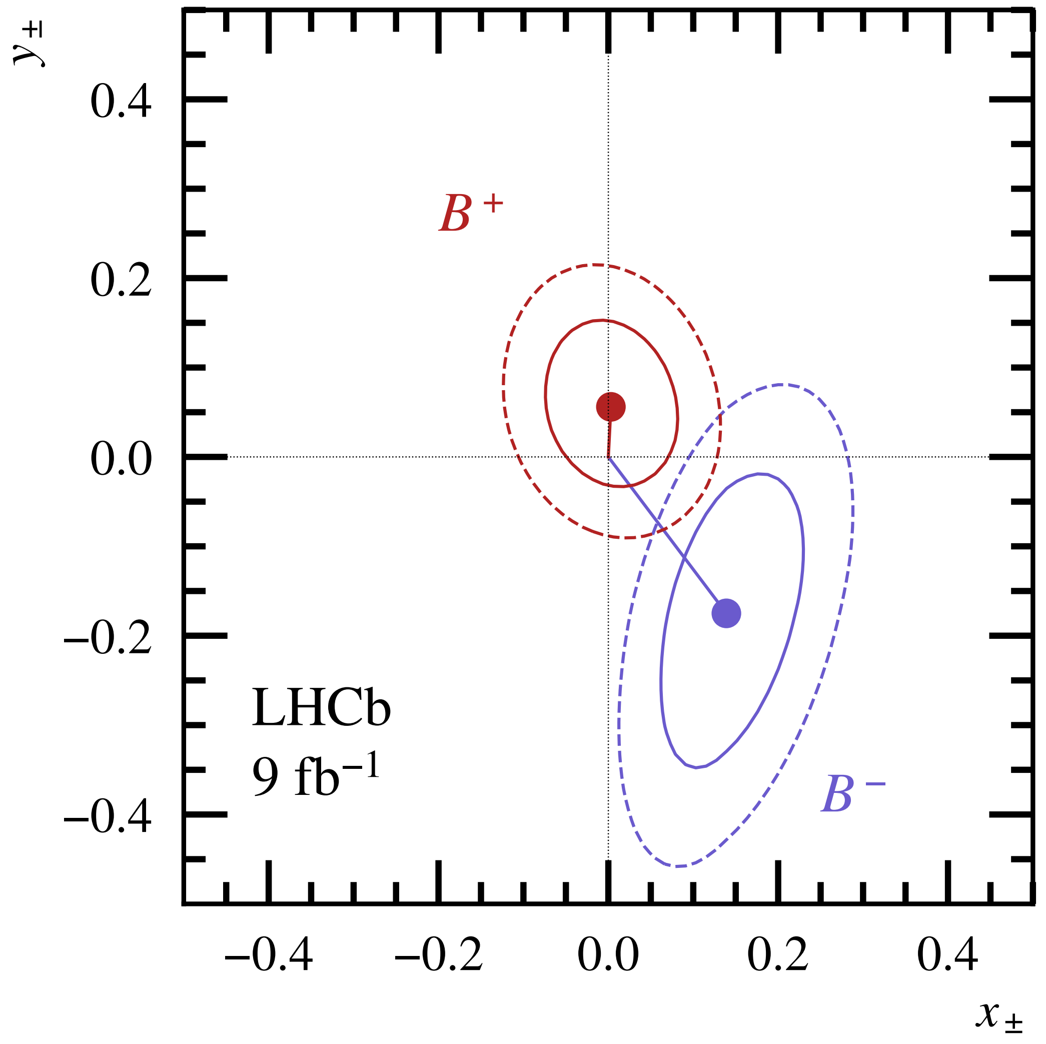


Measurements of CPV parameters and γ (LHCb) [JHEP 02 (2025)]

- $B^{\pm} \to DK^{*\pm}$, full Run 1+2 dataset
- D meson reconstructed in several decay channels
  - CP eigenstates $\pi^+\pi^-$ and K^+K^-
  - Quasi-CP eigenstates $\pi^+\pi^-\pi^+\pi^-$
  - Self-conjugate states $K^0_S\pi^+\pi^-$ and $K^0_S K^+K^-$
  - Net-strangeness states $K^{\pm}\pi^{\mp}$ and $K^{\pm}\pi^{\mp}\pi^+\pi^-$
- The CP asymmetries are measured for all channels
- First observation of suppressed $B^{\pm} \to D(\to \pi^{\pm}K^{\mp})K^{*\pm}$ decay
- Three-body decays $K^0_S h^+h^-$ analysed in bins of Dalitz plane to enhance sensitivity to γ [PRD 82 (2010)]
- CP-violating and mixing parameters are interpreted to obtain an estimate of γ, the strong-phase difference δ and the amplitude ratio r_{D_sK}







Measurements of CPV parameters and γ (LHCb) [JHEP 02 (2025)] [JHEP 03 (2025)]

- Results from $B_s^0 \to D_s^{\mp}K^{\pm}$

$$\gamma = (81^{+12}_{-11})^\circ$$
$$\delta_{D_sK} = (347.6 \pm 6.3)^\circ$$
$$r_{D_sK} = 0.318^{+0.034}_{-0.033}$$

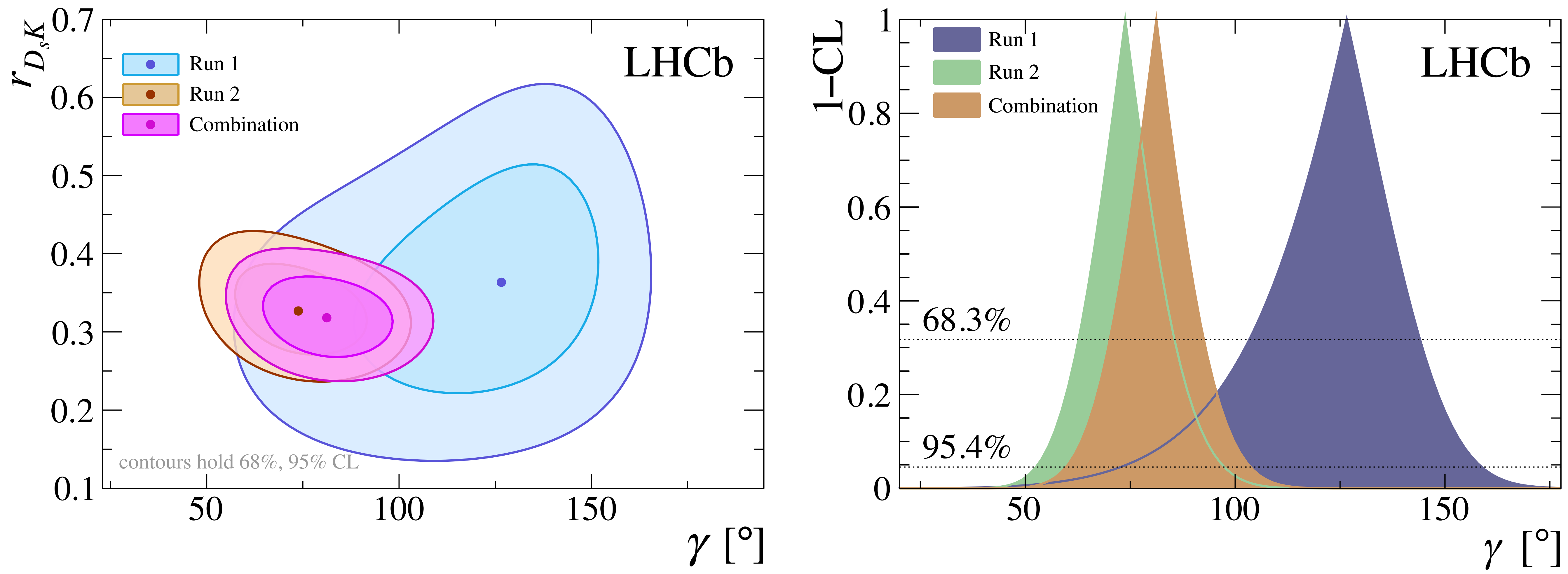
- Most precise measurement with B_s^0 mesons

- Results from $B^\pm \to DK^{*\pm}$

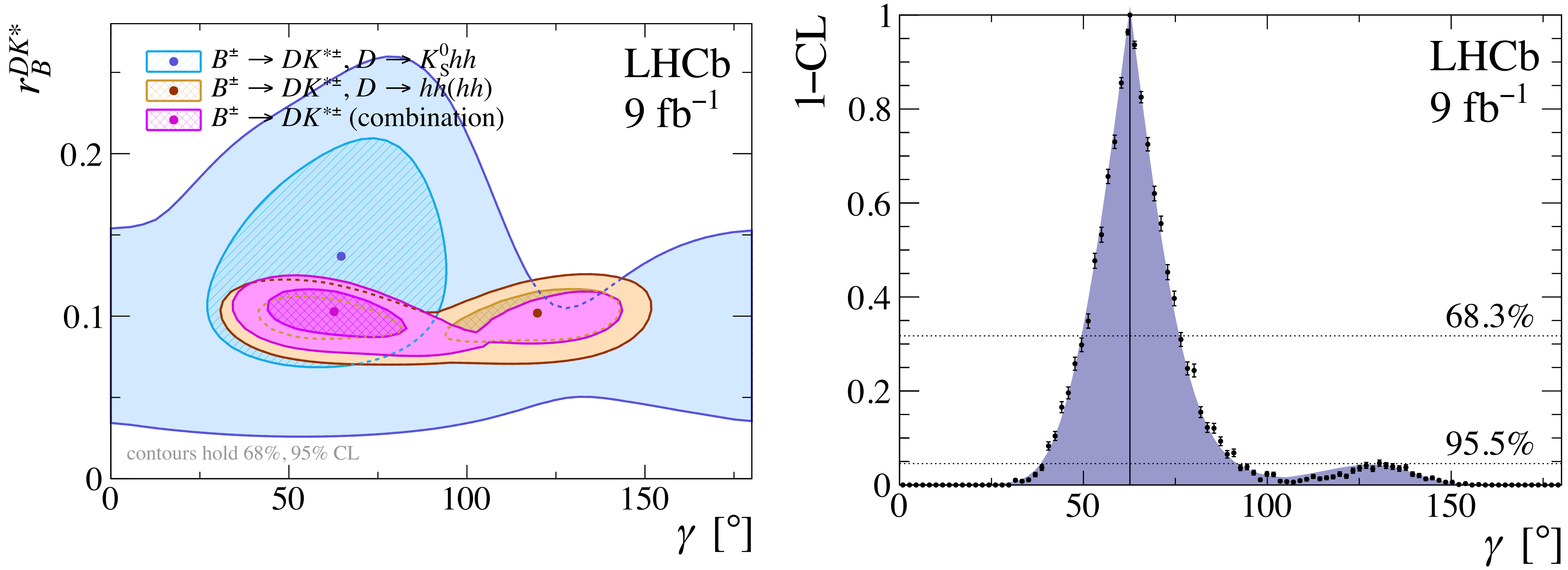
$$\gamma = (63 \pm 13)^\circ$$
$$\delta_{DK^{*\pm}} = (47^{+14}_{-12})^\circ$$
$$r_{DK^{*\pm}} = 0.103 \pm 0.010$$

- All consistent with previous LHCb measurements

$B_s^0 \to D_s^{\mp}K^{\pm}$



$B^\pm \to DK^{*\pm}$



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CP asymmetries with $\Lambda_b^0 \to ph^-$ decays (LHCb)

[arXiv:2412.13958]
Submitted to PRD

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

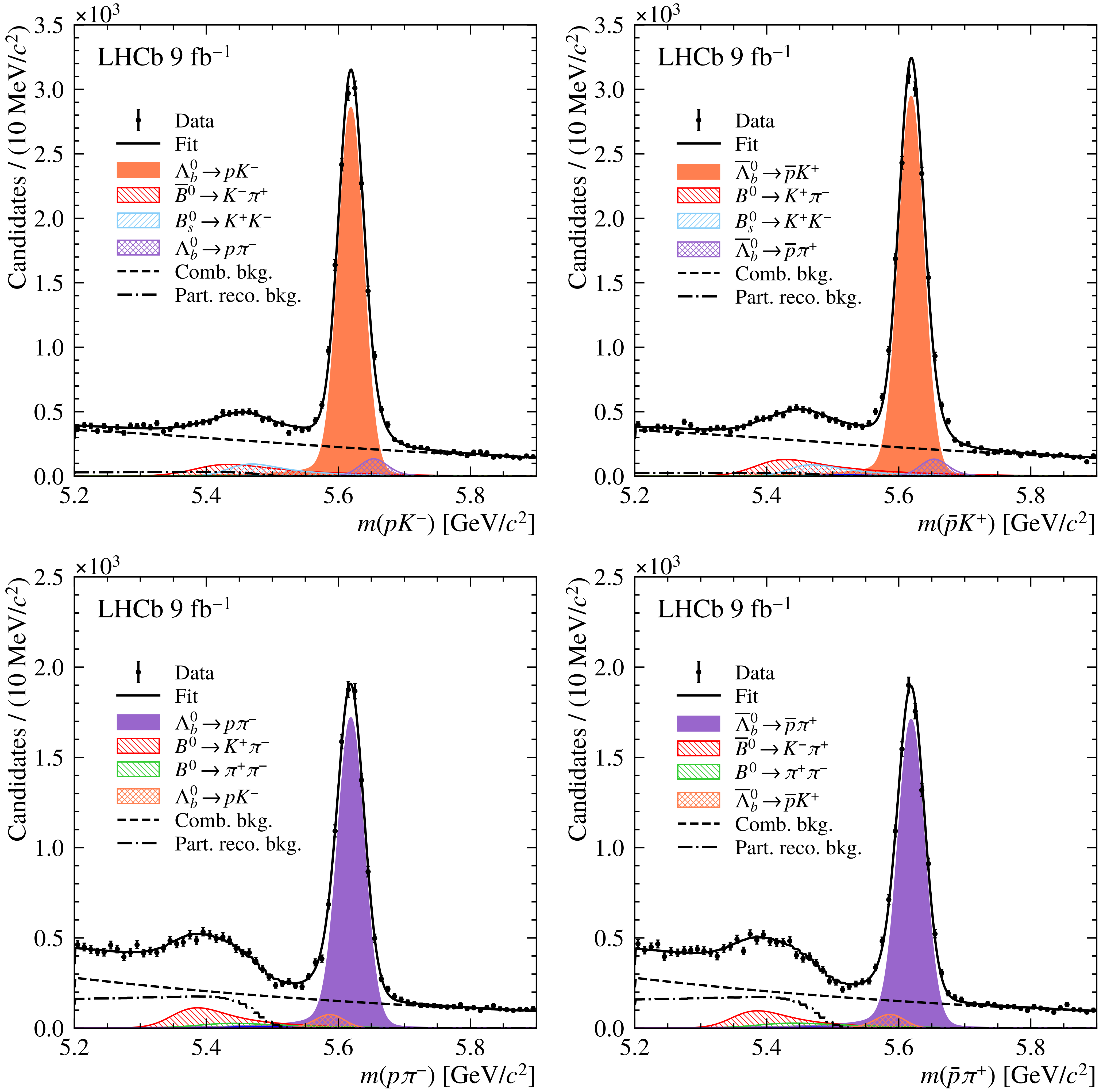
- Combined Run 1+2 results

$$A_{CP}(\Lambda_b^0 \to pK^-) = (-1.1 \pm 0.7 \pm 0.4)\,\%$$
$$A_{CP}(\Lambda_b^0 \to p\pi^-) = (0.2 \pm 0.8 \pm 0.4)\,\%$$

- No evidence of CP violation

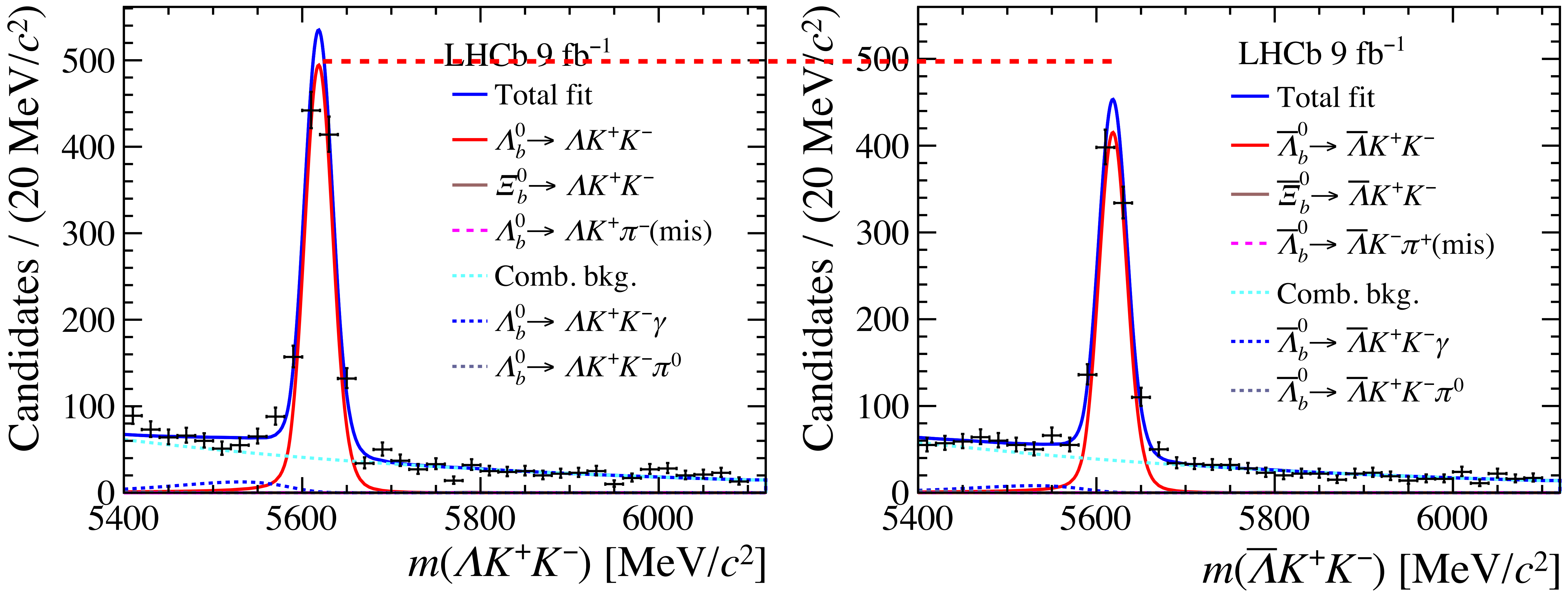
- $3\times$ improvement over current PDG average

- Not dominated by systematics anymore



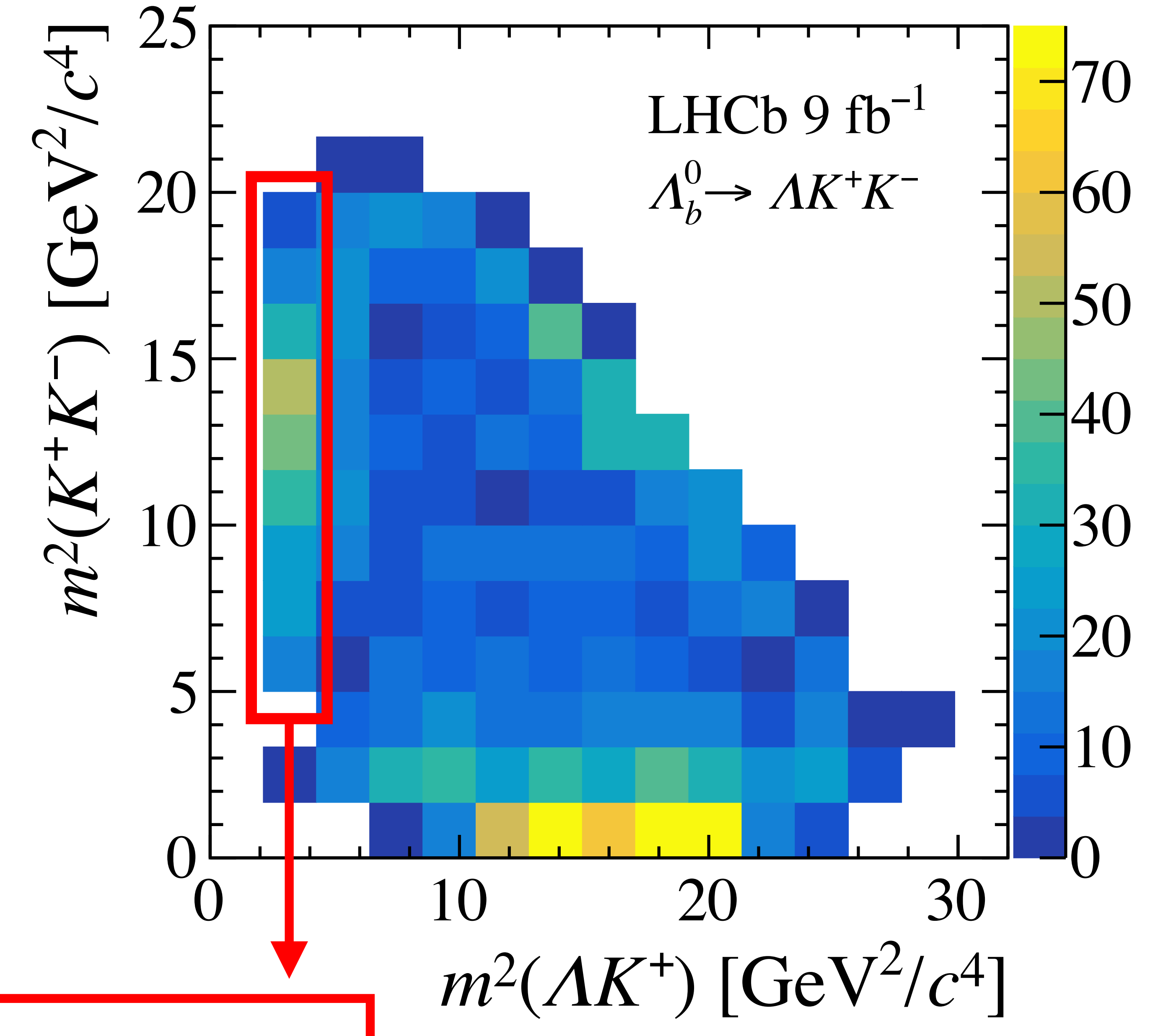
Evidence for CPV in $\Lambda_b^0 \to \Lambda K^+ K^-$ (LHCb)

[PRL 134 (2025)]



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

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



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

- *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 *CP* violation in $\Lambda_b^0 \to \Lambda K^+K^-$ decays (3.1σ)
- Possible interpretation: enhancement from $N^{*+} \to \Lambda K^+$ (3.2σ) resonance
- Amplitude analysis needed to clarify

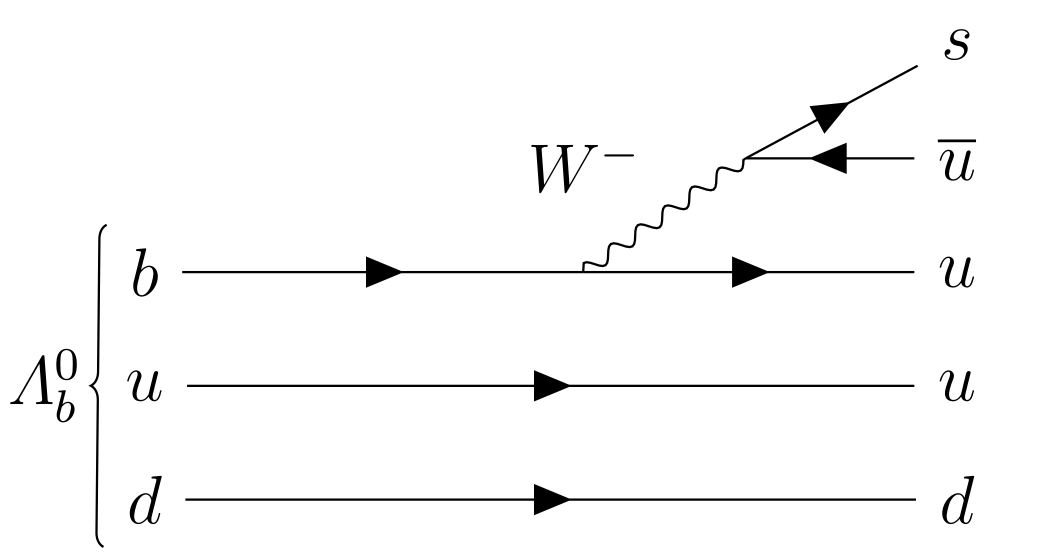
Observation of baryonic CPV (LHCb)

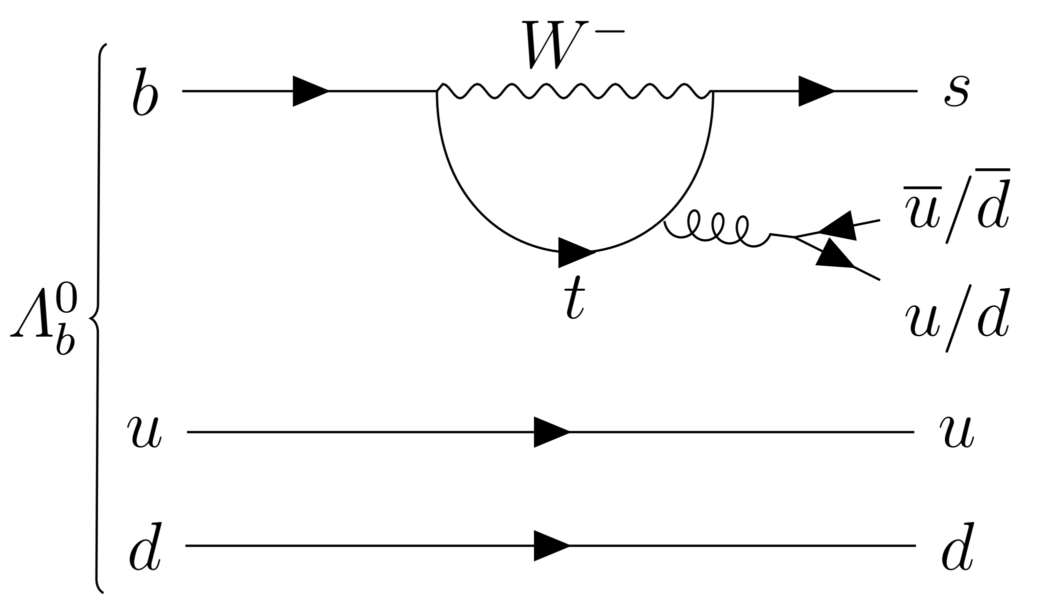
[arXiv:2503.16954]
Submitted to Nature

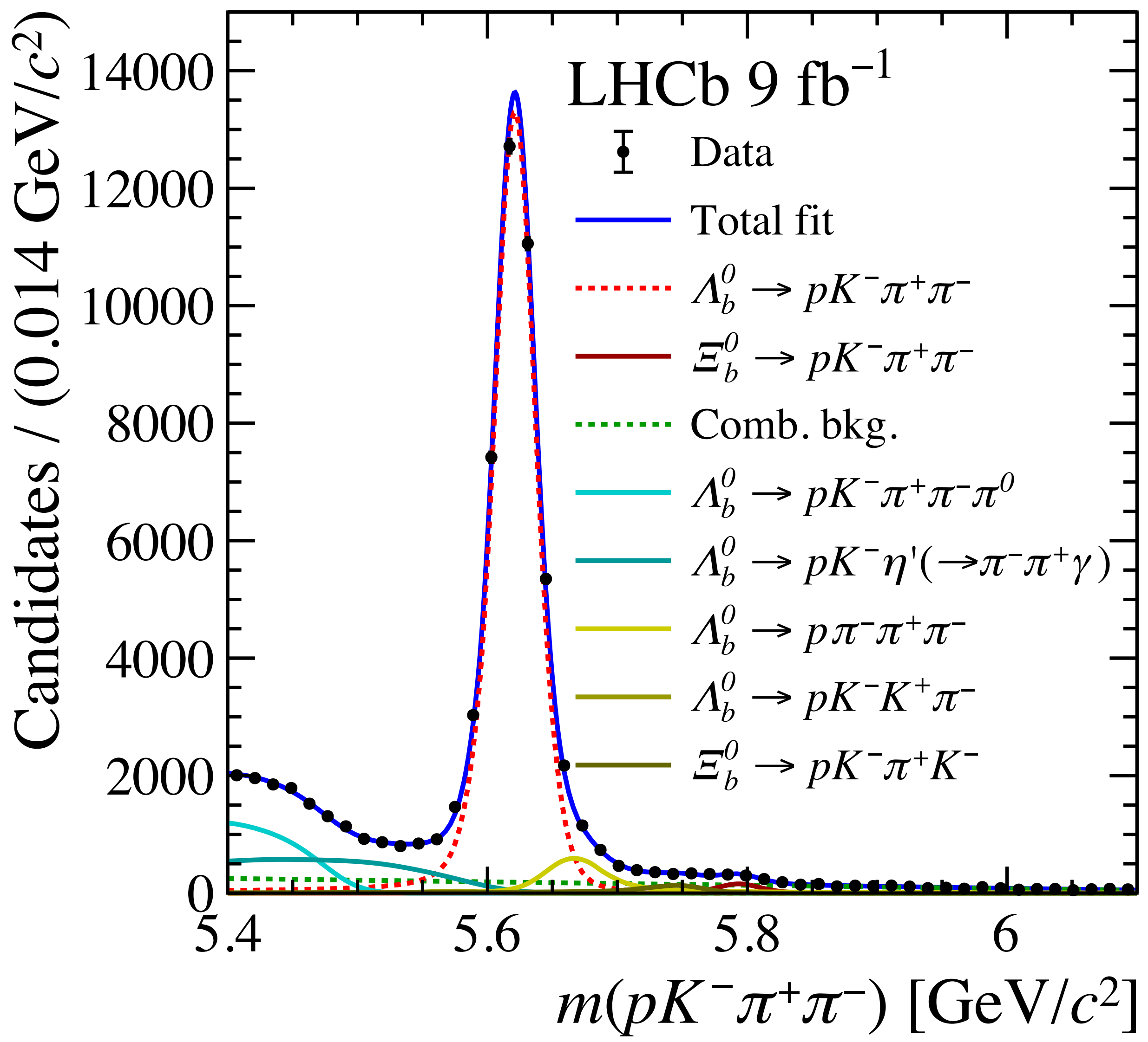
- Run 1+2 study of $\Lambda_b^0 \to pK^-\pi^+\pi^-$ decays
- CPV arises from interference between tree and loop amplitudes
- Resonant structure may enhance CPV across the phase space
- Clean measurement thanks to control sample of $\Lambda_b^0 \to (\Lambda_c^+ \to pK^-\pi^+)\pi^-$

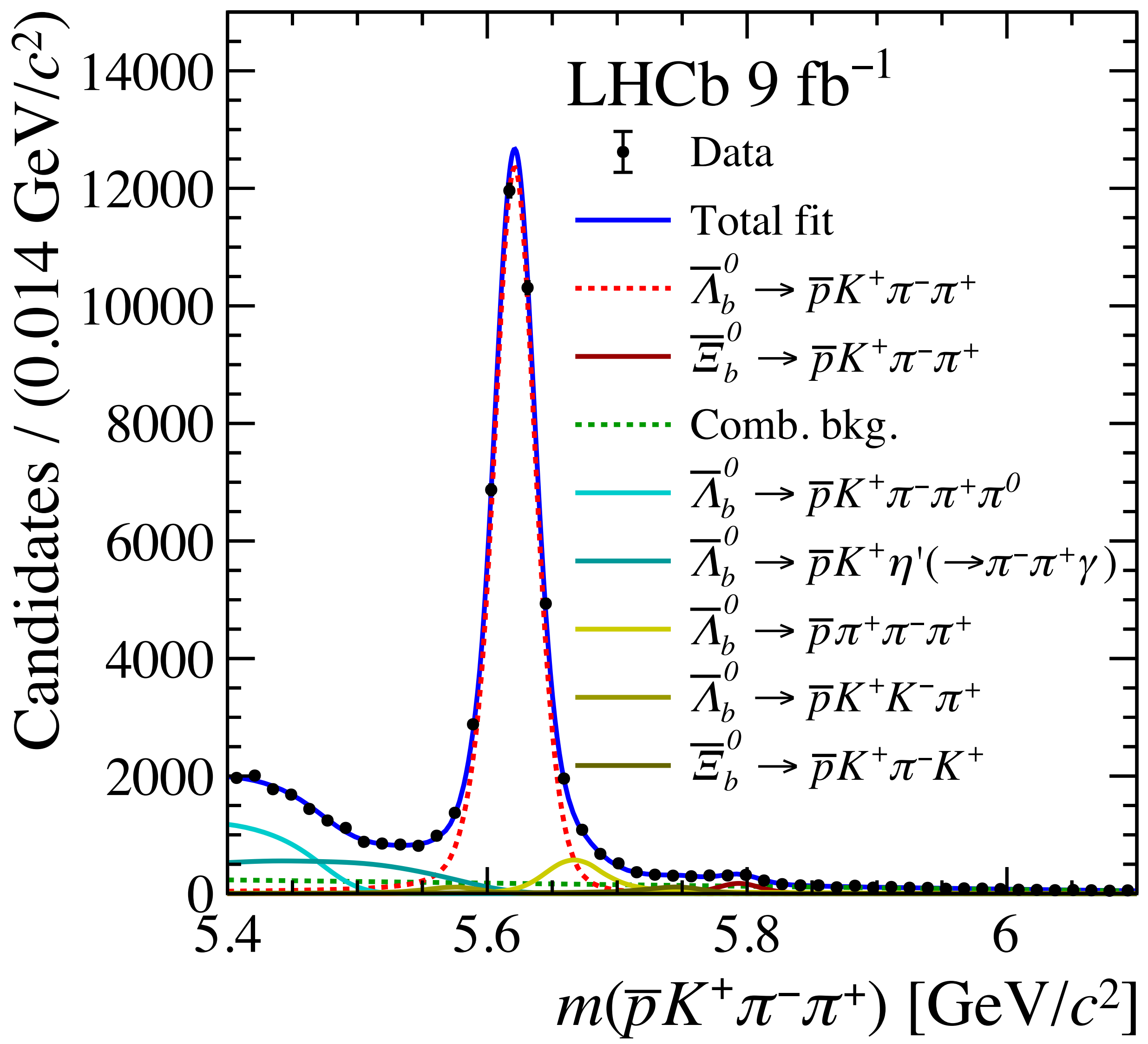
$$A_{CP} = (2.45 \pm 0.46 \pm 0.10)\,\%$$

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







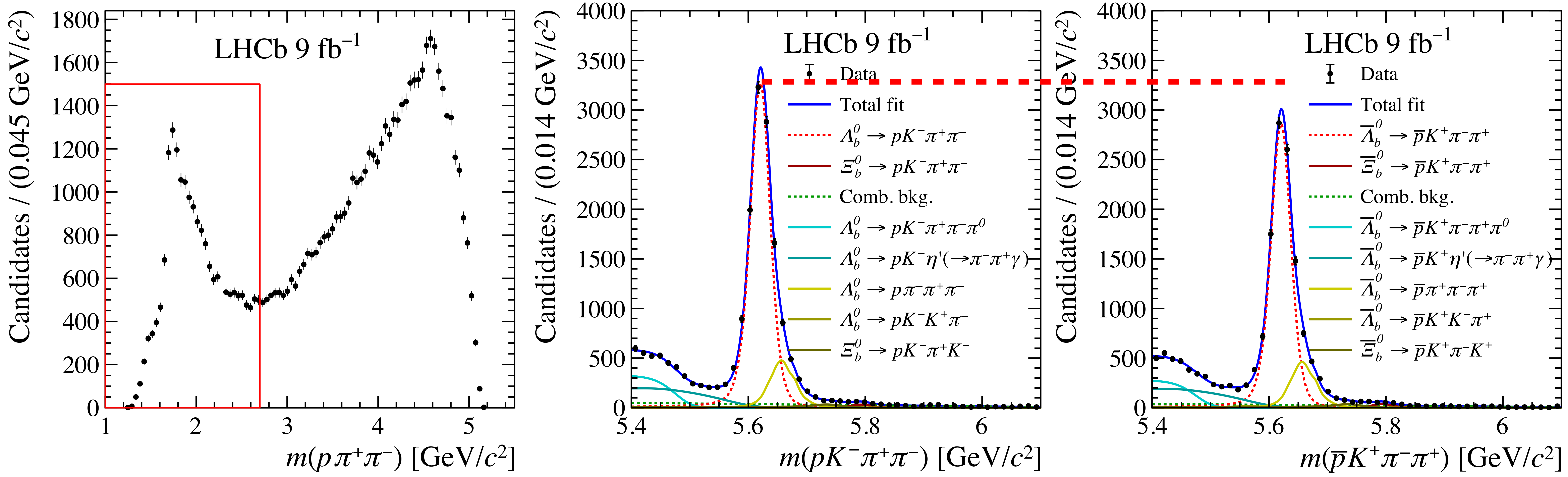


Observation of baryonic CPV (LHCb)

[arXiv:2503.16954]
Submitted to Nature

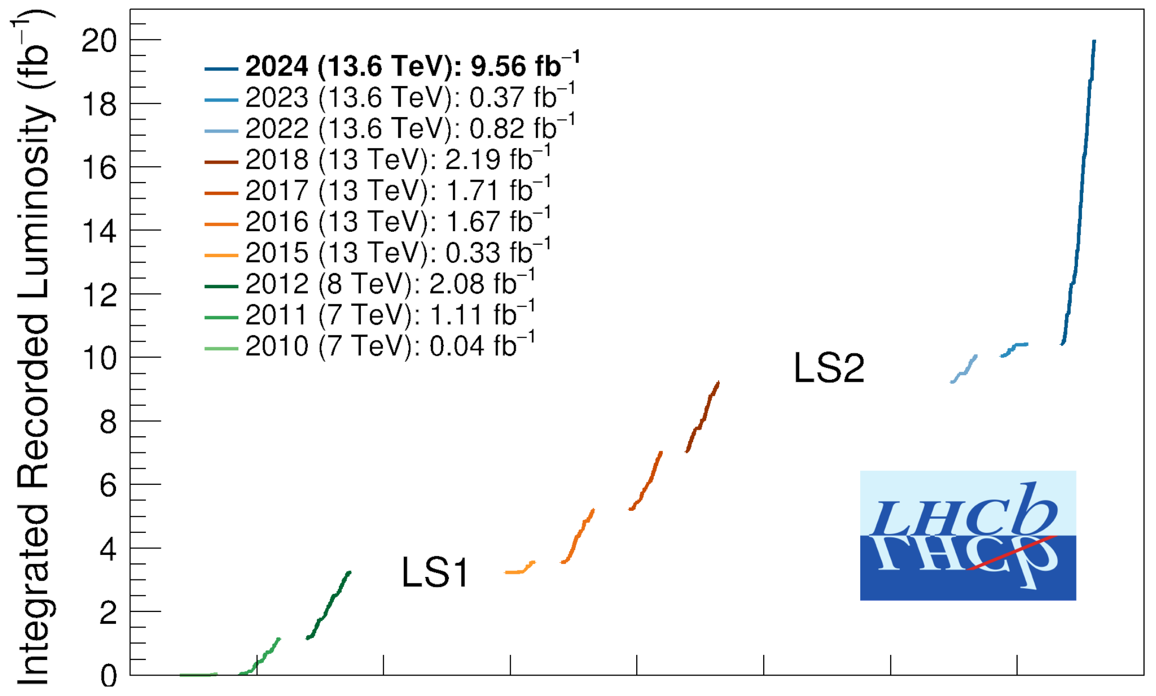
- Search for local CP violation in selected regions of the phase space
- Measured asymmetries up to 6σ (N^+ resonances)
- One of the last missing pieces of CPV in the SM has been found!

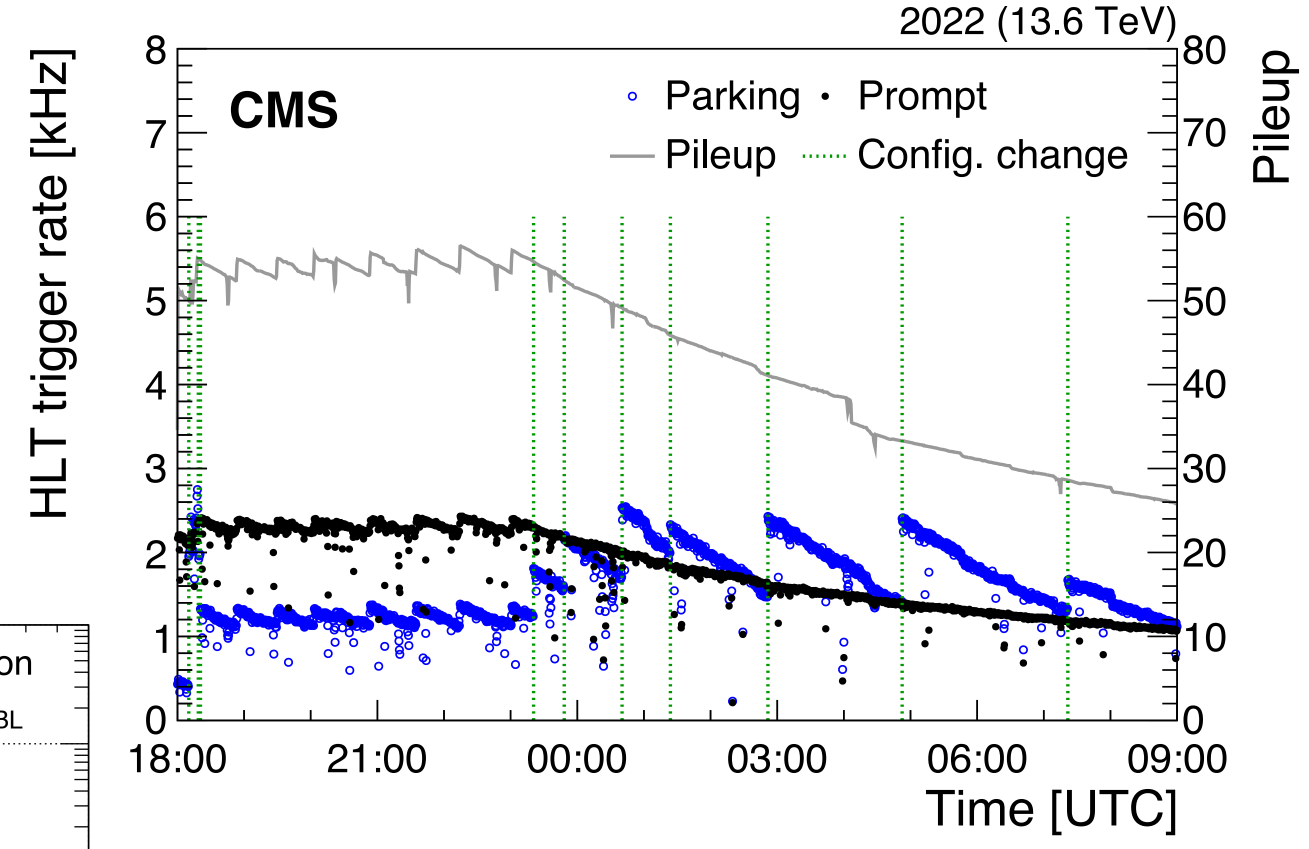
Decay topology	Mass region (GeV/c^2)	$\mathcal{A}_{CP}$
$\Lambda_b^0 \to R(pK^-)R(\pi^+\pi^-)$	$m_{pK^-} < 2.2$ $m_{\pi^+\pi^-} < 1.1$	$(5.3 \pm 1.3 \pm 0.2)\%$
$\Lambda_b^0 \to R(p\pi^-)R(K^-\pi^+)$	$m_{p\pi^-} < 1.7$ $0.8 < m_{\pi^+K^-} < 1.0$ or $1.1 < m_{\pi^+K^-} < 1.6$	$(2.7 \pm 0.8 \pm 0.1)\%$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

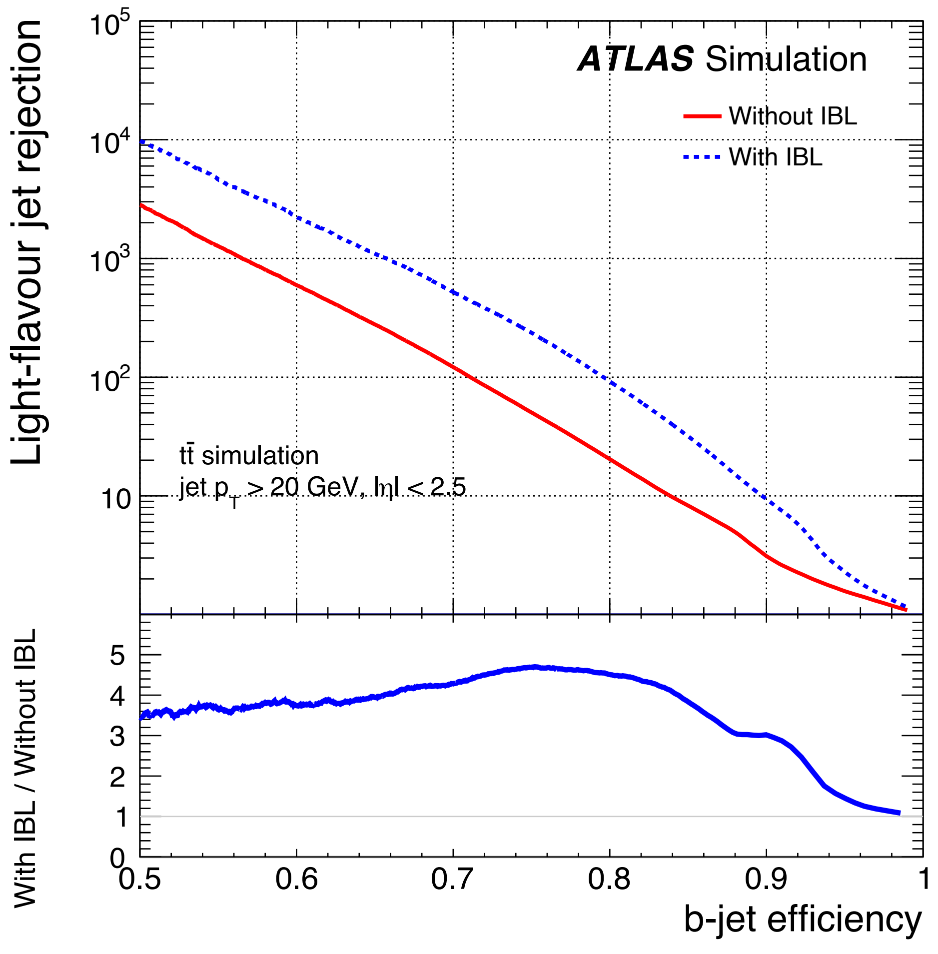


Prospects

- LHCb [JINST 19 (2024)]
  - Upgrade I detector allows to run at higher pileup than Run 1+2 ($\mu \sim 5$ instead of ~1/2)
  - Removal of hardware trigger since Run 3→ 2~3x improvement on signal reconstruction efficiency
  - 2024 sample size comparable to the sum of Run 1&2
- CMS [JINST 19 (2024)]
  - Data parking strategy provided huge samples of $b\bar{b}$ events with single displaced muon triggers in Run 2 [arXiv:2403.16134]
  - Extended in Run 3 to have dedicated low-p_T triggers for dimuon and dielectron events
- ATLAS [JINST 19 (2024)]
  - Insertable B-layer (IBL) was added to improve impact parameter resolution (3.3 cm from beam pipe)
  - Will enhance vertex reconstruction and flavour tagging performances







Conclusions

- CP violation is a rich field of study
- Essential to precisely test the SM and constraint/guide New Physics models
- LHCb has a leading role for hadronic final states
- Competition with ATLAS/CMS in muonic final-states
- Latest piece added to the puzzle: direct CP violation in baryon decays
- Only a fraction of the LHC data sample collected so far: the best is yet to come!

BACKUP

CP asymmetry of $B^+ \to J/\psi\pi^+$ decays (LHCb) [PRL 134 (2025)]

	Branching fraction ratio			CP-asymmetry difference		
	2016 (%)	2017 (%)	2018 (%)	2016 (10^{-2})	2017 (10^{-2})	2018 (10^{-2})
Mass fit	0.22	0.16	0.21	0.04	0.06	0.04
Trigger efficiency	0.40	0.39	0.37	...	...	...
Material budget	0.30	0.30	0.30	...	...	...
Simulation correction	0.17	0.15	0.14	...	...	...
PID	0.29	0.22	0.29	0.06	0.07	0.08
Detection asymmetry	...	...	...	0.05	0.05	0.05
Production asymmetry	...	...	...	0.02	0.02	0.02
Total	0.64	0.58	0.61	0.09	0.11	0.11

TD-CPV in $B^0_{(s)} \to D^+_{(s)} D^-_{(s)}$ (LHCb)

[JHEP 01 (2025)]

Source	$S_{D^+D^-}$	$C_{D^+D^-}$	ϕ_s [rad]	$\lvert\lambda_{D_s^+D_s^-}\rvert$
Mass model	0.001	0.005	0.003	0.005
$\Delta\Gamma$	0.010	0.005	—	—
Decay-time resolution	0.002	0.007	0.011	0.027
Decay-time bias	—	—	0.026	0.014
Acceptance function	0.001	0.001	< 0.001	0.001
Total	0.010	0.010	0.028	0.031

TD-CPV in $B_s^0 \to J/\psi\phi$ (CMS)

[arXiv:2412.19952]
Submitted to PRL

	ϕ_s [mrad]	$\Delta\Gamma_s$ [ps^{-1}]	Γ_s [ps^{-1}]	Δm_s [$\hbar$ ps^{-1}]	$\lvert\lambda\rvert$	$\lvert A_0\rvert^2$	$\lvert A_\perp\rvert^2$	$\lvert A_S\rvert^2$	$\delta_\parallel$ [rad]	$\delta_\perp$ [rad]	$\delta_{S\perp}$ [rad]
Statistical uncertainty	23	0.0043	0.0015	0.035	0.014	0.0016	0.0021	0.0033	0.074	0.089	0.15
Fit bias	4	0.0011	0.0002	0.004	0.006	0.0012	0.0022	0.0006	0.015	0.017	0.03
Flavor tagging	4	$<10^{-4}$	0.0005	0.007	0.002	$<10^{-4}$	$<10^{-4}$	0.0006	0.012	0.016	0.03
Angular efficiency	4	0.0002	$<10^{-4}$	0.015	0.011	0.0042	0.0019	0.0001	0.017	0.044	0.02
Time efficiency	<1	0.0014	0.0026	$<10^{-3}$	$<10^{-3}$	0.0004	0.0005	$<10^{-4}$	0.001	0.002	$<10^{-2}$
Time resolution	<1	$<10^{-4}$	$<10^{-4}$	$<10^{-3}$	$<10^{-3}$	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$	$<10^{-3}$	0.001	$<10^{-3}$
Model assumptions	—	0.0005	0.0006	—	—	—	—	—	—	—	—
B^0 background	<1	0.0002	0.0003	$<10^{-3}$	$<10^{-3}$	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$	$<10^{-3}$	$<10^{-3}$	$<10^{-2}$
Λ_b^0 background	—	—	0.0004	—	—	0.0004	0.0003	—	—	—	—
S-P wave interference	<1	$<10^{-4}$	$<10^{-4}$	$<10^{-3}$	$<10^{-3}$	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$	$<10^{-3}$	$<10^{-3}$	$<10^{-2}$
$P(\sigma_{ct})$ uncertainty	<1	0.0002	0.0003	$<10^{-3}$	$<10^{-3}$	0.0001	0.0001	$<10^{-4}$	$<10^{-3}$	$<10^{-3}$	$<10^{-2}$
Total systematic uncertainty	7	0.0019	0.0028	0.017	0.012	0.0044	0.0030	0.0009	0.025	0.050	0.05

Measurements of CPV parameters and γ (LHCb) [JHEP 02 (2025)] [JHEP 03 (2025)]

$$B_s^0 \to D_s^{\mp} K^{\pm}$$

Source	C_f	$A_f^{\Delta\Gamma}$	$A_{\bar{f}}^{\Delta\Gamma}$	S_f	$S_{\bar{f}}$
Invariant-mass fit	0.045	0.095	0.121	0.088	0.112
Flavour tagging	0.256	0.026	0.028	0.012	0.070
Oscillation frequency Δm_s	0.006	0.005	0.004	0.108	0.101
Detection asymmetry A_{det}	0.001	0.079	0.082	0.007	0.007
Decay-time resolution model	0.195	0.008	0.008	0.054	0.166
Decay-time acceptance, Γ_s, $\Delta\Gamma_s$	0.006	0.397	0.400	0.009	0.009
Decay-time acceptance simulation	0.004	0.064	0.064	—	0.004
Decay-time bias	0.062	0.027	0.046	0.188	0.167
Neglecting correlations	0.137	0.081	0.054	0.135	0.043
Total	0.358	0.430	0.439	0.277	0.293

Measurements of CPV parameters and γ (LHCb)

[JHEP 02 (2025)]
[JHEP 03 (2025)]

$B^{\pm} \to DK^{*\pm}$

2/4 body decays

	$A_{SS}^{K\pi}$	A_{CP}^{KK}	$A_{CP}^{\pi\pi}$	$A_{OS}^{\pi K}$	R_{CP}^{KK}	$R_{CP}^{\pi\pi}$	$R_{OS}^{\pi K}$	$A_{SS}^{K\pi\pi\pi}$	$A_{CP}^{\pi\pi\pi\pi}$	$A_{OS}^{\pi K\pi\pi}$	$R_{CP}^{\pi\pi\pi\pi}$	$R_{OS}^{\pi K\pi\pi}$
Asymmetry corrections	0.17	0.072	0.067	0.078	—	—	—	0.17	0.073	0.16	—	—
Branching fractions	—	—	—	—	0.88	1.2	—	—	—	—	3.5	—
Selection efficiencies	—	—	—	—	0.87	0.76	0.0024	—	—	—	1.2	0.0047
PID efficiencies	—	—	—	—	0.22	0.23	—	—	—	—	0.36	—
Signal shape	—	—	0.046	0.067	0.20	0.26	0.0011	—	0.020	0.069	0.31	0.0021
Combinatorial shape	0.034	0.053	0.14	2.6	0.30	0.29	0.021	0.014	0.22	0.097	0.14	0.0071
Part. reco. background	—	—	—	0.16	0.072	0.12	0.0043	—	—	—	—	—
Charmless background	—	—	4.9	0.034	—	4.5	—	—	2.9	—	3.0	—
Λ_b^0 background	—	—	0.016	0.044	0.030	0.039	—	—	—	—	—	—
B_s^0 background	0.046	0.011	0.38	1.1	0.020	0.032	0.0093	0.038	0.12	0.54	0.27	0.0054
Total systematic	0.18	0.09	4.9	2.8	1.3	4.7	0.02	0.17	2.9	0.5	4.8	0.01
Statistical	1.4	4.0	9.0	16.4	5.0	9.0	0.19	1.8	6.0	21.8	7.0	0.26

Measurements of CPV parameters and γ (LHCb) [JHEP 02 (2025)] [JHEP 03 (2025)]

$B^\pm \to DK^{*\pm}$

3 body decays

	$\sigma(x_+)$	$\sigma(y_+)$	$\sigma(x_-)$	$\sigma(y_-)$
c_i, s_i uncertainty	0.4	1.9	0.9	3.9
F_i inputs	1.5	0.4	1.7	0.4
Value of κ	0.8	0.4	0.6	0.8
Efficiency correction to c_i, s_i	0.0	0.0	0.2	0.6
Bin migration	0.4	0.2	0.3	0.4
Mass model	0.1	0.1	0.1	0.3
Bias correction	0.4	0.6	0.3	0.6
Total systematic	1.8	2.1	2.1	4.1
Statistical	5.2	6.4	6.0	11.4

CP asymmetries with $\Lambda_b^0 \to ph^-$ decays (LHCb)

[arXiv:2412.13958]
Submitted to PRD

	Run 1		Run 2	
	$\Lambda_b^0 \to pK^-$	$\Lambda_b^0 \to p\pi^-$	$\Lambda_b^0 \to pK^-$	$\Lambda_b^0 \to p\pi^-$
Fit model	0.1	0.2	0.1	0.2
Particle identification	0.3	0.3	0.2	0.2
TIS trigger	0.1	0.1	< 0.1	< 0.1
TOS hardware trigger	0.2	0.2	0.1	0.1
TOS software trigger	0.3	0.3	0.2	0.2
Proton detection	0.1	0.1	< 0.1	< 0.1
Kaon detection	0.3	–	0.1	< 0.1
Pion detection	–	0.1	< 0.1	< 0.1
Λ_b^0 production	0.1	0.1	–	–
$\Lambda_b^0 \to \Lambda_c^+\pi^-$ sample size	–	–	0.3	0.3
Total systematic	0.6	0.5	0.4	0.4
Statistical	1.5	1.9	0.7	0.9

Observation of baryonic CPV (LHCb)

[arXiv:2503.16954]
Submitted to Nature

Contribution	Run 1	Run 2
Nuisance asymmetry difference	0.193%	0.051%
Mass fit	0.044%	0.067%
Total systematic uncertainty	0.198%	0.084%