

CKM and CPV in Beauty and Charm decays at LHCb

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on behalf of the LHCb Collaboration

60th Rencontres de Moriond

Moriond EW

La Thuile, Italy 17th March 2026

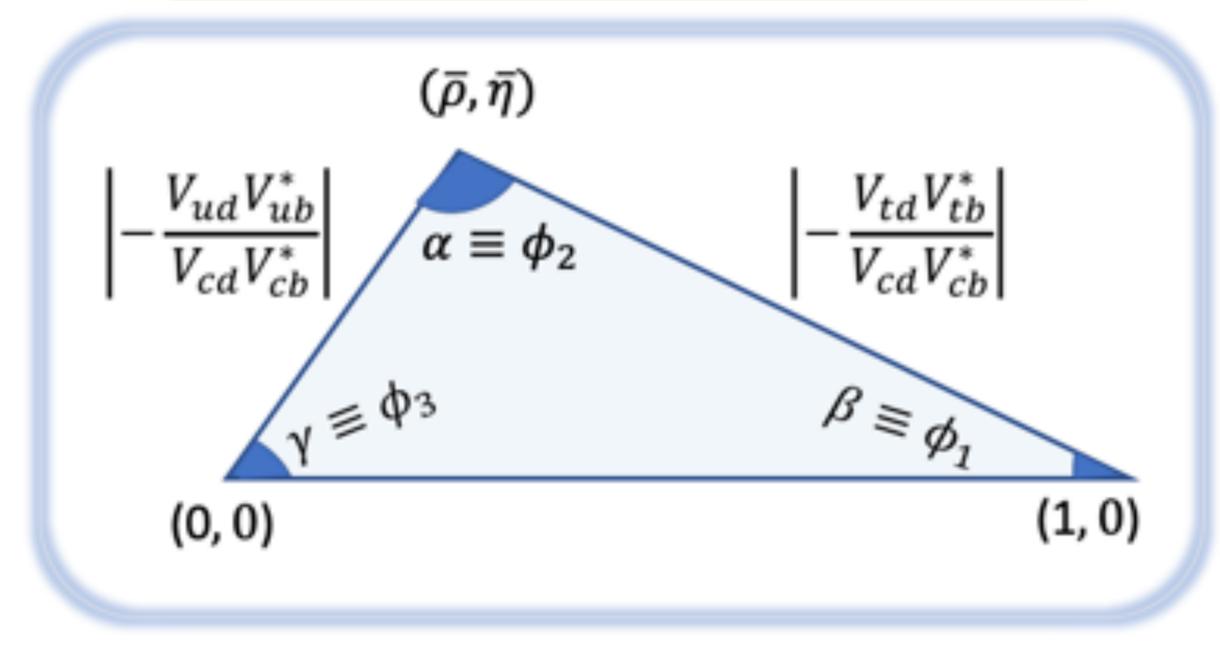


Physics motivation : CKM matrix and unitarity conditions

- The rates of the decay processes are parametrized by the CKM matrix elements

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1 - \frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1 - \frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

- Unitarity triangle in the $(\bar{\rho}, \bar{\eta})$ complex plane**

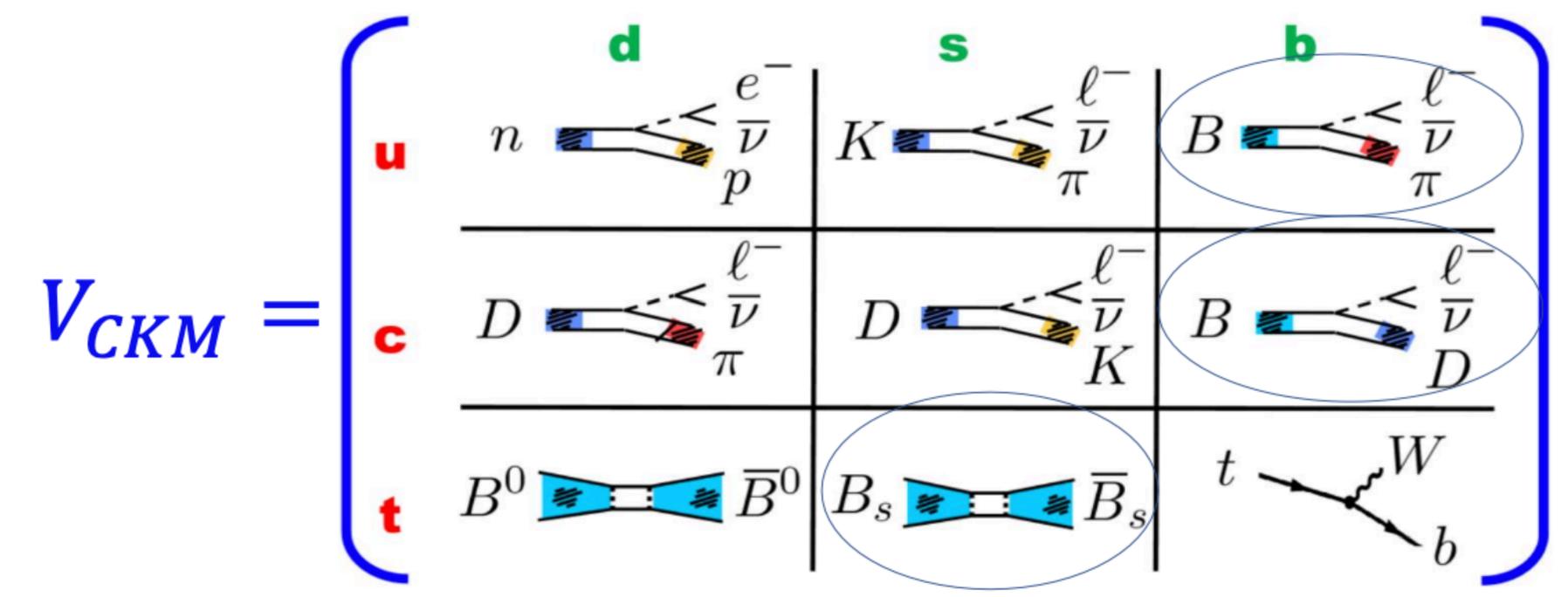


- Overconstraining the CKM elements is one of the key goals of flavour physics



$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

- 4 parameters: A, λ, ρ, η
 - 3 angles
 - 1 complex phase
- Parameters are measured (overconstrained systems) (rich pheno and large mass range):
 - Nucleons, K, D, $B_{(s)}$, and top quark physics



Physics motivation : CKM matrix and unitarity conditions

- In order to verify the unitarity of the CKM matrix

→ Complex phase $\gamma = \arg(-V_{ud}V_{ub}^*/V_{cd}V_{cb}^*)$ which is a source of CP violation can be measured from the processes mediated by the interference between $b \rightarrow c$ and $b \rightarrow u$ quark transitions

- Only angle measurable with tree-level decays
 - theoretically clean
 - **“Standard candle” of the Standard Model**



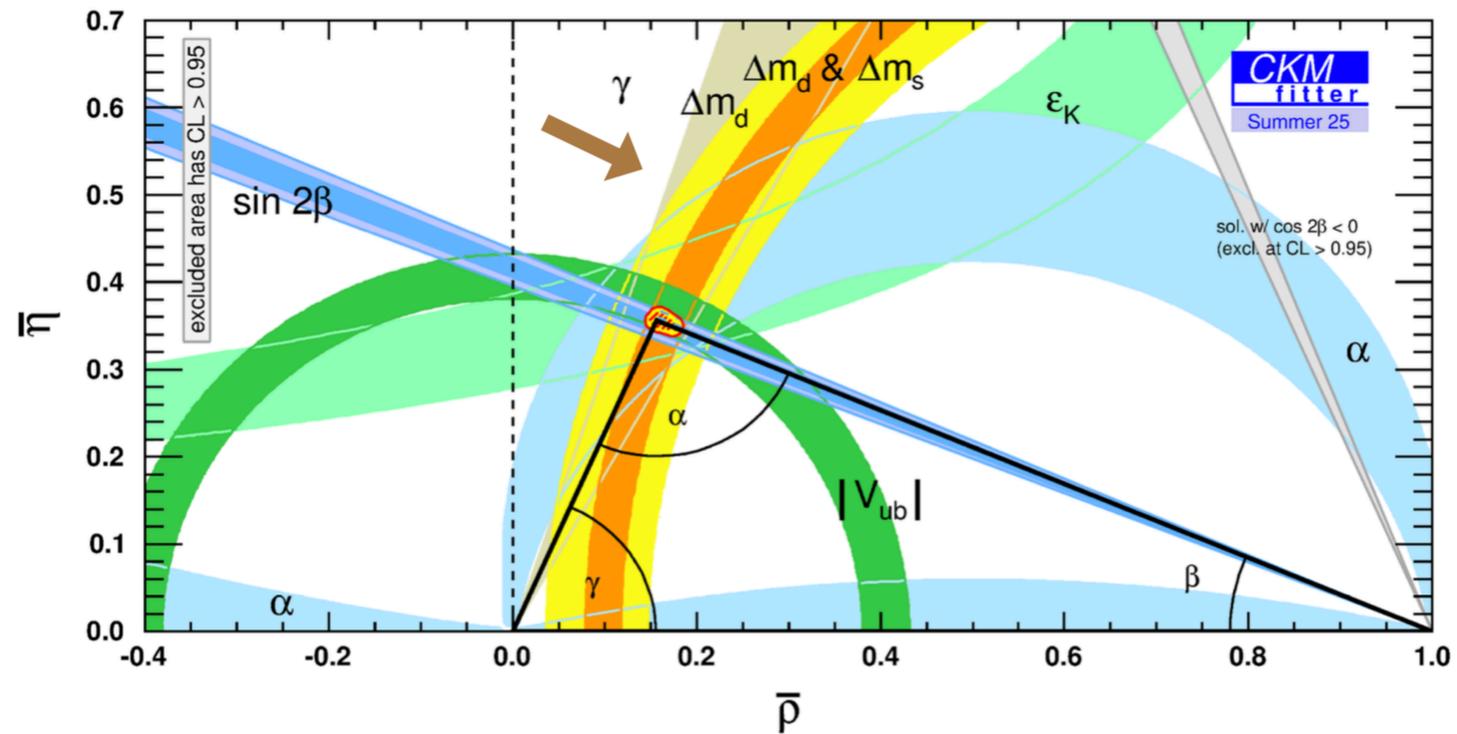
- Precise measurements of the magnitudes of the CKM matrix elements : **mixing, branching fractions**
- **Sub-degree level of measurements to be compared with the CKMfitter global fit to challenge the Standard Model**

• Loop level (indirect measurement)

- **“sensitive to New Physics”**

CKM angle γ measurements

- ✓ A model-independent measurement of the CKM angle γ in the decay $B^\pm \rightarrow [K^+K^-\pi^+\pi^-]_D h^\pm$ and $B^\pm \rightarrow [\pi^+\pi^-\pi^+\pi^-]_D h^\pm$ ($h = K, \pi$) ([JHEP02(2026)253], [arxiv:2509.15139])
- ✓ Simultaneous determination of the CKM angle γ and parameters related to the mixing and CP violation in the charm sector [LHCb-CONF-2025-003]
- ✓ Measurement of γ using $B^\pm \rightarrow DK^\pm$ and $B^\pm \rightarrow D\pi^\pm$ decays with $D \rightarrow K_S^0\pi^+\pi^-$ and $D \rightarrow K_S^0K^+K^-$ with Run3 [LHCb-PAPER-2026-010] **NEW**
- ✓ Unbinned measurement of the CKM angle γ in $B^\pm \rightarrow D(\rightarrow K_S^0 h'^+ h'^-) h^\pm$ decays [LHCb-PAPER-2025-063], [LHCb-PAPER-2025-064] **NEW**



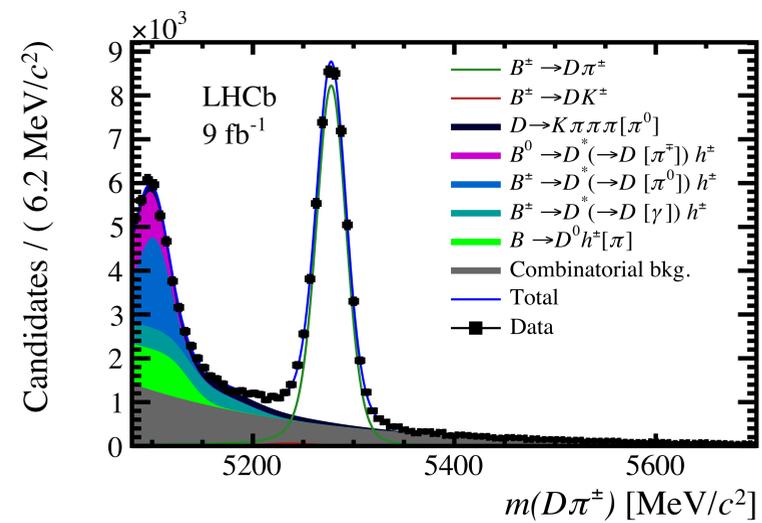
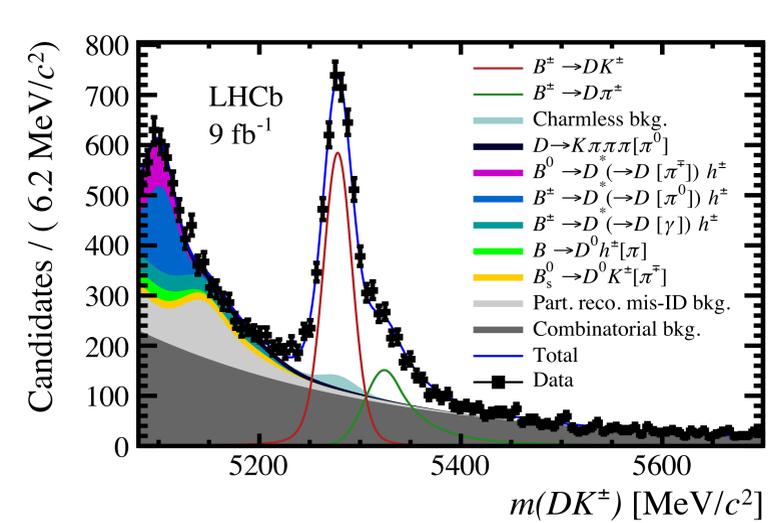
arxiv:2509.15139

JHEP02(2026)253

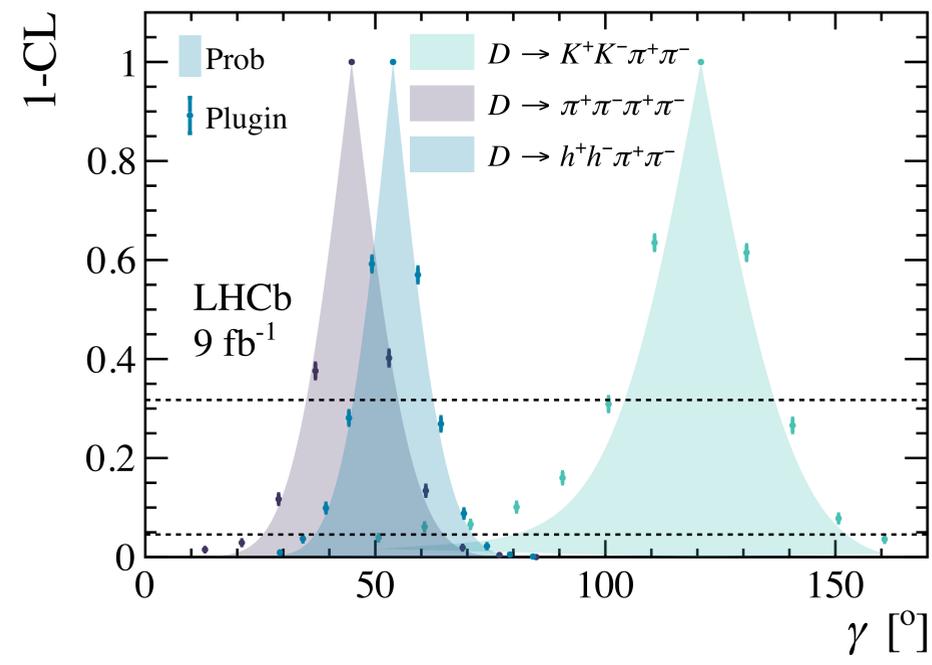
A model-independent measurement of the CKM angle γ in the decays $B^{\pm} \rightarrow [K^+K^-\pi^+\pi^-]_D h^{\pm}$ and $B^{\pm} \rightarrow [\pi^+\pi^-\pi^+\pi^-]_D h^{\pm}$ ($h = K, \pi$)

✓ Analysis based on data samples Run1&2 corresponding to an integrated luminosity of $9fb^{-1}$

A model-independent measurement of the CKM angle γ in the decays $B^\pm \rightarrow [K^+K^-\pi^+\pi^-]_D h^\pm$ and $B^\pm \rightarrow [\pi^+\pi^-\pi^+\pi^-]_D h^\pm$

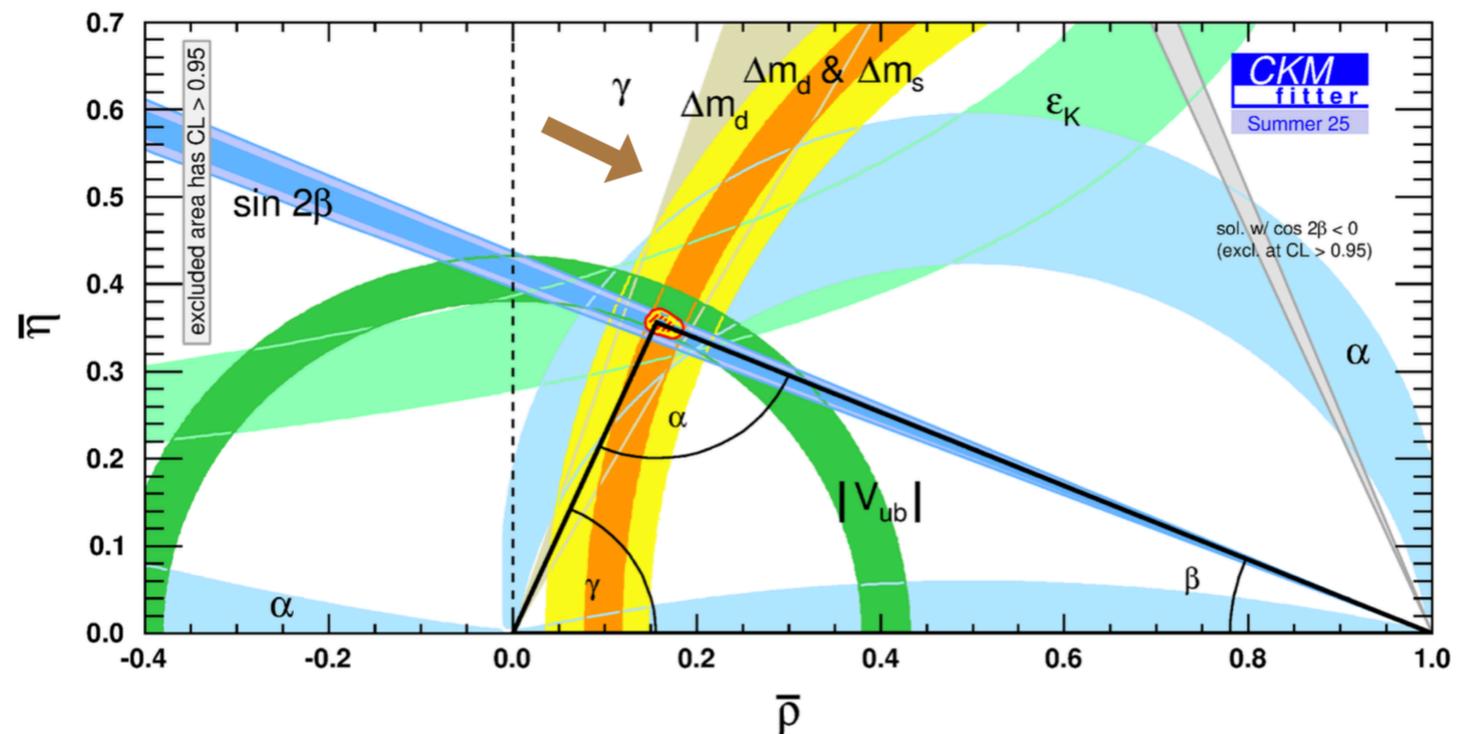


- The variation of the strong-phase over $D \rightarrow h^+h^-\pi^+\pi^-$ provides enhanced sensitivity to γ angle
- Provides a model independent update, replacing [EPJ C 83 (2023) 547]



- ♦ γ measured for the first time with a model-independent phase-space binning approach using $B^\pm \rightarrow Dh^\pm$ mode
- ♦ The result from the phase-space binned analysis is: $\gamma = (53.9^{+9.5}_{-8.9})^\circ$
- ♦ Combination with phase-space integrated analysis: $\gamma = (52.6^{+8.5}_{-6.4})^\circ$
- ♦ One of the most precise determinations of the SM parameter γ -> significant impact on global fits
- ♦ $\sim 2\times$ better precision compared with the 2023 measurement

JHEP02(2026)253 , arxiv:2509.15139



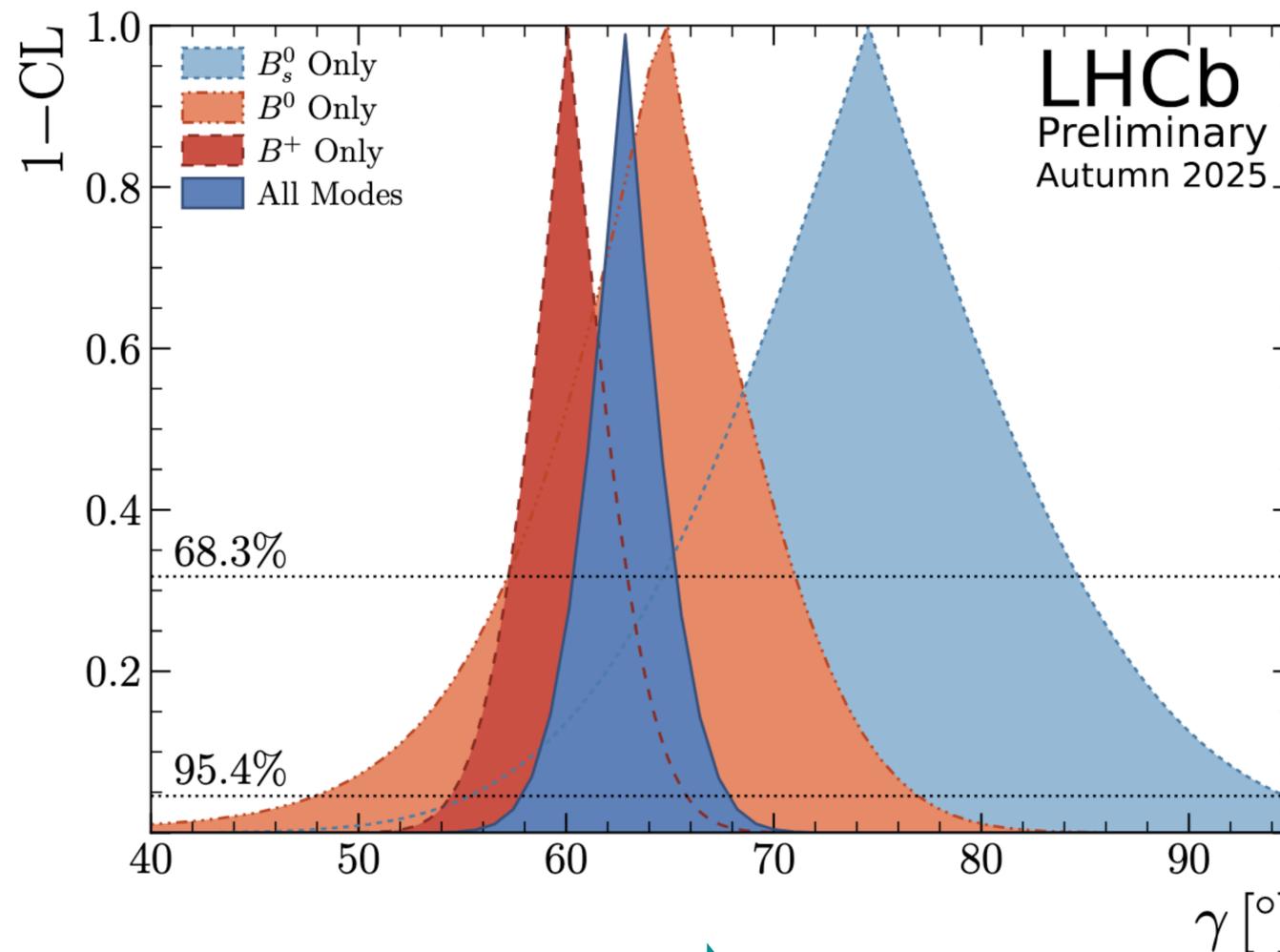
LHCb-CONF-2025-003

Simultaneous determination of the CKM angle γ and parameters related to the mixing and CP violation in the charm sector

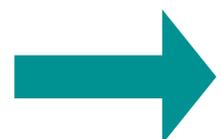
- ✓ Updated LHCb simultaneous combination constraining the CKM angle γ , charm mixing and CP-violation parameters
- ✓ Analysis based on data samples Run1&2 corresponding to an integrated luminosity of $9fb^{-1}$
- ✓ New measurements significantly contribute to sensitivity on CKM angle γ : $D^0 \rightarrow K^\pm \pi^\mp \pi^\pm \pi^\mp$, $B^\pm \rightarrow [K^+ K^- \pi^+ \pi^-]_D h^\pm$ and $B^\pm \rightarrow [\pi^+ \pi^- \pi^+ \pi^-]_D h^\pm$ decays

Combination of CKM angle γ

LHCb-CONF-2025-003



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



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

$$\gamma = (66.3^{+0.7}_{-1.9})^\circ$$

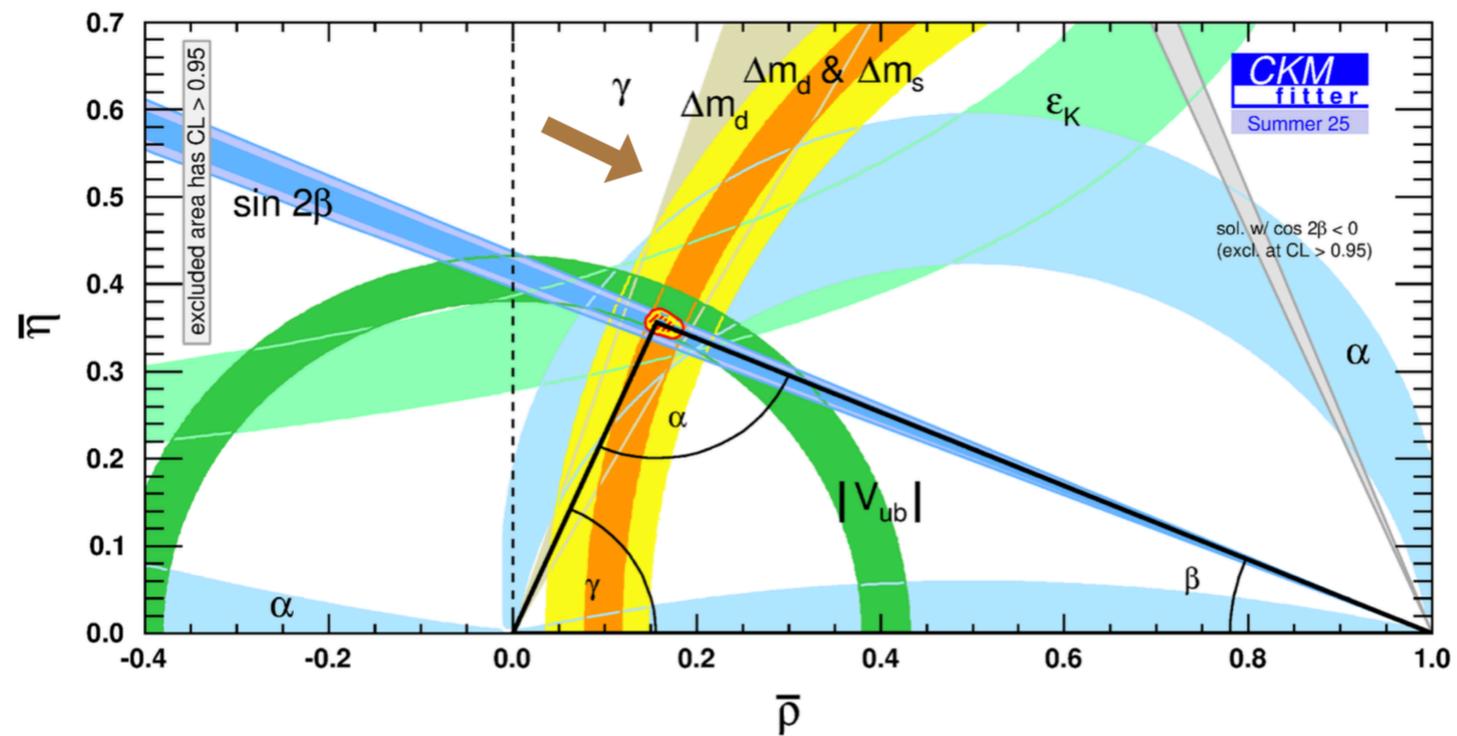
(**CKM fitter**, frequentist)

$$\gamma = (64.9 \pm 1.4)^\circ$$

(**UTfit**, Bayesian)

- ◆ The most precise determination of γ from a single experiment to date!
- ◆ Compatible with the previous LHCb combination
- ◆ Precision achieved beyond the original 4° expectation

◆ **Coherence
with indirect
measurements**



LHCb-PAPER-2026-010

Preliminary

NEW

Measurement of γ using $B^\pm \rightarrow DK^\pm$ and $B^\pm \rightarrow D\pi^\pm$ decays with $D \rightarrow K_S^0\pi^+\pi^-$ and $D \rightarrow K_S^0K^+K^-$ with Run3

✓ A measurement of the CKM angle γ from $B^\pm \rightarrow Dh^\pm$ (h^\pm can be either kaon or pion) where D meson decays to $D \rightarrow K_S^0\pi^+\pi^-$ and $D \rightarrow K_S^0K^+K^-$

✓ Analysis based on data corresponding to a total integrated luminosity of 5.8 fb^{-1} collected by the LHCb in 2024

Measurement of γ using $B^\pm \rightarrow DK^\pm$ and $B^\pm \rightarrow D\pi^\pm$ decays with $D \rightarrow K_S^0\pi^+\pi^-$ and $D \rightarrow K_S^0K^+K^-$ with Run3

- ◆ $B^\pm \rightarrow DK^\pm/\pi^\pm$ decays with all final states reconstructed :
- ◆ Signal yields of B^\pm in the i^{th} bin dependent on the CP-violating observables

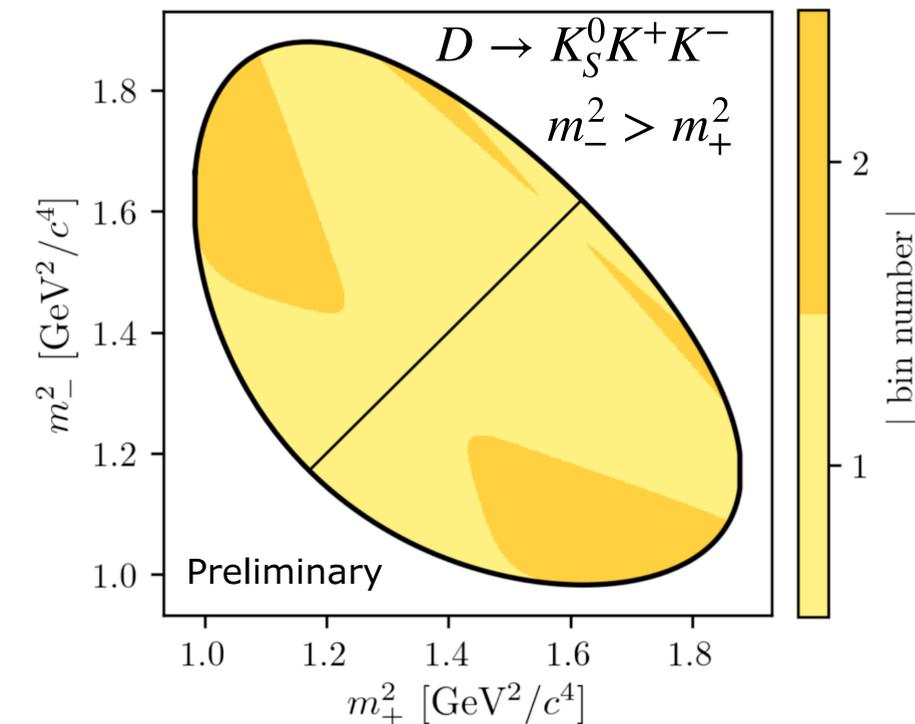
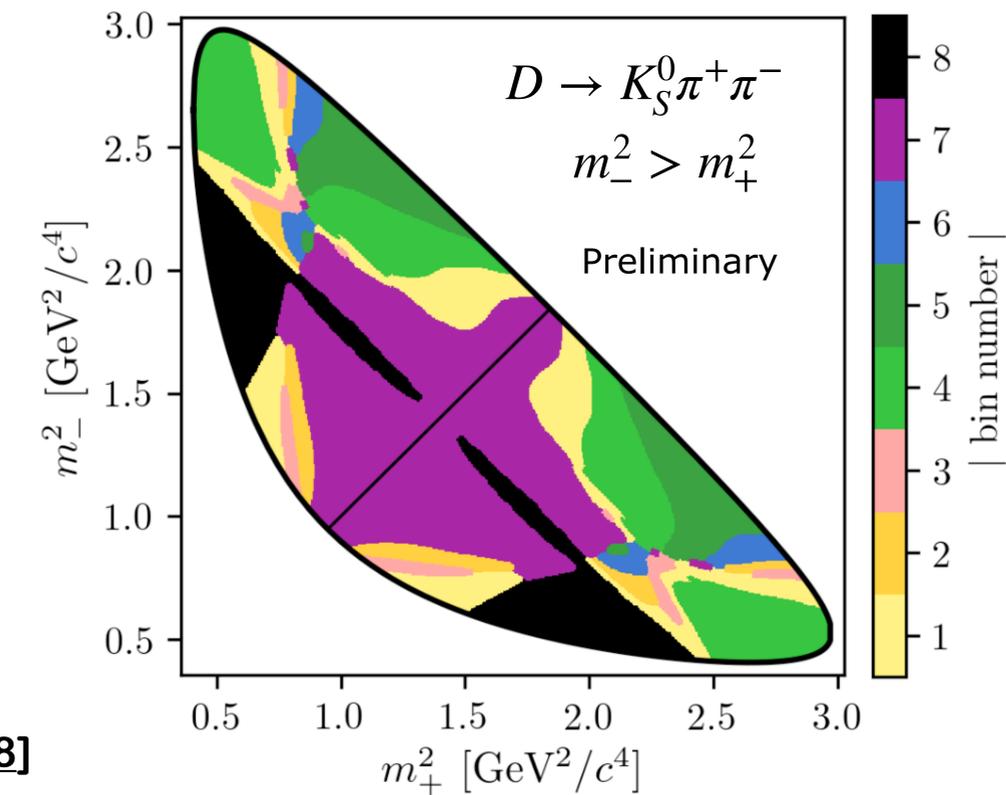
$$x_\pm + iy_\pm = r_B e^{i(\delta_{B^\pm} + \gamma)}$$

$$N_i(B^\pm) = H^{B^\pm} [F_{\mp i} + (x_\pm^2 + y_\pm^2)F_i + 2\sqrt{F_i F_{-i}}(x_\pm c_i \mp y_\pm s_i)]$$

Fractional yield of $D^0 \rightarrow K_S^0 hh$, common for DK and $D\pi$ (same relative efficiency)

Strong-phase parameters of $D^0 \rightarrow K_S^0 hh$
 c_i and s_i inputs taken from combined measurement of BESIII and CLEO)

[JHEP06(2025)086]
 [PhysRevD.102.052008]



◆ The first γ measurement with Run3:

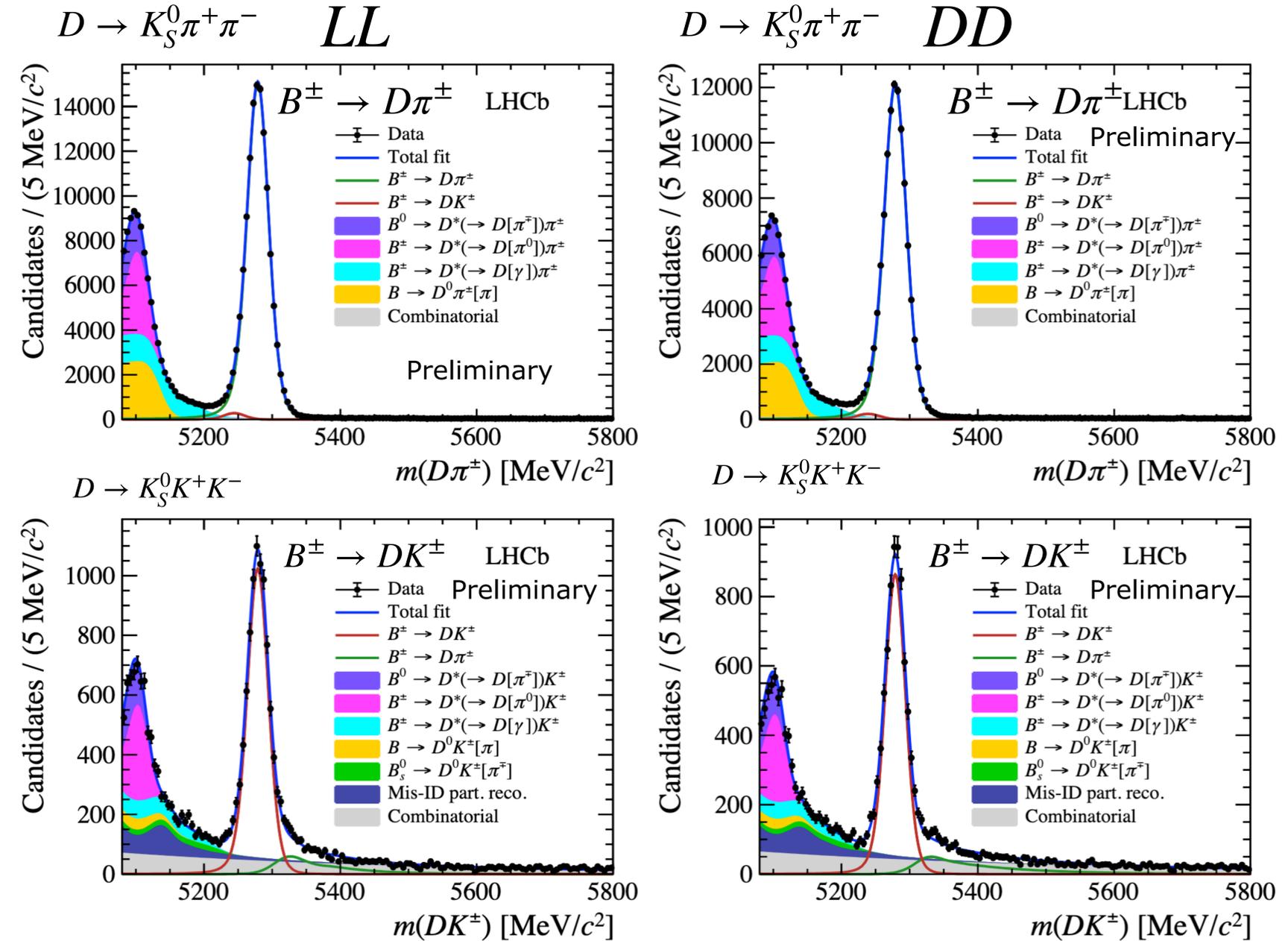
- ◆ Self normalising approach γ sensitivity from relative bin yields
- ◆ Reduced impact of detector asymmetries and simulation, etc.
- ◆ Run3 advantages: higher luminosity, higher trigger efficiency (removal of L0 + dedicated exclusive HLT2 lines for this decay)

Measurement of γ using $B^\pm \rightarrow DK^\pm$ and $B^\pm \rightarrow D\pi^\pm$ decays with $D \rightarrow K_S^0\pi^+\pi^-$ and $D \rightarrow K_S^0K^+K^-$ with Run3

- Global mass fit used to determine signal and background components.
- Simultaneous fit performed across categories (8) defined:

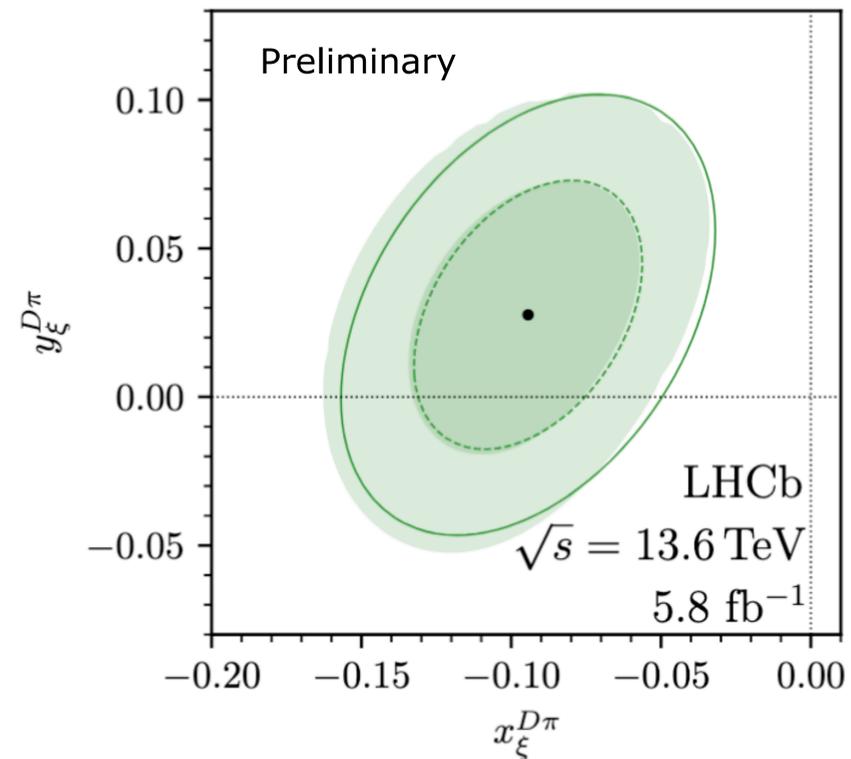
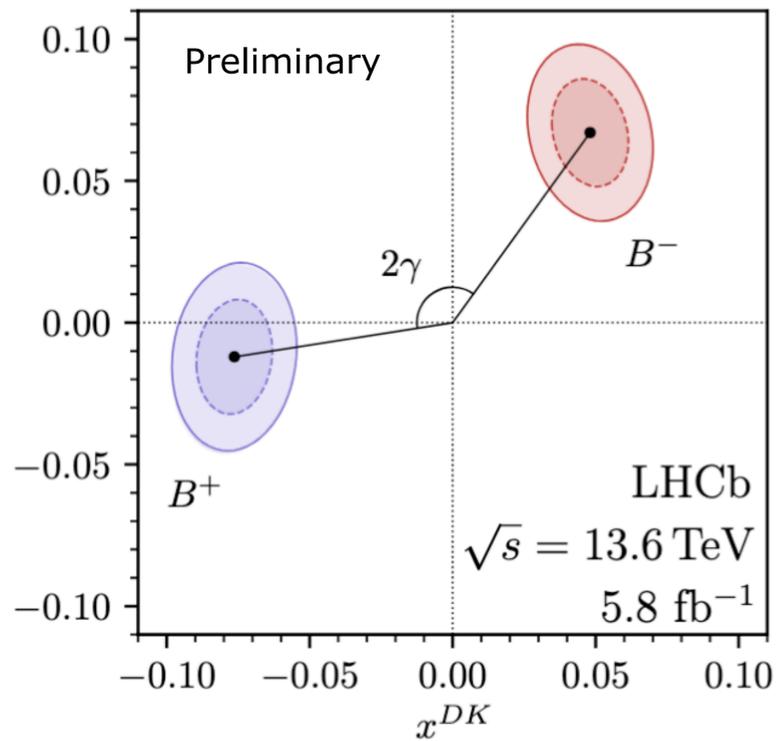
$$[DK, D\pi] \times [K_S^0\pi\pi, K_S^0KK] \times [LL, DD]$$

- ◆ The number of signal yields from global mass fit $\sim 200k$
- ◆ Relative to Run 1+2 measurement:
 - ◆ $\sim 17\%$ higher signal yield despite lower luminosity
 - ◆ LL yields per lumi is $2.7\times$ of run 2



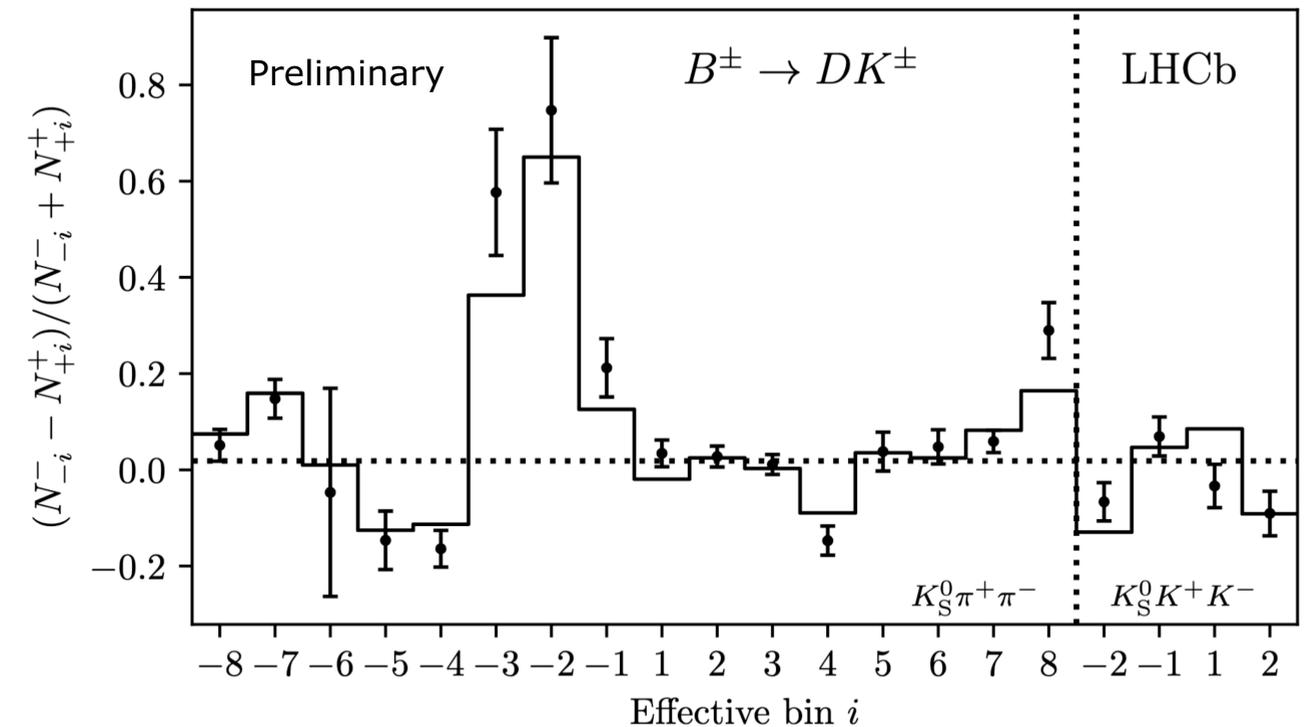
Measurement of γ using $B^\pm \rightarrow DK^\pm$ and $B^\pm \rightarrow D\pi^\pm$ decays with $D \rightarrow K_S^0\pi^+\pi^-$ and $D \rightarrow K_S^0K^+K^-$ with Run3

- ◆ Likelihood scans of x, y show close agreement fit results : uncertainties are well approximated by Gaussian distribution
- ◆ The vectors pointing to the coordinates (x_{DK}^+, y_{DK}^+) and (x_{DK}^-, y_{DK}^-) form an angle of 2γ



- **The resulting CP observables are:**

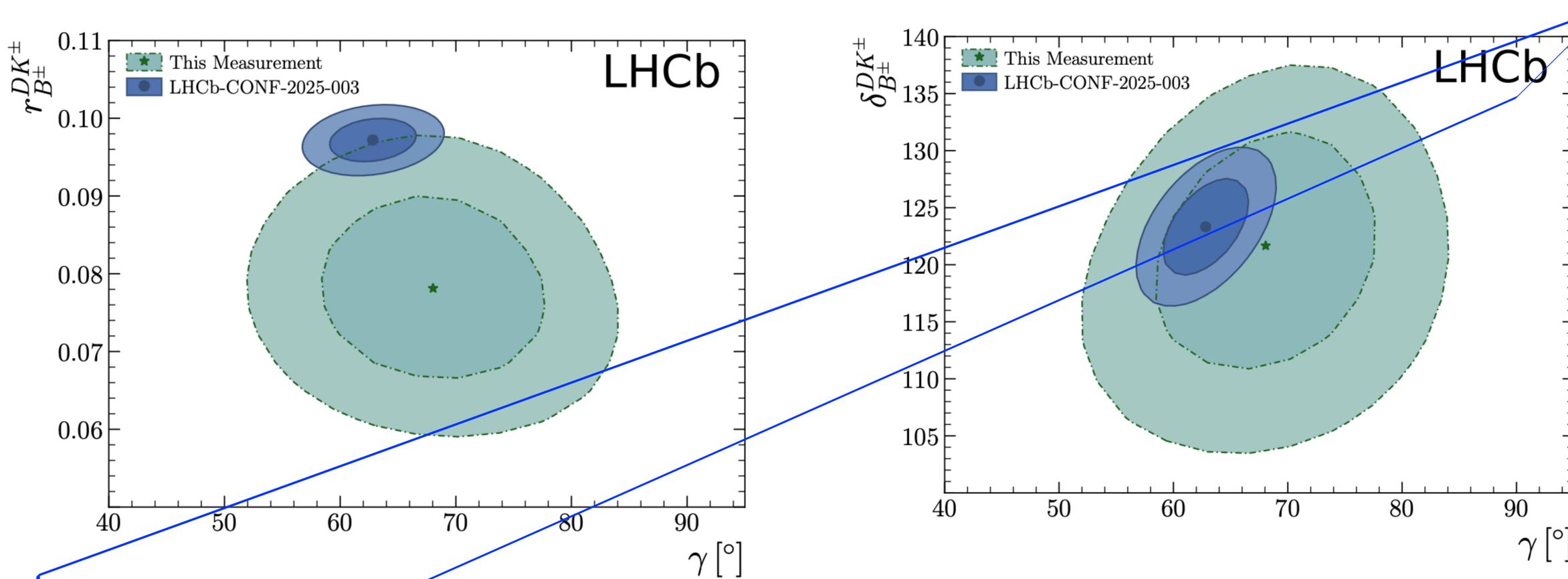
$$\begin{aligned}
 x_-^{DK} &= (4.81 \pm 0.88 \pm 0.20 \pm 0.23) \times 10^{-2}, \\
 y_-^{DK} &= (6.70 \pm 1.26 \pm 0.44 \pm 0.56) \times 10^{-2}, \\
 x_+^{DK} &= (-7.63 \pm 0.88 \pm 0.28 \pm 0.15) \times 10^{-2}, \\
 y_+^{DK} &= (-1.20 \pm 1.34 \pm 0.35 \pm 0.44) \times 10^{-2}, \\
 x_\xi^{D\pi} &= (-9.44 \pm 2.51 \pm 0.57 \pm 0.69) \times 10^{-2}, \\
 y_\xi^{D\pi} &= (2.76 \pm 2.99 \pm 0.19 \pm 1.21) \times 10^{-2},
 \end{aligned}$$



- CP asymmetries show good agreement across different fit methods.

Measurement of γ using $B^\pm \rightarrow DK^\pm$ and $B^\pm \rightarrow D\pi^\pm$ decays with $D \rightarrow K_S^0\pi^+\pi^-$ and $D \rightarrow K_S^0K^+K^-$ with Run3

- **Comparison with Run1+Run2 measurements:**
 - Consistent γ , δ_B^{DK} , $\delta_B^{D\pi}$ values, smaller r_B^{DK} larger $r_B^{D\pi}$
 - Higher γ uncertainty from changed strong-phase inputs and a smaller r_B^{DK} value
- **Comparison with LHCb γ combination :**
 - good agreement with a p-value of 12% in 5D parameter space



◆ Physics parameters:

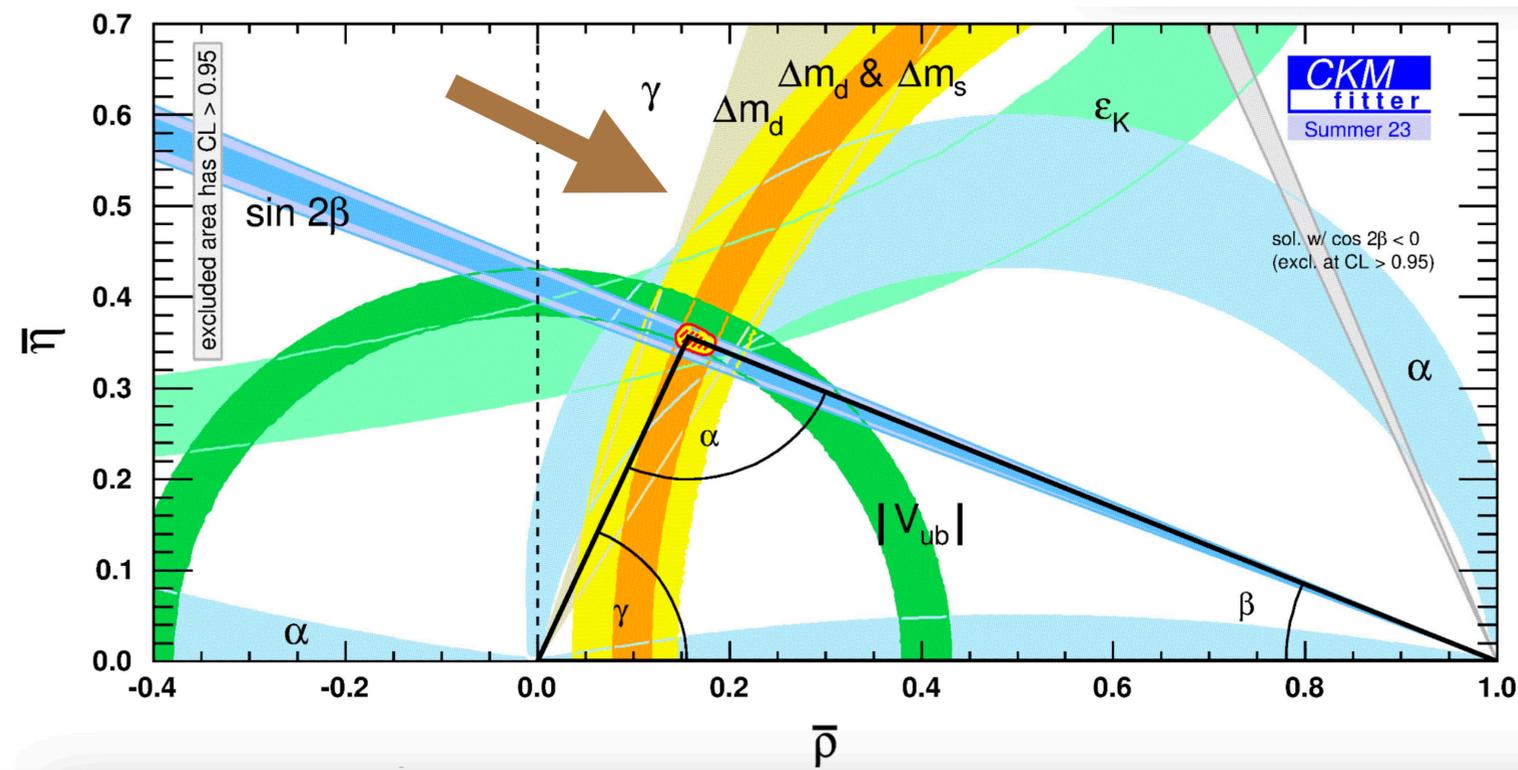
$$\begin{aligned} \gamma &= (68.1 \pm 6.7)^\circ, \\ r_B^{DK} &= 0.0781_{-0.0079}^{+0.0078}, \\ \delta_B^{DK} &= (121.5_{-7.4}^{+6.9})^\circ, \\ r_B^{D\pi} &= 0.0073_{-0.0015}^{+0.0016}, \\ \delta_B^{D\pi} &= (286_{-23}^{+20})^\circ, \end{aligned}$$

- ◆ **It is the first γ measurement with Run3 !**
- ◆ **Higher signal yields observed with less integrated luminosity**
- ◆ **These results show good agreement with the previous measurement**



LHCb-PAPER-2025-063

LHCb-PAPER-2025-064



NEW

Unbinned measurement of the CKM angle γ in $B^\pm \rightarrow D(\rightarrow K_S^0 h'^+ h'^-) h^\pm$ decays

- ✓ Joint analysis between BESIII and LHCb experiments (in preparation)
- ✓ The CKM angle γ determined via model-independent measurement unbinned approach (novel)
- ✓ The analysis based on data samples collected by LHCb Run1&2 and BESIII at $\Psi(3770)$ corresponding to a total integrated luminosity of $9fb^{-1}$ and $8fb^{-1}$

Preliminary

Unbinned measurement of the CKM angle γ in $B^\pm \rightarrow D(\rightarrow K_S^0 h' h')h^\pm$ decays

NEW

✓ The γ determination : Model-independent unbinned approach

◆ **Goal:** extract the angle γ with CP violation in $B^\pm \rightarrow D(\rightarrow K_S^0 h' h')h^\pm$ ($h \rightarrow K, \pi$) decay

Decay rate densities for B^\pm : $x_\pm + iy_\pm = r_B e^{i(\delta_{B^\pm} + \gamma)}$

r_B^{Dh} : ratio of suppressed to favored B-decay amplitudes
 δ_B^{Dh} : strong-phase difference

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

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

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

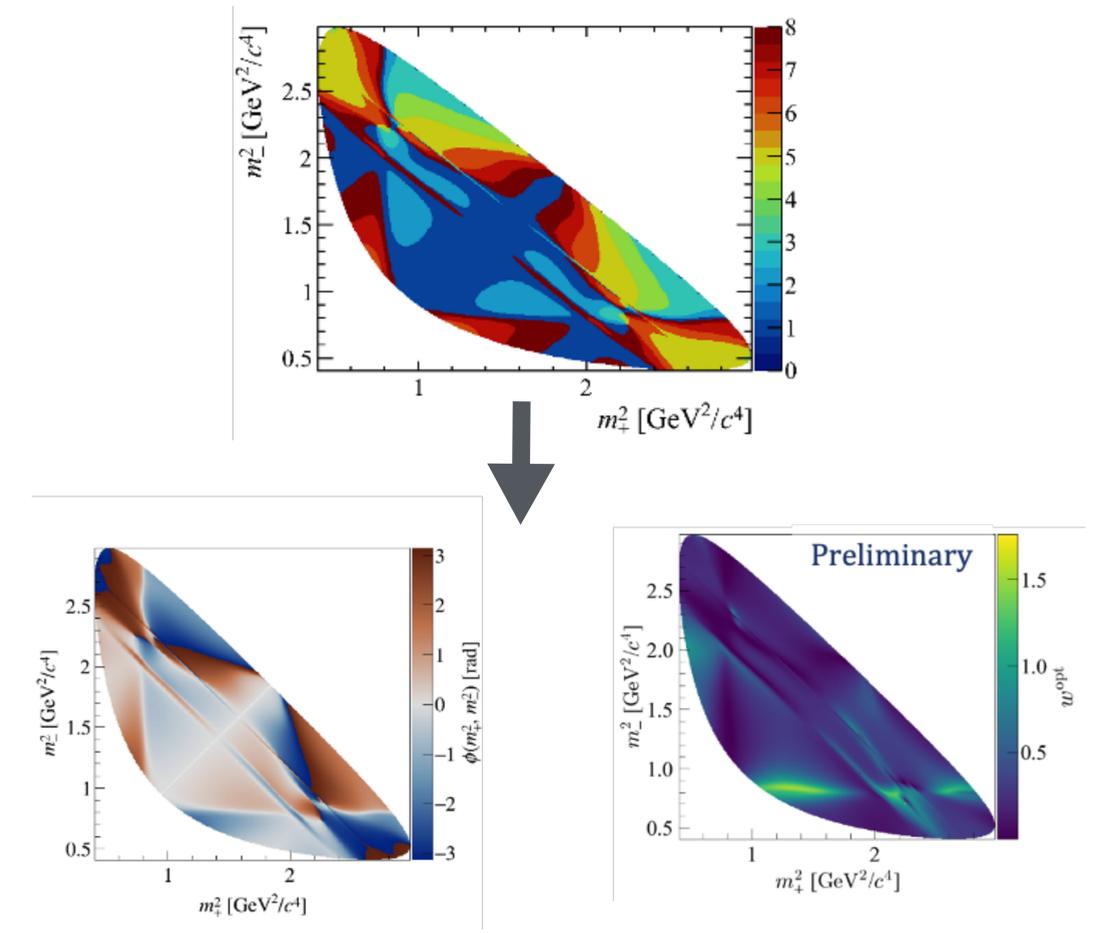
$$\{\mathcal{C}, \mathcal{S}\} = \sqrt{p_D \bar{p}_D} \{\cos, \sin\}(\phi)$$

$p_D(z)$: decay rate of $D \rightarrow K_S^0 h^+ h^-$

◆ **Weighting Methods:**

- Binned approach
 - Step weighting function
 - Average strong-phase differences are measured per bin
- Unbinned Fourier (novel)
 - Introduce an additional weight that takes into account the amplitude magnitude and signal purity
 - Using Fourier expansion of the phase difference $\Phi(z) = \delta_D(z) - \delta_D(\bar{z})$
 - Strong-phase parameters determined from BESIII - model independent

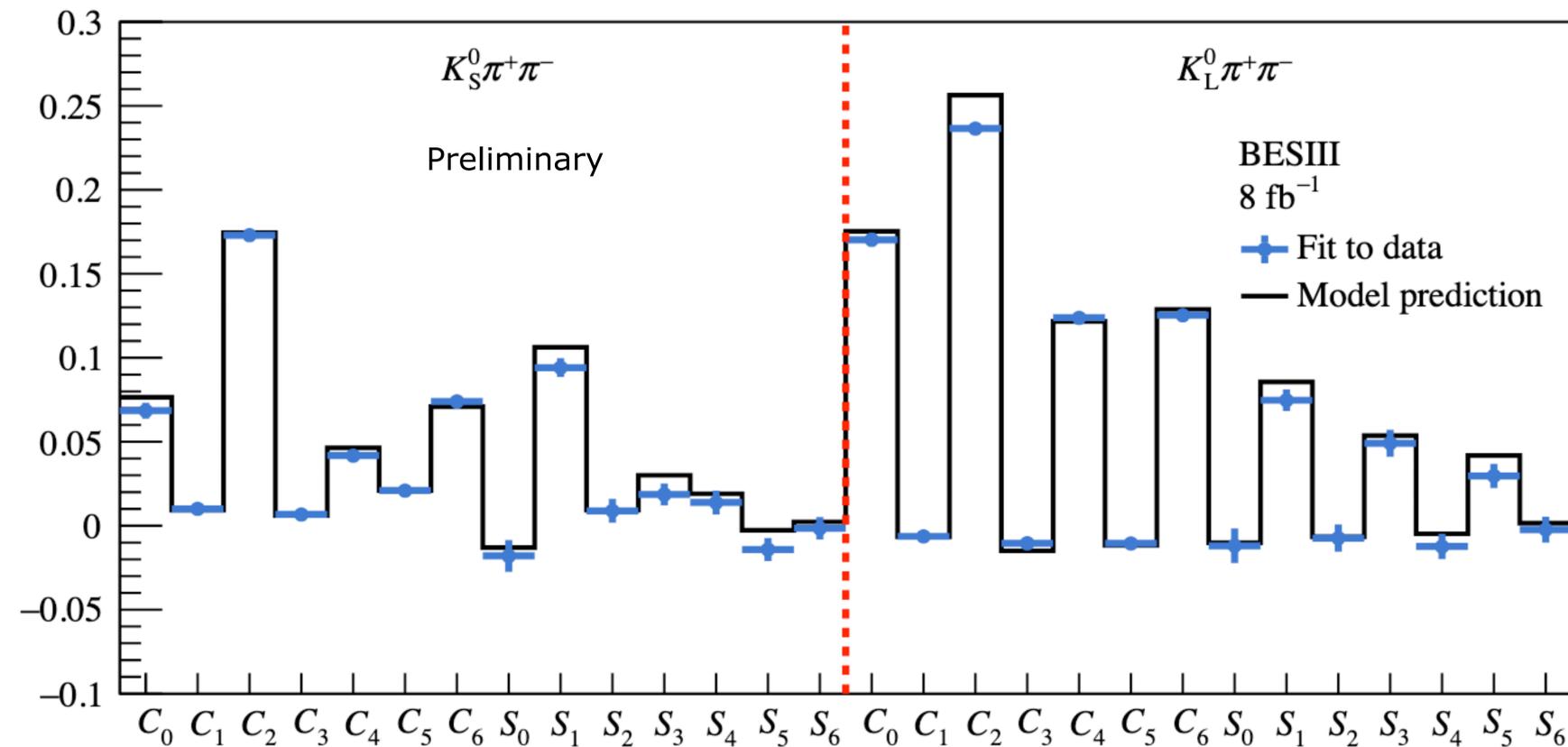
◆ **Advantage:** A novel unbinned Fourier weighting retains full phase information -> improved statistical precision than binned methods



Unbinned measurement of the CKM angle γ in $B^\pm \rightarrow D(\rightarrow K_S^0 h'^+ h'^-) h^\pm$ decays

NEW

- CP-violating observables extracted from a simultaneous fit to both datasets
- Determined strong-phase parameters from BESIII data



◆ **The result of the physics parameters:** $\gamma, r_B^{DK}, \delta_B^{DK}, r_B^{D\pi}, \delta_B^{D\pi}$

$$\begin{aligned} \gamma &= (71.3 \pm 5.0)^\circ, \\ r_B^{DK} &= 0.0949_{-0.0085}^{+0.0086}, \\ \delta_B^{DK} &= (121.6_{-5.9}^{+5.6})^\circ, \\ r_B^{D\pi} &= 0.0064_{-0.0019}^{+0.0021}, \\ \delta_B^{D\pi} &= (311_{-20}^{+17})^\circ. \end{aligned}$$

- ◆ Novel approach shows $\sim 5\%$ improvement in the statistical precision of γ compared to the binned phase-space analysis
- ◆ Optimising the analysis strategy can enhance the precision of γ with the current data set.
- ◆ Joint BESIII–LHCb publications under preparation.

Mixing and CP violation measurements

- ✓ Search for CP violation in $D^+ \rightarrow \Phi\pi^+$ decays [LHCb-PAPER-2026-011] **NEW**
- ✓ Precision measurement of CP violation and branching fractions in $B^\pm \rightarrow K_S^0 h^\pm$ $h(K, \pi)$ decays and search for the rare decay $B_c^\pm \rightarrow K_S^0 K^\pm$ (submitted to PRL, [[arXiv:2512.09288](https://arxiv.org/abs/2512.09288)])
- ✓ Observation of CP violation in $B^0 \rightarrow J/\psi\rho(770)^0$ decays (Submitted to PRL, [[arxiv:2601.15646](https://arxiv.org/abs/2601.15646)])
- ✓ First measurement of the decay-time integrated CP asymmetry in $B_S^0 \rightarrow D_S^- \pi^+$ decays [[arXiv:2603.1086](https://arxiv.org/abs/2603.1086)]
- ✓ Measurement of CP asymmetries in $\bar{B}^0 \rightarrow D_s^- D^+$ and $\bar{B}_S^0 \rightarrow D_s^+ D^-$ decays

◆ Recent measurements but not covered in this talk (backup)

- ✓ Study of charm mixing and CP violation with $D^0 \rightarrow K^\pm \pi^\mp \pi^\pm \pi^\mp$ decays ([[JHEP12\(2025\)153](https://arxiv.org/abs/2510.04963)], [[arXiv:2510.04963](https://arxiv.org/abs/2510.04963)]) (contribution to gamma combination)
- ✓ Measurement of CP asymmetry in $D^0 \rightarrow K_S^0 K_S^0$ decays with Run 3 data. ([[JHEP02\(2026\)253](https://arxiv.org/abs/2510.14732)], [[arXiv:2510.14732](https://arxiv.org/abs/2510.14732)])
- ✓ Measurement of branching fractions and CP asymmetries in $\Lambda_b^0(\Xi_b^0) \rightarrow p K_S^0 h^-$ decays ([[arxiv:2508.17836](https://arxiv.org/abs/2508.17836)], [[JHEP10\(2025\)169](https://arxiv.org/abs/2508.17836)])



LHCb-PAPER-2025-049

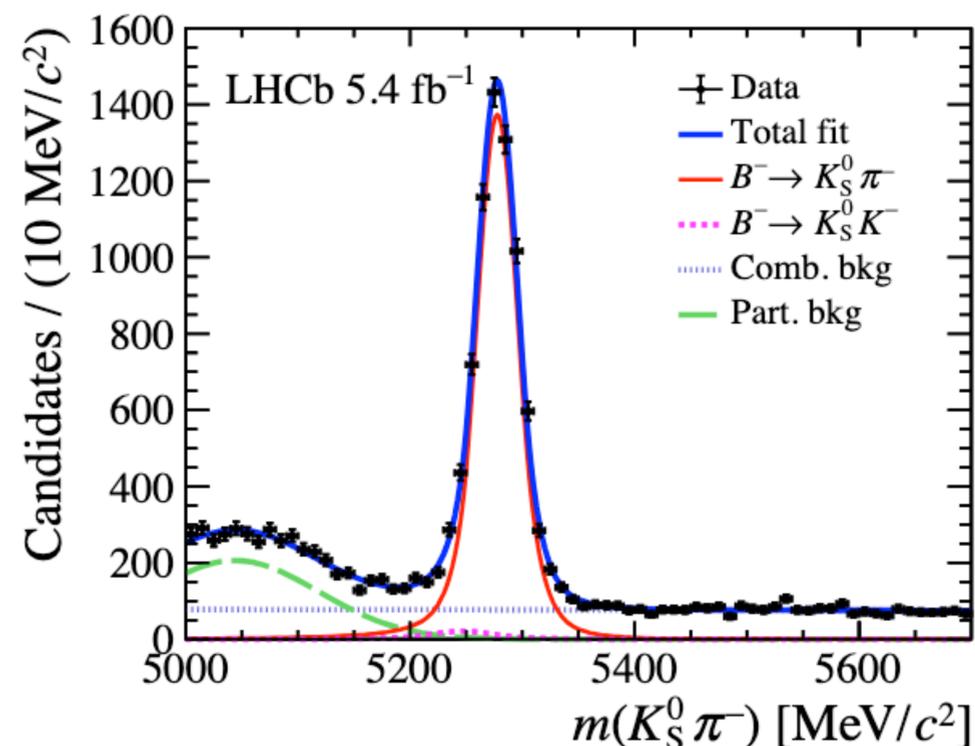
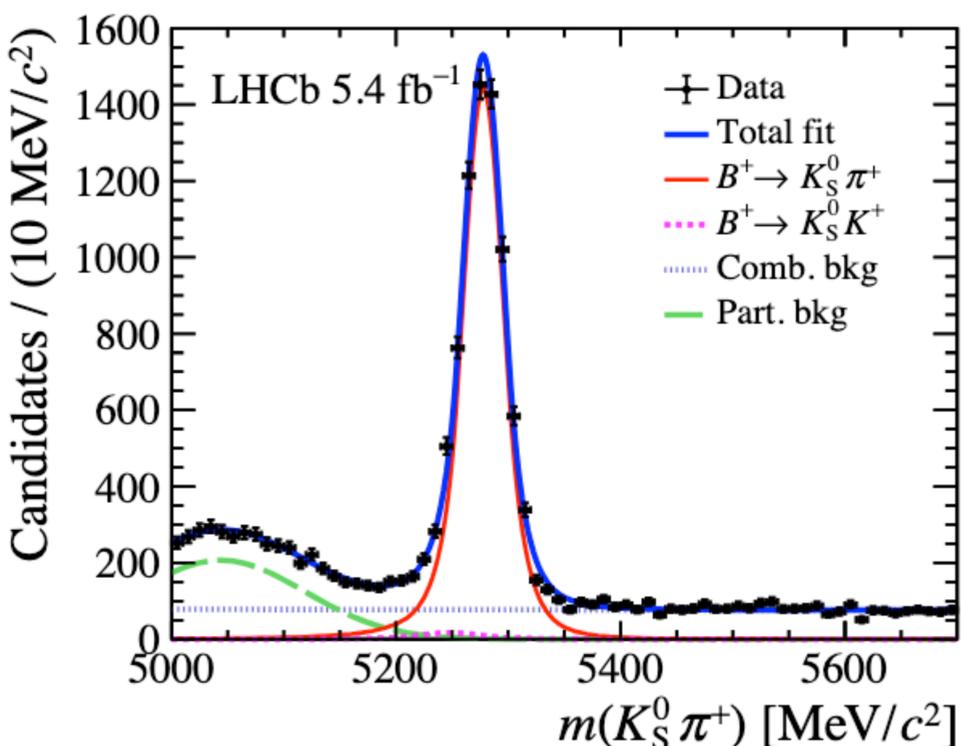
submitted to PRL, [arXiv:2512.09288](https://arxiv.org/abs/2512.09288)

Precision measurement of CP violation and branching fractions in $B^\pm \rightarrow K_S^0 h^\pm$ $h(K, \pi)$ decays and search for the rare decay $B_c^\pm \rightarrow K_S^0 K^\pm$

✓ Analysis performed based pp data collected at $\sqrt{s} = 13\text{TeV}$, corresponding to an integrated luminosity of 5.4 fb^{-1}

Precision measurement of CP violation and branching fractions in $B^\pm \rightarrow K_S^0 h^\pm$ ($h = K, \pi$) decays and search for the rare decay $B_c^\pm \rightarrow K_S^0 K^\pm$

- Primary focus on the measurement of CP violation in $B^+ \rightarrow K^0 \pi^+$ and $B^+ \rightarrow K^0 K^+$ via $b \rightarrow d\bar{d}s$ and $b \rightarrow s\bar{s}d$
- $B^\pm \rightarrow K^0 h^\pm$ testing isospin-sum rule, also with $B^\pm \rightarrow K_S^0 h^\pm$ independent null test of SM
- Dominated by gluonic penguin $b \rightarrow s$ transitions, direct CPV expected to be very small in the SM \rightarrow ($A_{CP} = \mathcal{O}(1\%)$ in $B^\pm \rightarrow K_S^0 K^\pm$)
- Provides a clean reference channel for testing the $B \rightarrow K\pi$ isospin sum rule
- Signal yield extracted via an unbinned extended maximum likelihood-fit to the B^\pm mass
- Control channel $B^+ \rightarrow J/\psi K^+$ used to determine the detection & production asymmetries, cancelling most of nuisance asymmetries



◆ The CP-violating observables determined as:

$$A_{CP}(B^+ \rightarrow K_S^0 \pi^+) = 0.028 \pm 0.009 \pm 0.009$$

$$A_{CP}(B^+ \rightarrow K_S^0 K^+) = 0.118 \pm 0.062 \pm 0.031$$

◆ Most precise determination so far $\sim 2\times$ more precise than the Run 1 measurement.

◆ No significant signal is observed for $B_c^\pm \rightarrow K_S^0 K^\pm$

submitted to PRL, [arXiv:2512.09288](https://arxiv.org/abs/2512.09288)



LHCb-PAPER-2025-059

Submitted to PRL, [arxiv:2601.15646](https://arxiv.org/abs/2601.15646)

Observation of CP violation in $B^0 \rightarrow J/\psi\rho(770)^0$ decays

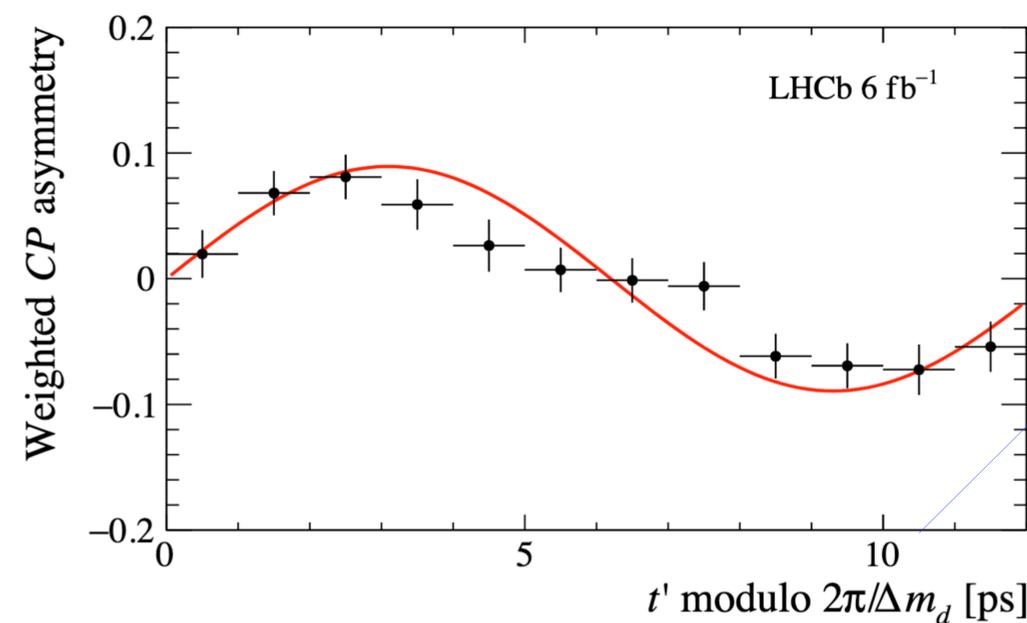
- ✓ The flavour tagged time-dependent CP-asymmetry in $B^0 \rightarrow J/\psi\rho(770)$ decay
- ✓ Based on data collected by the LHCb at $\sqrt{s} = 13\text{TeV}$ Run2 (2015-2018) corresponding to an integrated luminosity of 6 fb^{-1}

Observation of CP violation in $B^0 \rightarrow J/\psi \rho(770)^0$ decays

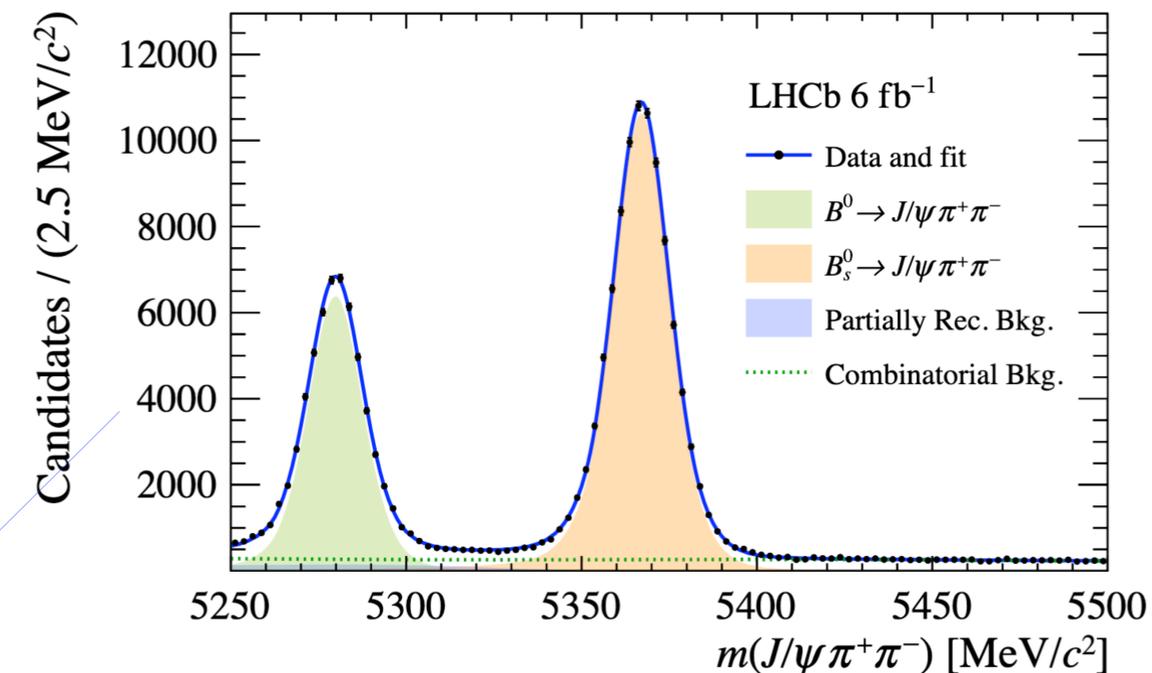
- Proceeds via $b \rightarrow c\bar{c}d$ and is sensitive to the CP-violating phase 2β
- Provides a control of penguin contributions in ϕ_S measurements from $B_S^0 \rightarrow J/\psi\phi$ using SU(3) flavour symmetry

- B^0 momentum required to originate from the closest PV and the mass $\mu^+\mu^-$ constrained to the J/ψ mass

- Combinatorial background described by a 5th-order polynomial.
- Background-subtracted sample used in a multidimensional likelihood fit to the decay time, $m(\pi\pi)$; angular variables $3\times$ helicity angles to extract 2β and λ



- Signal extracted unbinned extended maximum likelihood-fit to the $m(J/\psi\pi^+\pi^-)$



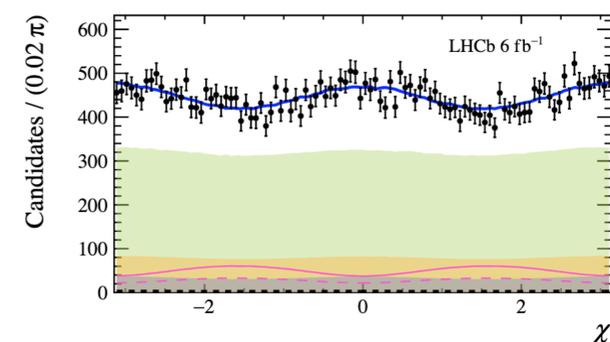
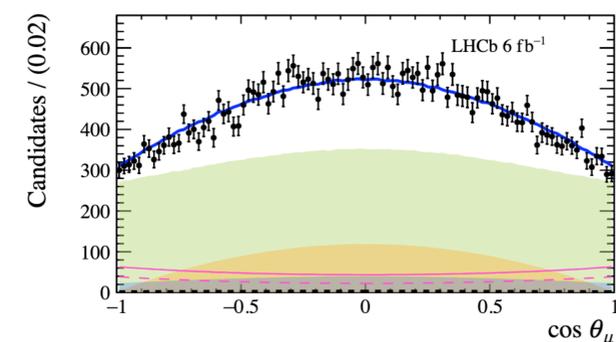
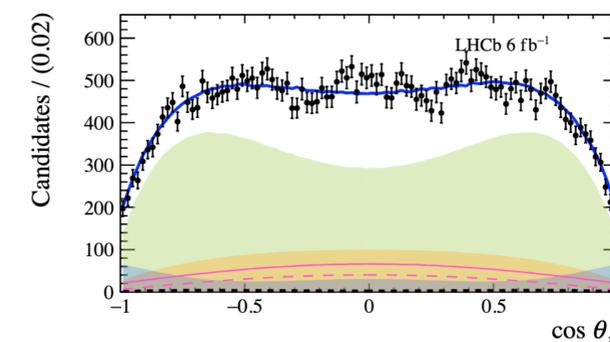
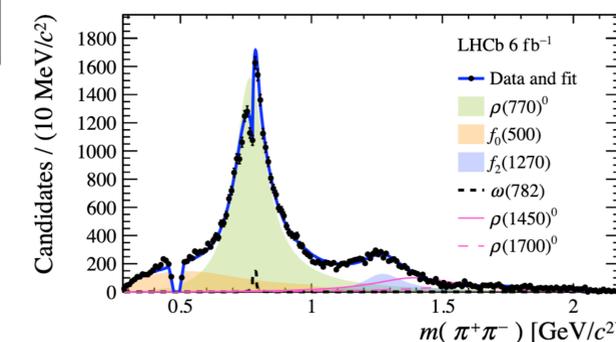
- ♦ First observation of time-dependent CP violation in $b \rightarrow c\bar{c}d$ B-meson to charmonium decays

- ♦ The CP-violating observables determined as:

$$2\beta_{c\bar{c}d}^{eff} = (0.710 \pm 0.084 \pm 0.028)rad \quad |\lambda| = 1.019 \pm 0.034 \pm 0.009$$

- ♦ Consistent with earlier results, with a twofold improvement in precision!

- ♦ The most stringent limit on the penguin contribution: $\Delta\Phi_S = 5.0 \pm 4.2$ mrad



arxiv:2601.15646



LHCb-PAPER-2025-074

[arXiv:2603.1086](https://arxiv.org/abs/2603.1086)

First measurement of the decay-time integrated CP asymmetry in $B_S^0 \rightarrow D_S^- \pi^+$ decays

- ✓ A measurement performed on the flavour-untagged decay-time-integrated CP asymmetry in flavour-specific decay $B_S^0 \rightarrow D_S^- \pi^+$, $\langle A_{untagged}^S \rangle$
- ✓ Analysis based on data collected by the LHCb at $\sqrt{s} = 13\text{TeV}$ Run2 (2016-2018) corresponding to an integrated luminosity of 5.4 fb^{-1}

First measurement of the decay-time integrated CP asymmetry in $B_S^0 \rightarrow D_S^- \pi^+$ decays

- $B_S^0 \rightarrow D_S^* h^+$ ($h = \pi, K$) decays dominated by color-allowed tree level amplitudes, proceed via $b \rightarrow c\bar{u}q$ transitions, with ($q = d, s$)
- Predictions/experimental measurements disagree, could induced direct CP-violation, resulting in a small decay rate asymmetry. ($B_S^0 \rightarrow D_S^- \pi^+$)
- To increase the statistical power untagged time-integrated asymmetry $B_S^0 \rightarrow D_S^- \pi^+$:

$$\langle A_{\text{untagged}}^s \rangle \approx A_{\text{dir}}^s - \frac{a_{\text{fs}}^s}{2} (1 - \rho_s)$$

Where A_{dir}^s can be up to $\mathcal{O}(10^{-2})$ and $\rho_s \approx 0.001$

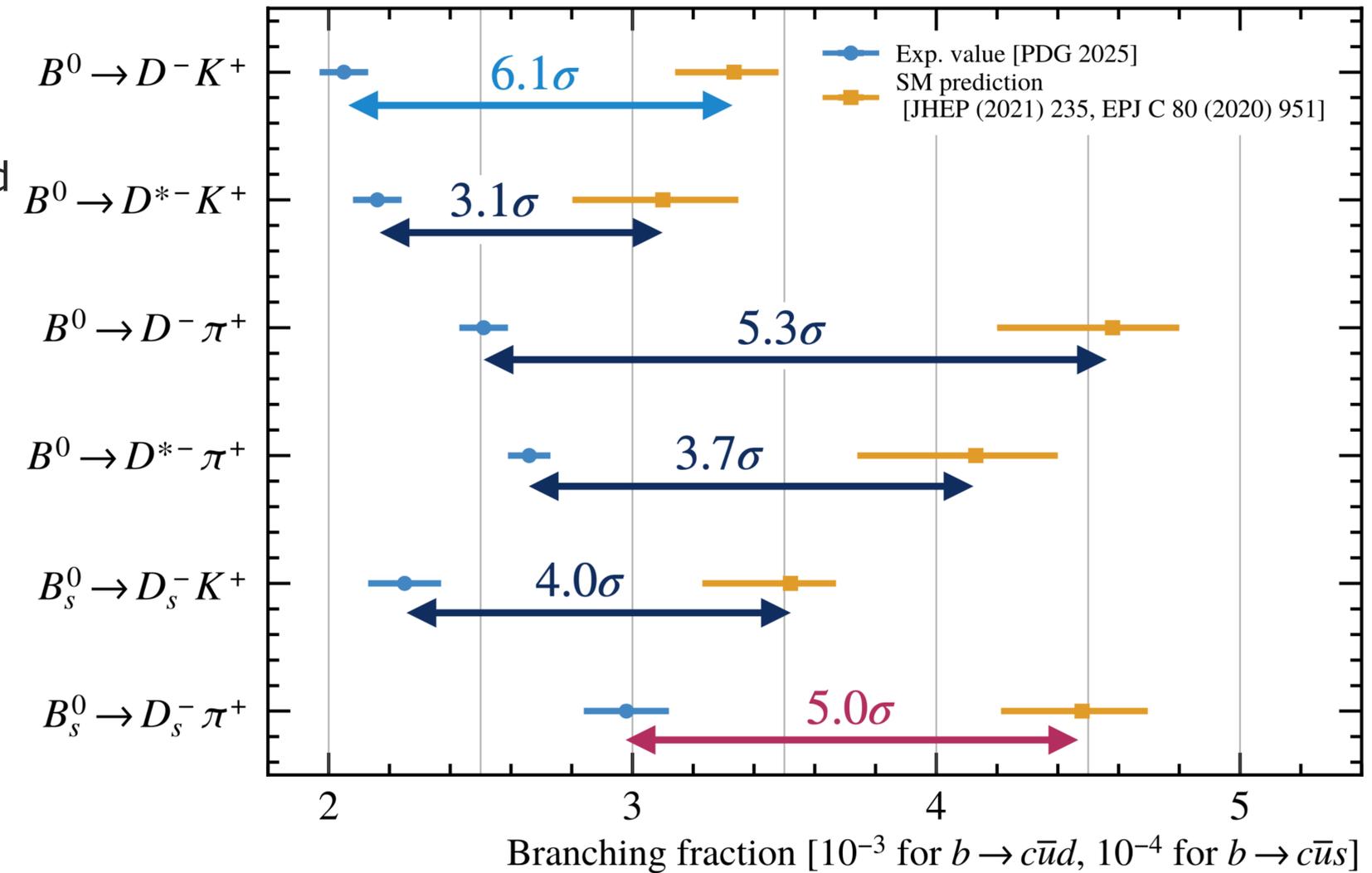
- $\langle A_{\text{untagged}}^s \rangle$ measured across 2016-2018 data

$$\langle A_{\text{untagged}}^s \rangle = A_{\text{raw}} - A_{\text{det.}} - A_{\text{prod.}} \frac{\int_{t=0}^{\infty} e^{-\Gamma_s t} \cos(\Delta M_s t) \epsilon(t) dt}{\int_{t=0}^{\infty} e^{-\Gamma_s t} \cosh\left(\frac{\Delta \Gamma_s t}{2}\right) \epsilon(t) dt}$$

$$A_{\text{raw}} = \frac{N(D_s^+ \pi^-) - N(D_s^- \pi^+)}{N(D_s^+ \pi^-) + N(D_s^- \pi^+)}$$

$$A_{\text{det.}} = A_{\text{det.}}^{\text{sel.}} + A_{\text{det.}}^{\text{LO}} + A_{\text{det.}}^{\text{PID}} + A_{\text{det.}}^{\text{track}}$$

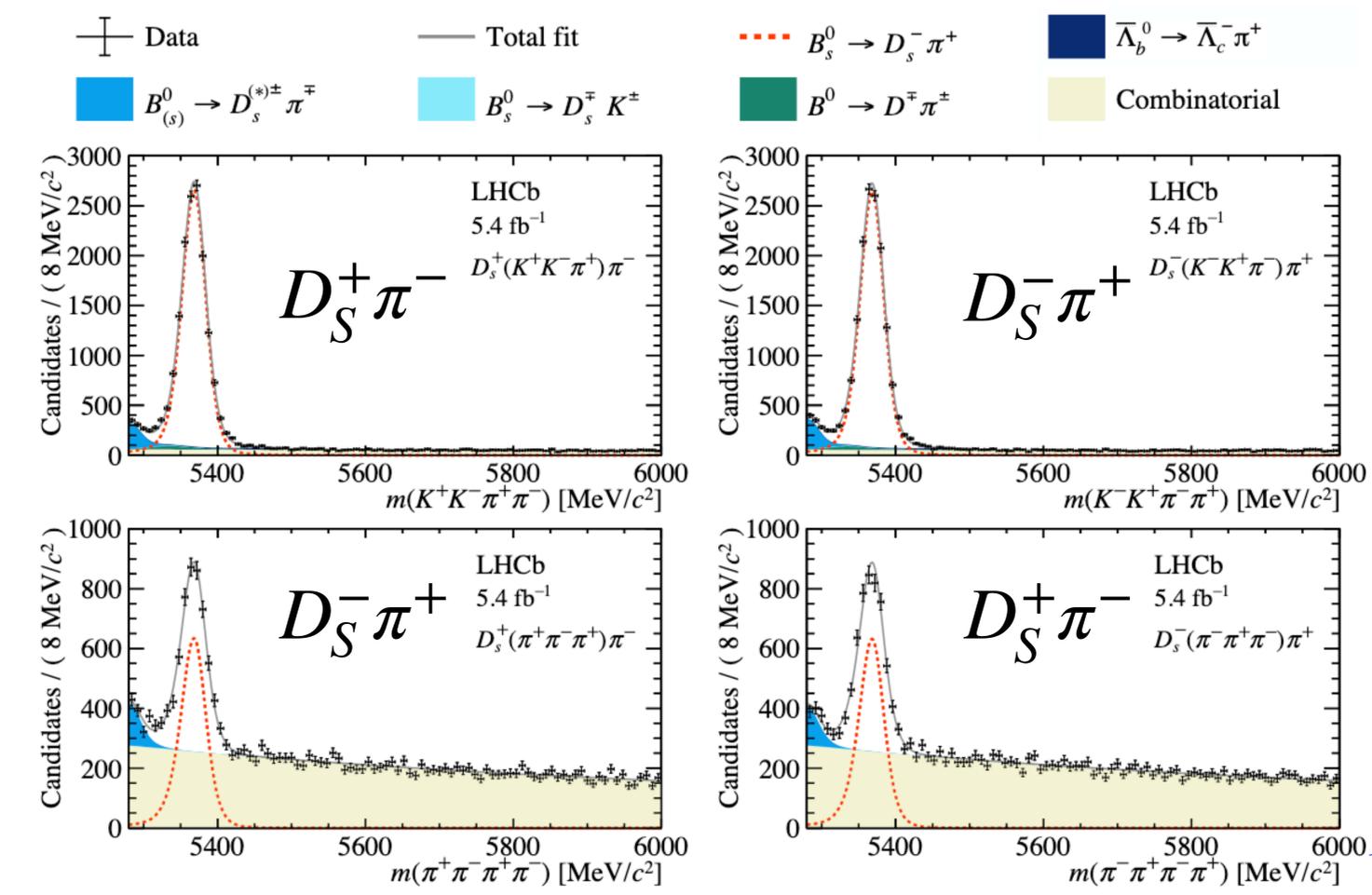
Washed out by $B^0 - \bar{B}^0$ mixing up to $\mathcal{O}(10^{-4})$



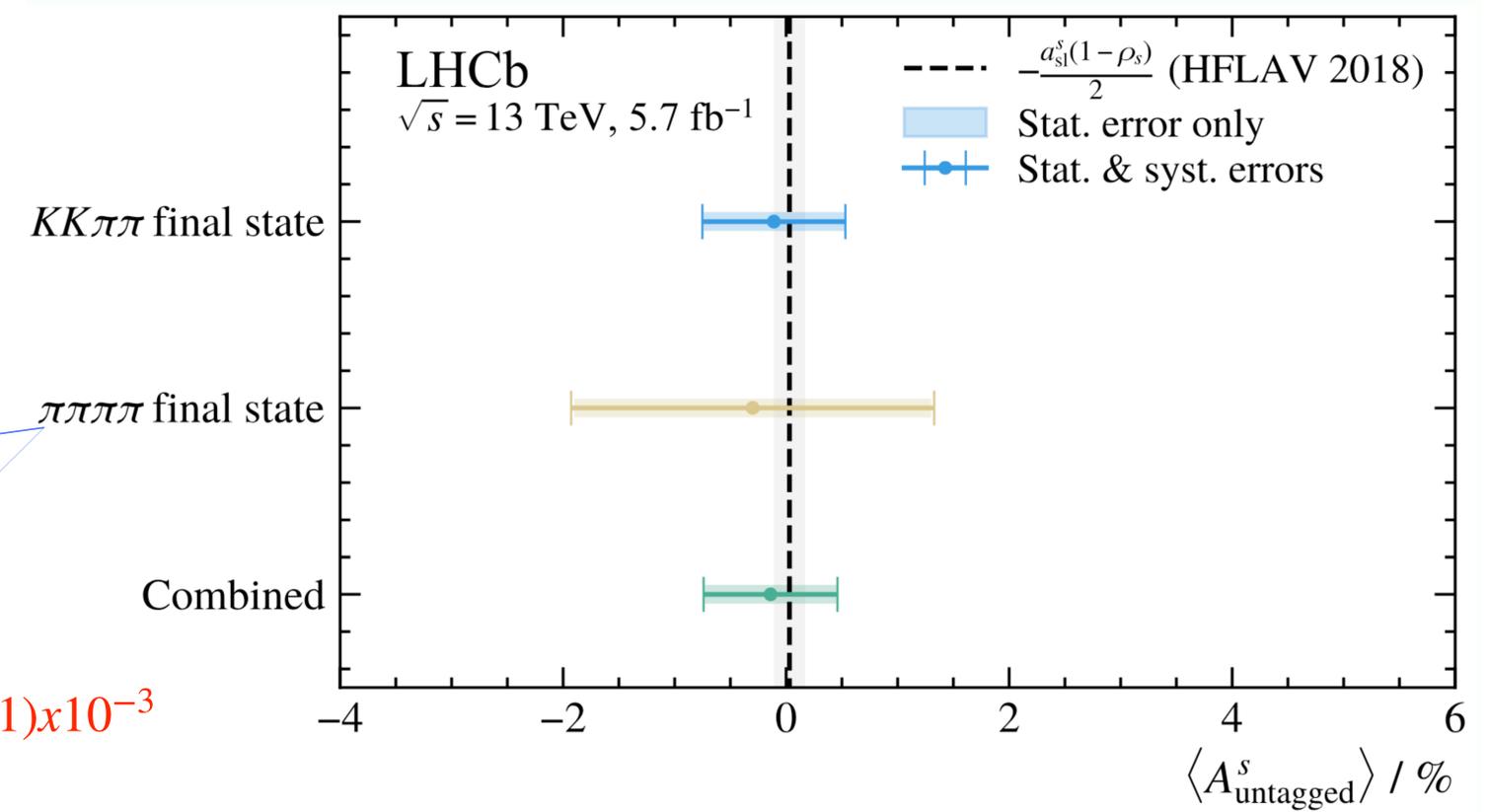
arXiv:2603.10860

First measurement of the decay-time integrated CP asymmetry in $B_S^0 \rightarrow D_S^- \pi^+$ decays

- First measurement performed on the flavour-untagged decay-time-integrated CP asymmetry in flavour-specific decay $B_S^0 \rightarrow D_S^- \pi^+$, $\langle A_{untagged}^S \rangle$: two D_S^- modes: $D_S^- \rightarrow K^- K^+ \pi^-$ and $D_S^- \rightarrow \pi^- \pi^+ \pi^-$



- Maximum likelihood fit to $m(hh\pi\pi)$ determine A_{raw} for each mode
- Contributions to determine A_{det} : hardware trigger and PID provide larger contribution and minor contributions from software trigger, etc.



[arXiv/2603.1086](https://arxiv.org/abs/2603.1086)

- ◆ First time measured this asymmetry : $\langle A_{untagged}^S \rangle = (-1.4 \pm 5.9 \pm 1.1) \times 10^{-3}$
- ◆ In agreement with SM expectations, no evidence for direct CPV
- ◆ Currently statistics-limited \rightarrow expected to reach per-mille precision in Run 3

[arXiv:2603.1086](https://arxiv.org/abs/2603.1086)

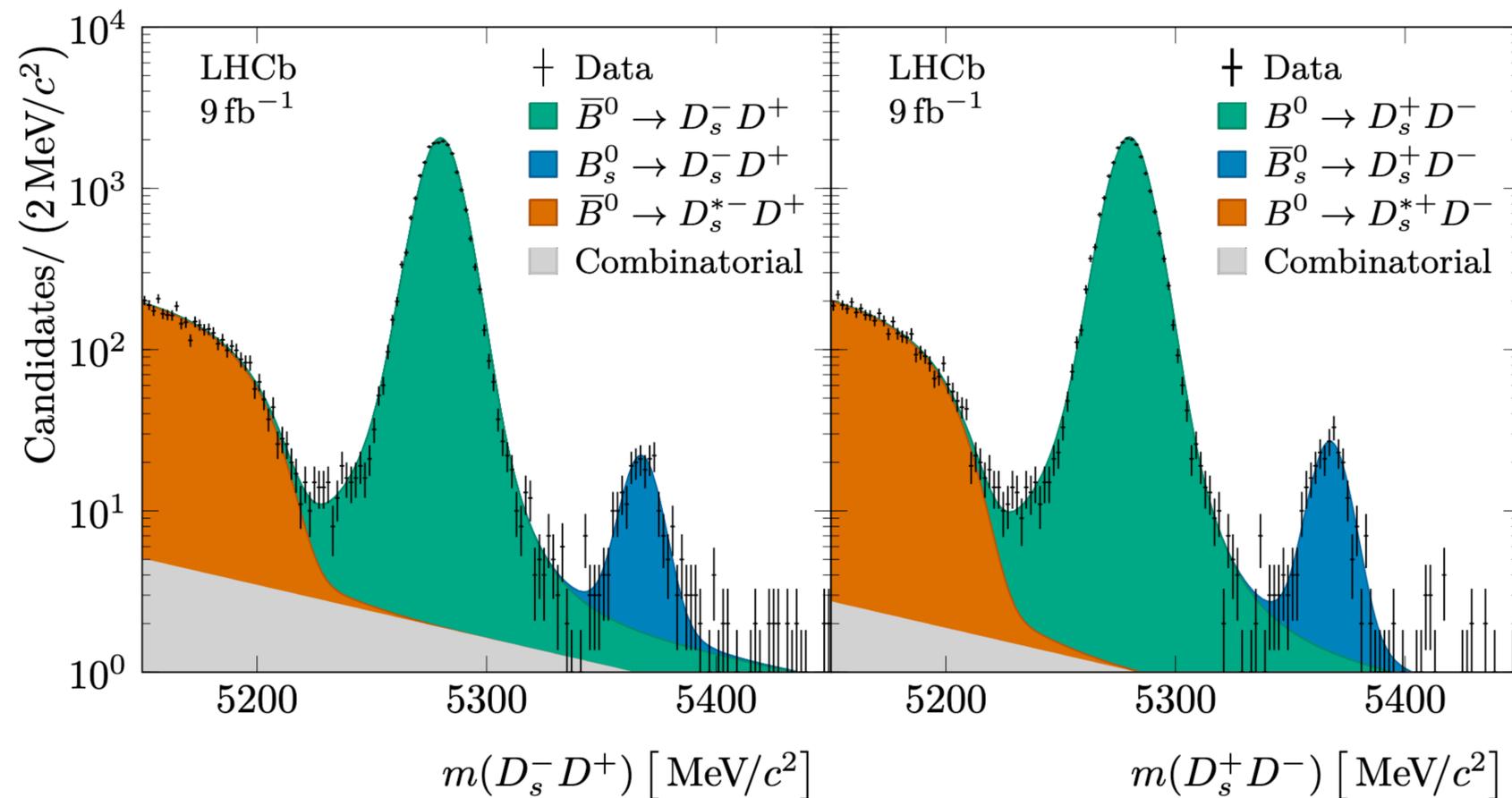


Measurement of CP asymmetries in $\bar{B}^0 \rightarrow D_s^- D^+$ and $\bar{B}_S^0 \rightarrow D_s^+ D^-$ decays

- ✓ Analysis based on data samples Run1&2 corresponding to an integrated luminosity of $9fb^{-1}$ of pp collision at center-of-mass energy $\sqrt{s} = 7,8$ and 13 TeV

Measurement of CP asymmetries in $\bar{B}^0 \rightarrow D_s^- D^+$ and $\bar{B}_S^0 \rightarrow D_S^+ D^-$

- The measurement of $\bar{B}^0 \rightarrow D_s^\pm D^\mp$ decays proceed through $b \rightarrow c\bar{c}s$ and $b \rightarrow c\bar{c}d$



- Similar strategy : $\langle A_{untagged}^S \rangle$ analysis

A_{raw} : extracted from maximum likelihood fit

A_{det} : determined using data-driven techniques

A_{prod} : evaluated from production cross-sections for different neutral B-meson flavours : 0.0013 ± 0.0015

$$A_{CP}(\bar{B}_S^0 \rightarrow D_S^+ D^-) = 0.1029 \pm 0.0534 \pm 0.0099$$

$$A_{CP}(\bar{B}^0 \rightarrow D_S^- D^+) = 0.0007 \pm 0.0053 \pm 0.0041$$

- First time measured this asymmetry in \bar{B}_S^0 decays; most precise \bar{B}^0 result to date
- No CP violation observed
- Significantly improves the measurement precision of \bar{B}^0 relative to Belle ($\sim 4\times$)
- Hardware trigger removal in Run 3 boosts fully hadronic performance

**NEW**

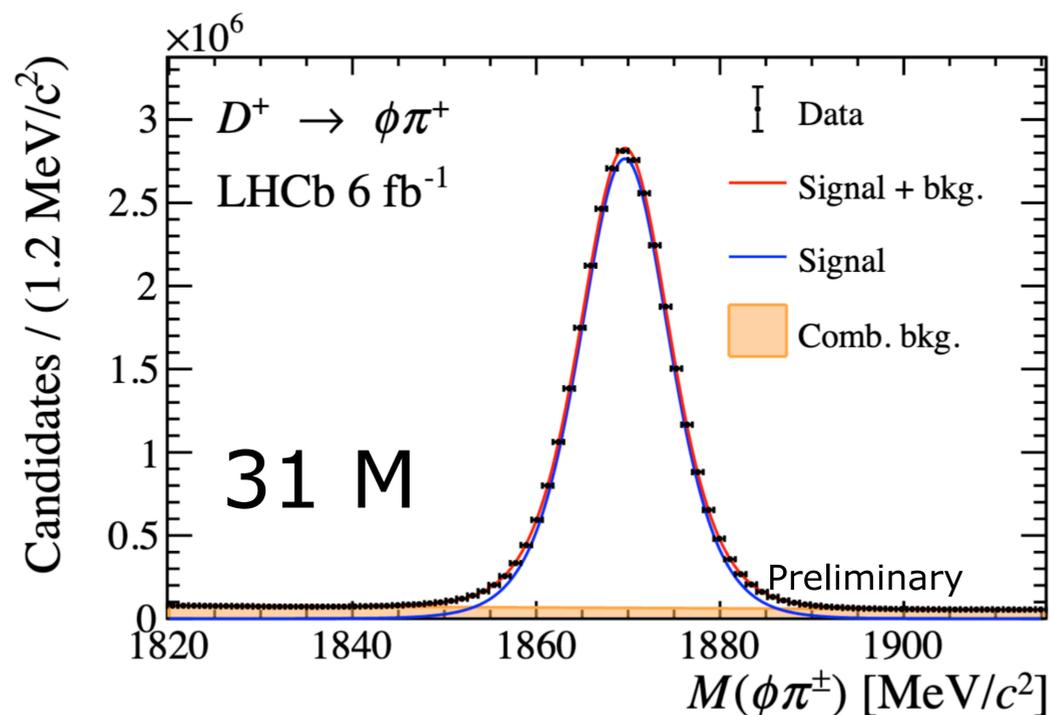
Search for CP violation in $D^+ \rightarrow \phi\pi^+$ decays

- ✓ A measurement of the direct CP asymmetry in the $D^+ \rightarrow \phi\pi^+$ performed.
- ✓ Analysis based on data samples Run2 (2015-2018) corresponding to an integrated luminosity of $6fb^{-1}$ of pp collision at center-of-mass energy $\sqrt{s} = 13$ TeV

Search for CP violation in $D^+ \rightarrow \phi\pi^+$ decays

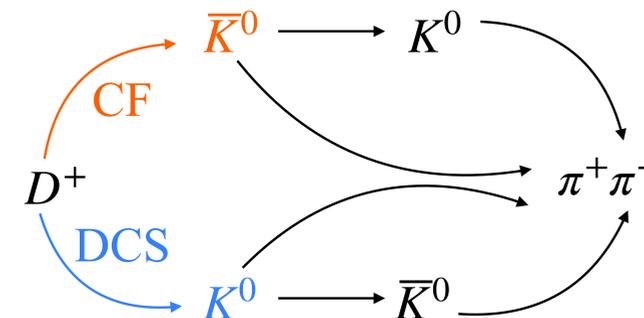
NEW

- $D^+ \rightarrow \phi\pi^+$ decay is governed by a singly Cabibbo-suppressed transition
- Superseding of previous LHCb measurement: $A_{CP}(D^+ \rightarrow \phi\pi^+) = (0.5 \pm 4.2 \text{ (stat.)} \pm 2.9 \text{ (syst.)}) \times 10^{-4}$ [PRL 122 \(2019\) 19, 191803](#)
 - performed with a partial LHCb Run 2 dataset (2015-2017) $\rightarrow 3.8 \text{ fb}^{-1}$
 - used $D^+ \rightarrow K_S^0\pi^+$ decays to cancel production and detection asymmetries [employed only $K_S^0(\text{LL})$ decayed within the VELO]



- $A_{CP}(D^+ \rightarrow \phi\pi^+)$ using the full Run 2 dataset (2015-2018) $\rightarrow 6 \text{ fb}^{-1}$
- $D^+ \rightarrow K_S^0\pi^+$ decays include $K_S^0(\text{DD})$ decayed **downstream** of the vertex detector. **First time ever in a high precision measurement**
- Neutral kaon asymmetry model highly improved, even at higher decay times.
- Account for interference between DCS $D^+ \rightarrow K^0\pi^+$ and CF $D^+ \rightarrow \bar{K}^0\pi^+$ decays, regulated by strong parameters r_π and δ_π .

$$r_\pi e^{i(\delta_\pi + \varphi)} \equiv \frac{\mathcal{A}(D^+ \rightarrow K^0\pi^+)}{\mathcal{A}(D^+ \rightarrow \bar{K}^0\pi^+)}$$



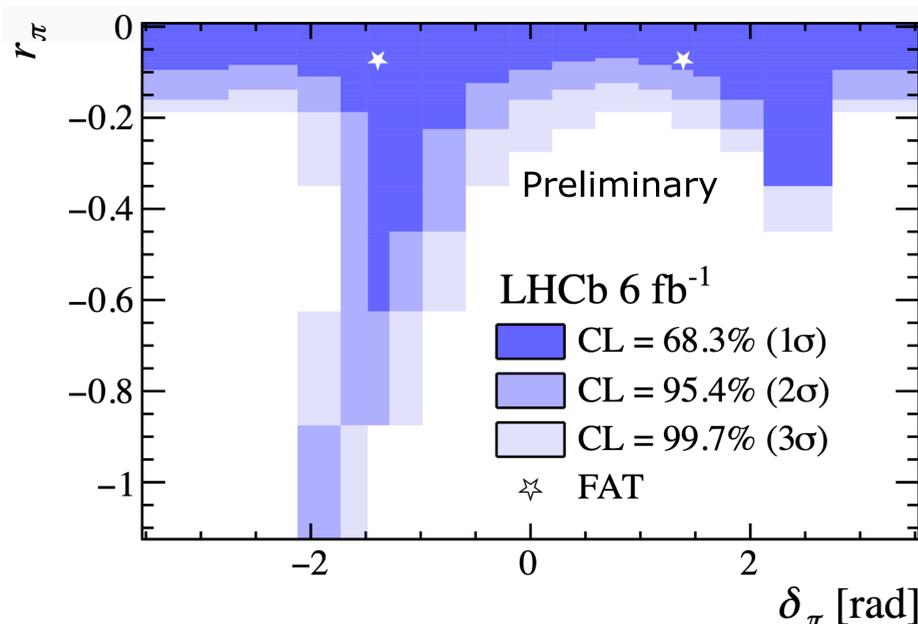
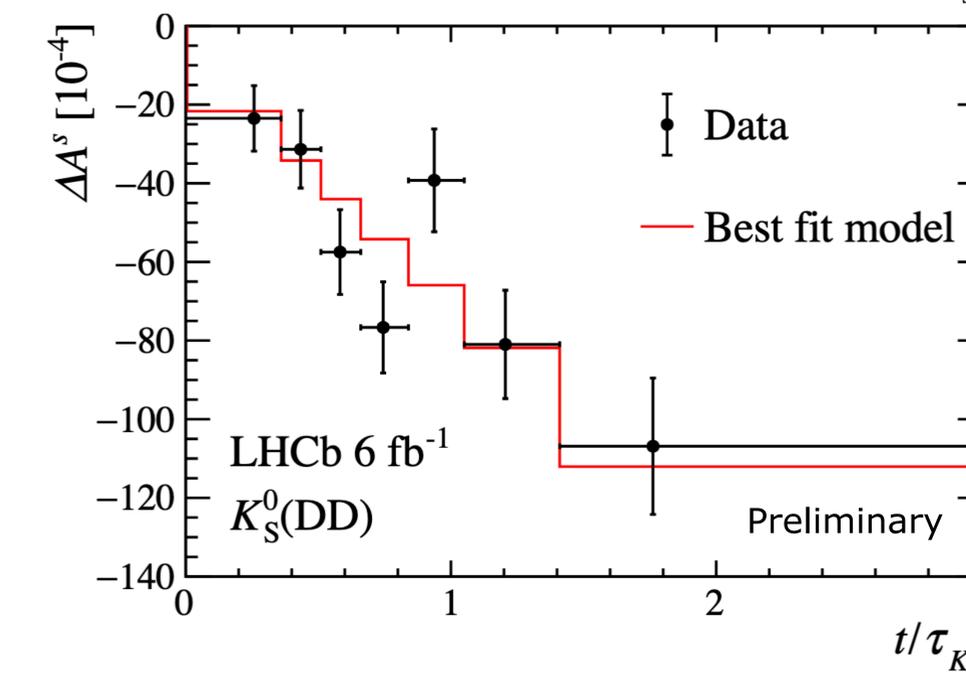
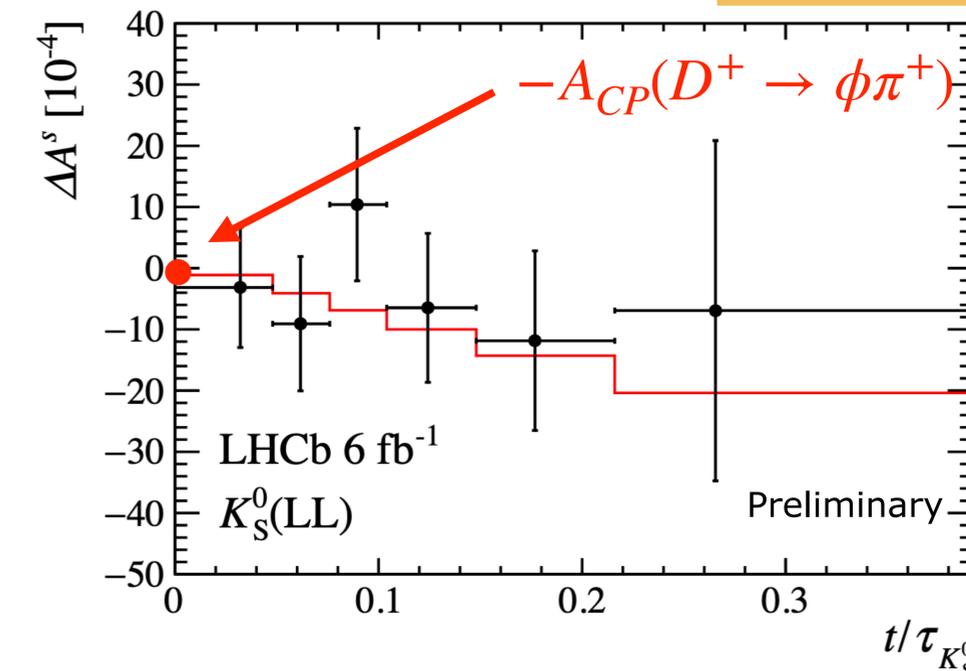
FAT prediction [1]
 $r_\pi = (-0.073 \pm 0.004)$
 $\delta_\pi = \pm (1.39 \pm 0.05)$

[1] Factorisation-Assisted Topological amplitudes [PRL 119, 181802](#)

- Also include contribution from “Incoherent regeneration” [[Charpak et al. \(1966\)](#)]. [checked to be negligible in asymmetry measurements] (this contribution might become dominant in certain cases—specifically regarding thin regenerators like the VELO layers.)

- Analysis strategy: time-dependent analysis in bins of K_S^0 decay time
 - $\Delta A_s \equiv A_{raw}^s(D^+ \rightarrow K_S^0\pi^+) - A_{raw}^s(D^+ \rightarrow \phi\pi^+)$, with s labelling the K_S^0 decay-time bin
 - Equalise the 3D momentum distributions of signal and control channels to cancel production and detection asymmetries
 - Raw asymmetries from simultaneous fit to D^+ and D^- mass peaks
 - Model: $\Delta \tilde{A}_s = \tilde{A}_D^s(K_S^0; r_\pi, \delta_\pi) - A_{CP}(D^+ \rightarrow \phi\pi^+)$
 - $A_{CP}(D^+ \rightarrow \phi\pi^+)$ from a fit to ΔA_s , optimizing r_π and δ_π on data (*Profile Likelihood*)

$$A_{CP}(D^+ \rightarrow \phi\pi^+) = (0.1 \pm 4.9 \text{ (stat)} \pm 1.9 \text{ (syst)}) \times 10^{-4}$$



- ◆ No CP violation observed
- ◆ Agreement with earlier LHCb result at 0.67σ .
- ◆ **First measurement (confidence intervals) of strong parameters r_π and δ_π :**
- ◆ Inclusion of DCS/CF interference in the model and extraction of (r, δ) from data crucial to perform charm CPV measurements in Run 3 and beyond ($A_{CP}(KK)$ etc.)

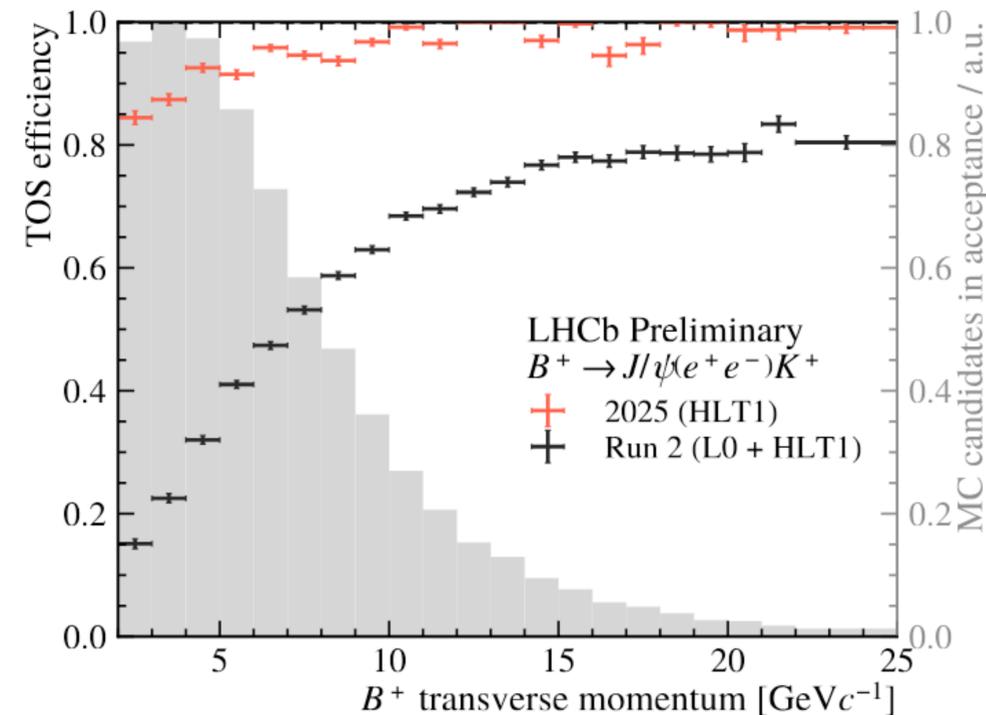
✓ A large number of precision results have been obtained in CKM and CPV measurements using the Run 1–2 dataset (9fb^{-1}) and more on the way with Run3 data (~ 2.5 larger dataset than Run 1+2)

✓ **Numerous first observations and improved precision results from Run1&2** : CPV in $D^+ \rightarrow \phi\pi^+$, $\bar{B}^0 \rightarrow D_s^\pm D^\mp$, $B_S^0 \rightarrow D_S^\mp \pi^+$, γ in $B^\pm \rightarrow D(\rightarrow K_S^0 h^+ h^-)h^\pm$

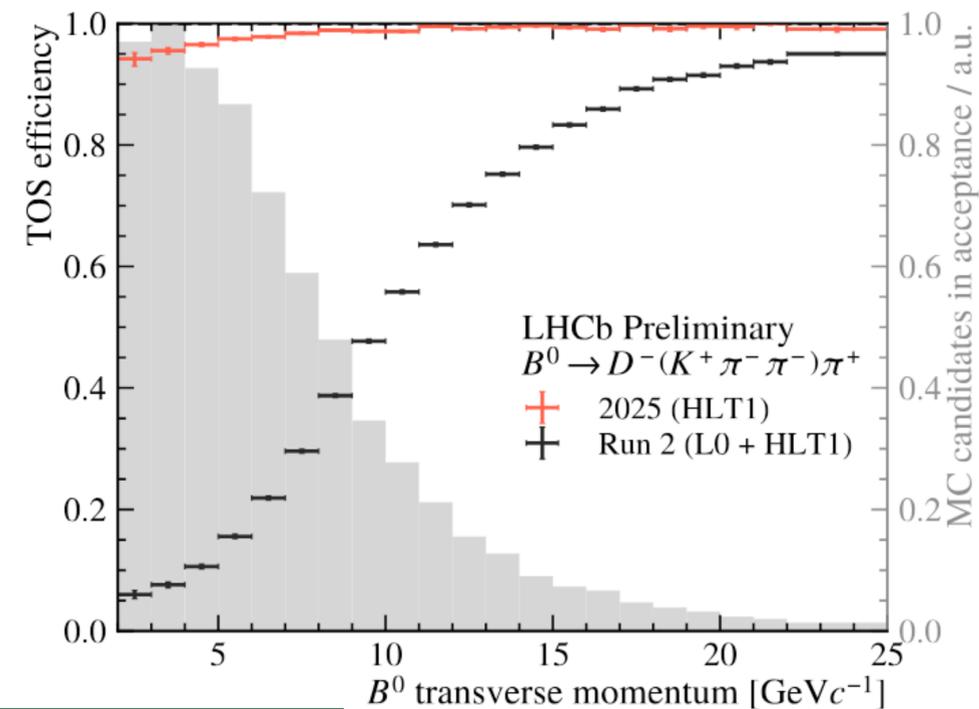
✓ **First γ measurement shown with Run3 data** : $B^\pm \rightarrow Dh^\pm$ ($h = K, \pi$) **with** $D \rightarrow K_S^0 \pi^+ \pi^-$, $D \rightarrow K_S^0 K^+ K^-$

✓ Higher efficiency with a fully software-based trigger in Run3

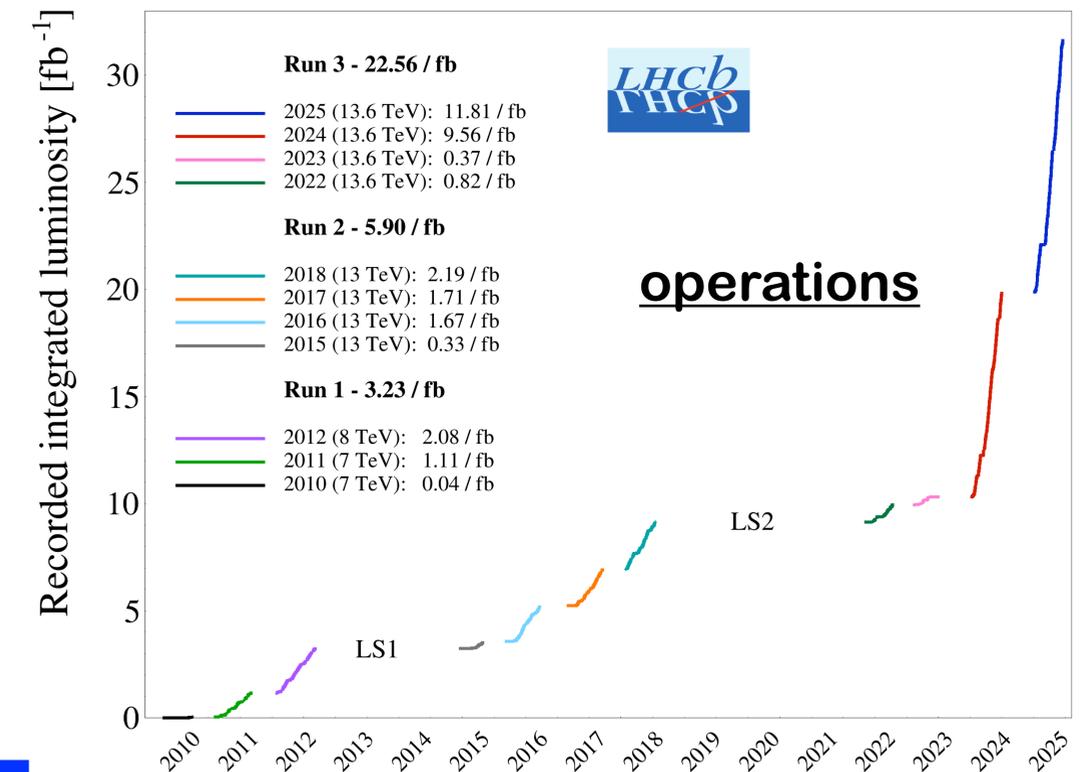
✓ **With Run 3 still in progress, increasing statistics will enhance measurement precision and future analyses**



LHCb-FIGURE-2025-015



Total recorded luminosity – pp – 31.7 fb^{-1}

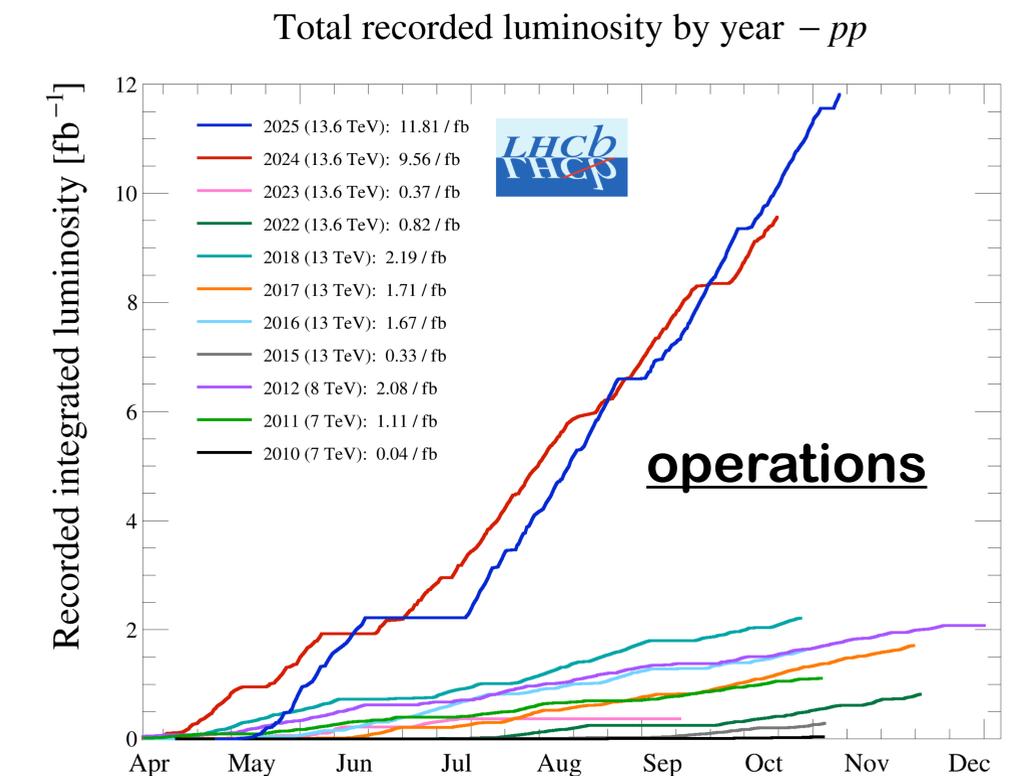
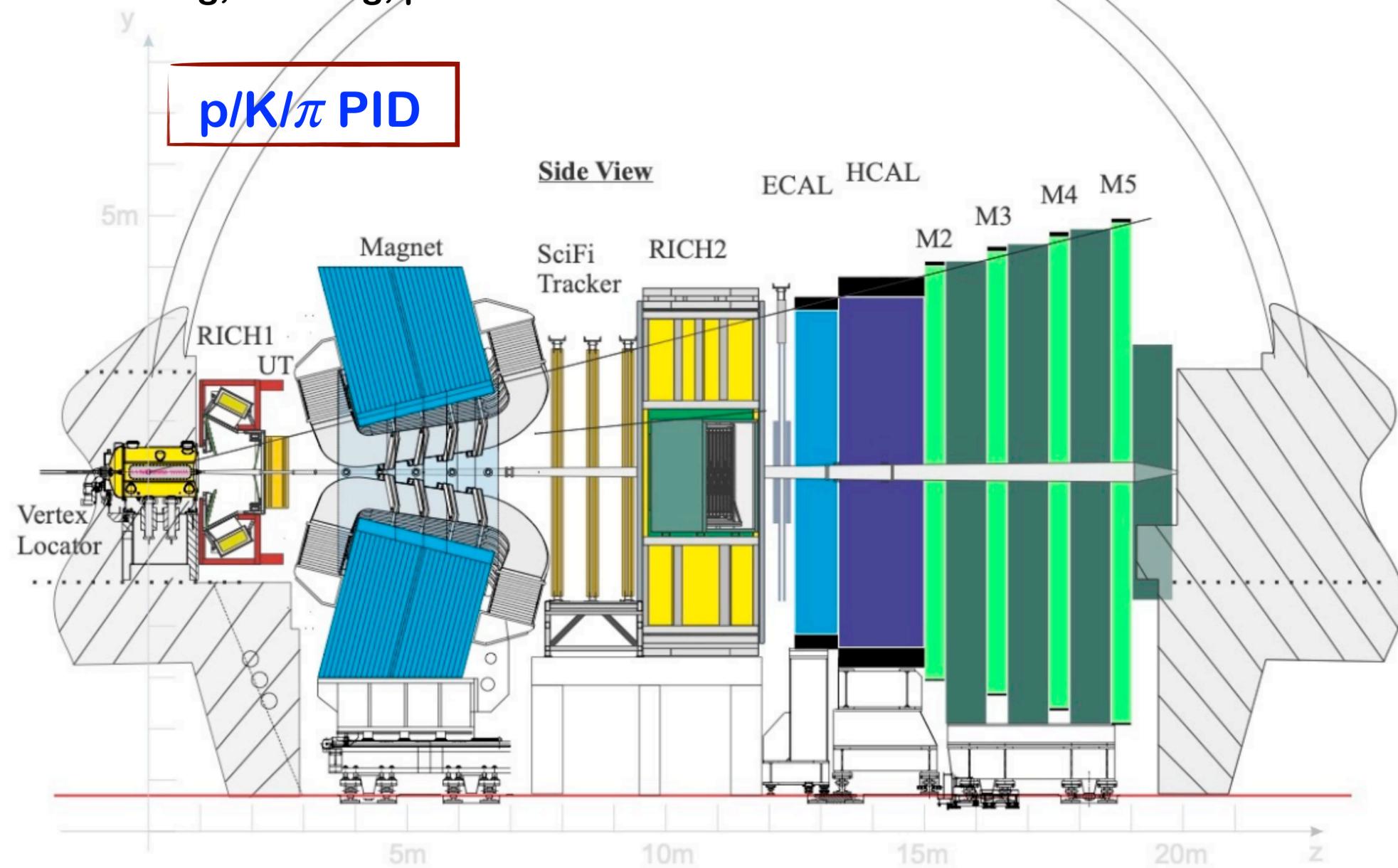


Thank you for your attention !

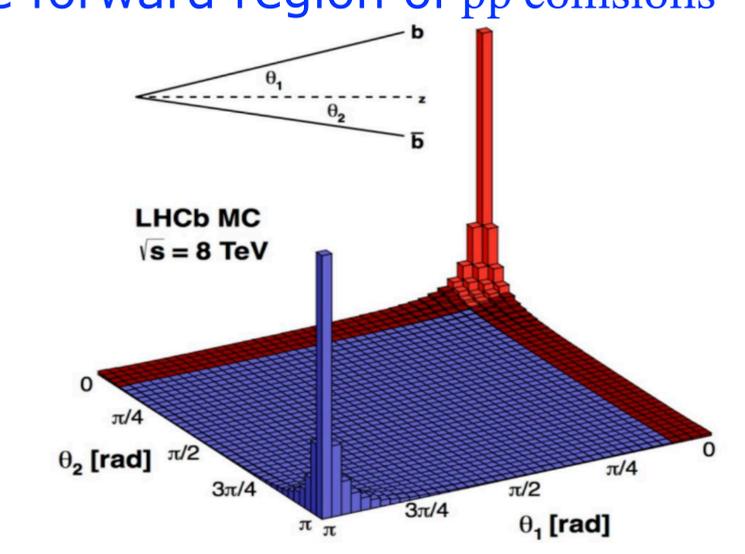
BACKUP

LHCb: Large Hadron Collider Beauty Experiment

- Precision measurements of particles containing b & c quarks mainly produced in the forward direction at LHC
- A single-arm forward spectrometer covering the pseudo-rapidity range $2 < \eta < 5$
- Precise vertexing, tracking, particle identification and the reconstruction

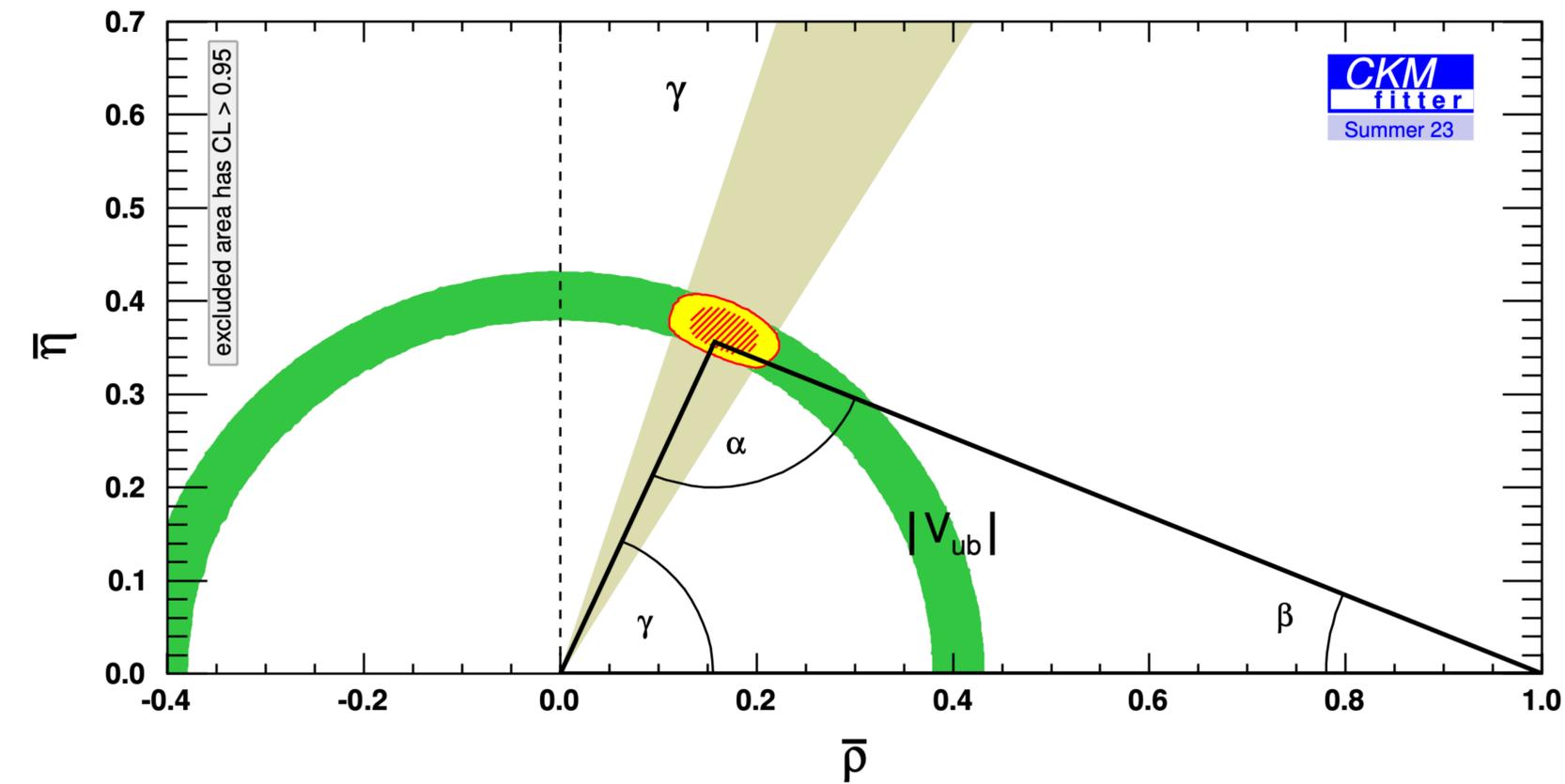


♦ bb^- pairs are predominantly produced in the forward region of pp collisions



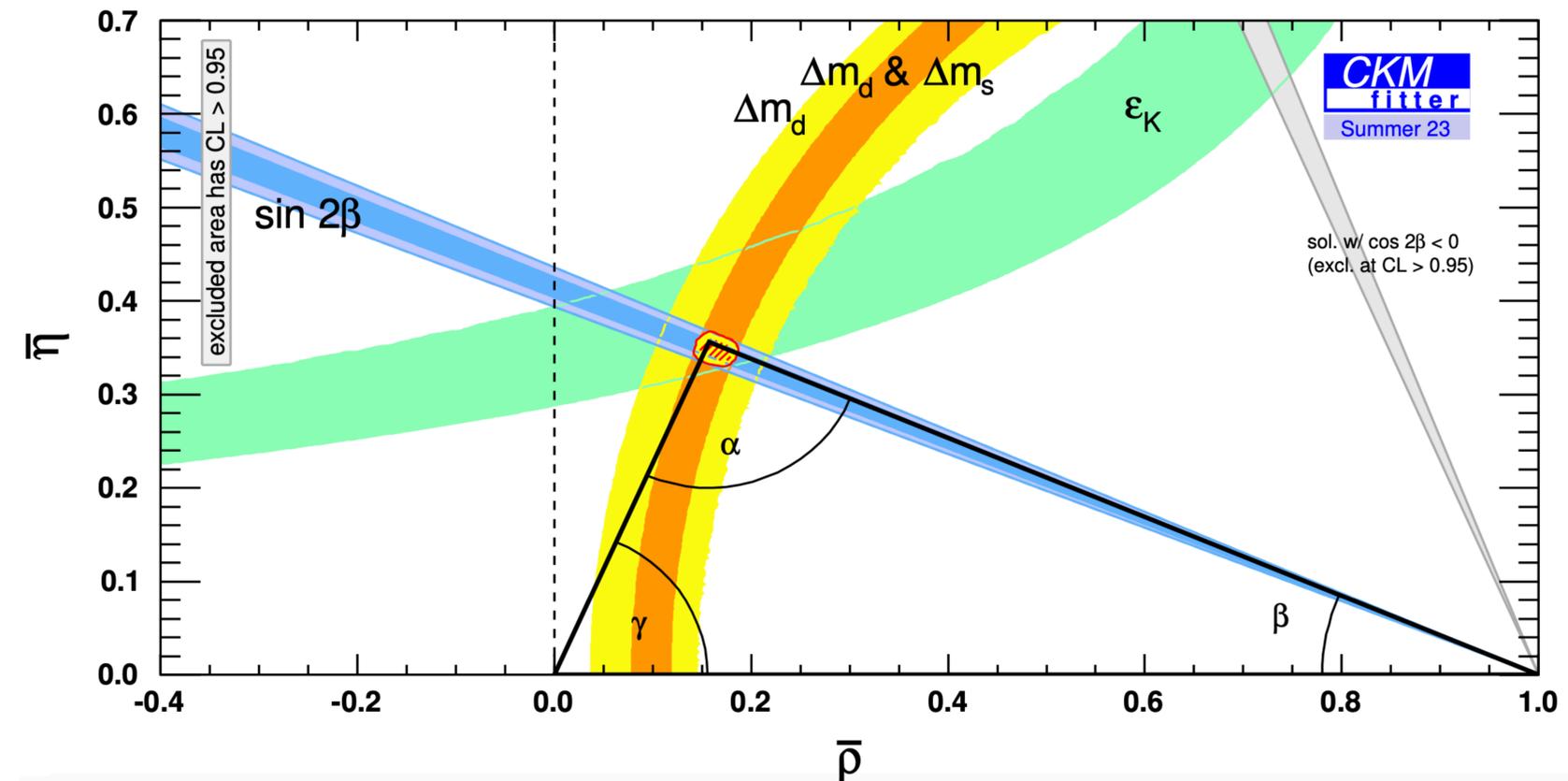
Physics motivation : Unitarity triangle

- Discrepancy between these will indicate "New Physics"
- Many different channels used to measure the angles and sides of the triangle



**Direct measurements
(Pure SM like)**

$$\gamma_{direct} = (66.4^{+2.8}_{-3.0})$$



**Indirect measurements
(Possible sensitivity to NP)**

$$\gamma_{indirect} = (66.3^{+0.72}_{-1.86})$$

→ Inputs from beauty sector

B decay	D decay	Ref.	Dataset	Status since Ref. [16]
$B^\pm \rightarrow Dh^\pm$	$D \rightarrow h^\pm h'^\mp$	[29]	Run 1&2	<i>As before</i>
$B^\pm \rightarrow Dh^\pm$	$D \rightarrow h^+ h^- \pi^+ \pi^-$	[30]	Run 1&2	<i>As before</i>
$B^\pm \rightarrow Dh^\pm$	$D \rightarrow h^+ h^- \pi^+ \pi^-$	[20]	Run 1&2	New
$B^\pm \rightarrow Dh^\pm$	$D \rightarrow K^\pm \pi^\mp \pi^+ \pi^-$	[24]	Run 1&2	<i>As before</i>
$B^\pm \rightarrow Dh^\pm$	$D \rightarrow h^\pm h'^\mp \pi^0$	[31]	Run 1&2	<i>As before</i>
$B^\pm \rightarrow Dh^\pm$	$D \rightarrow K_S^0 h^+ h^-$	[32]	Run 1&2	<i>As before</i>
$B^\pm \rightarrow Dh^\pm$	$D \rightarrow K_S^0 K^\pm \pi^\mp$	[33]	Run 1&2	<i>As before</i>
$B^\pm \rightarrow D^* h^\pm$	$D \rightarrow h^\pm h'^\mp$ (PR)	[29]	Run 1&2	<i>As before</i>
$B^\pm \rightarrow D^* h^\pm$	$D \rightarrow K_S^0 h^+ h^-$ (PR)	[34]	Run 1&2	<i>As before</i>
$B^\pm \rightarrow D^* h^\pm$	$D \rightarrow K_S^0 h^+ h^-$ (FR)	[35]	Run 1&2	<i>As before</i>
$B^\pm \rightarrow DK^{*\pm}$	$D \rightarrow h^\pm h'^\mp$	[36]	Run 1&2	<i>As before</i>
$B^\pm \rightarrow DK^{*\pm}$	$D \rightarrow h^\pm \pi^\mp \pi^+ \pi^-$	[36]	Run 1&2	<i>As before</i>
$B^\pm \rightarrow DK^{*\pm}$	$D \rightarrow K_S^0 h^+ h^-$	[36]	Run 1&2	<i>As before</i>
$B^\pm \rightarrow Dh^\pm \pi^+ \pi^-$	$D \rightarrow h^\pm h'^\mp$	[37]	Run 1	<i>As before</i>
$B^0 \rightarrow DK^{*0}$	$D \rightarrow h^\pm h'^\mp$	[38]	Run 1&2	<i>As before</i>
$B^0 \rightarrow DK^{*0}$	$D \rightarrow h^\pm \pi^\mp \pi^+ \pi^-$	[38]	Run 1&2	<i>As before</i>
$B^0 \rightarrow DK^{*0}$	$D \rightarrow K_S^0 h^+ h^-$	[39]	Run 1&2	<i>As before</i>
$B^0 \rightarrow D^\mp \pi^\pm$	$D^+ \rightarrow K^- \pi^+ \pi^+$	[40]	Run 1	<i>As before</i>
$B_s^0 \rightarrow D_s^\mp K^\pm$	$D_s^+ \rightarrow h^+ h^- \pi^+$	[41, 42]	Run 1&2	<i>As before</i>
$B_s^0 \rightarrow D_s^\mp K^\pm \pi^+ \pi^-$	$D_s^+ \rightarrow h^+ h^- \pi^+$	[43]	Run 1&2	<i>As before</i>

- Combination of measurements sensitive to CKM angle γ
- 235 observables to determine 64 free parameters with all frequentist treatment
- External inputs from BESIII and CLEO Collaborations

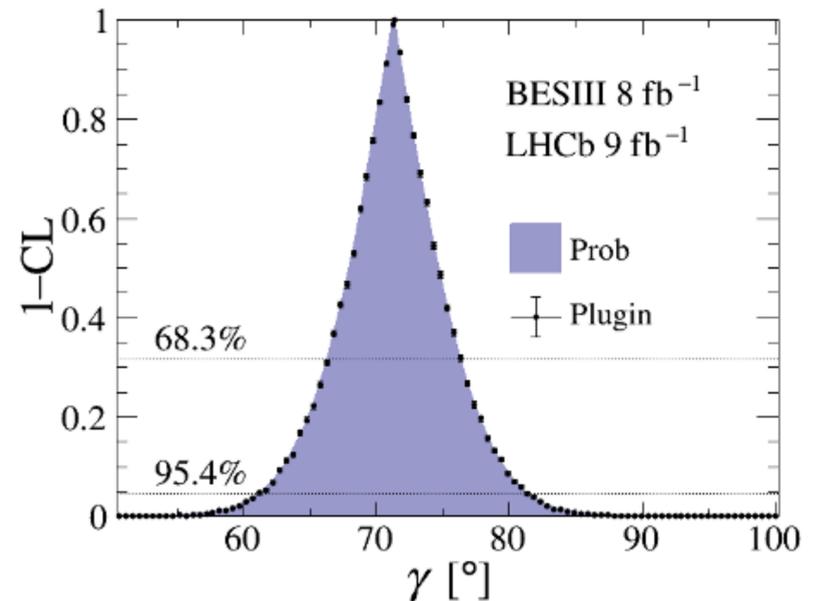
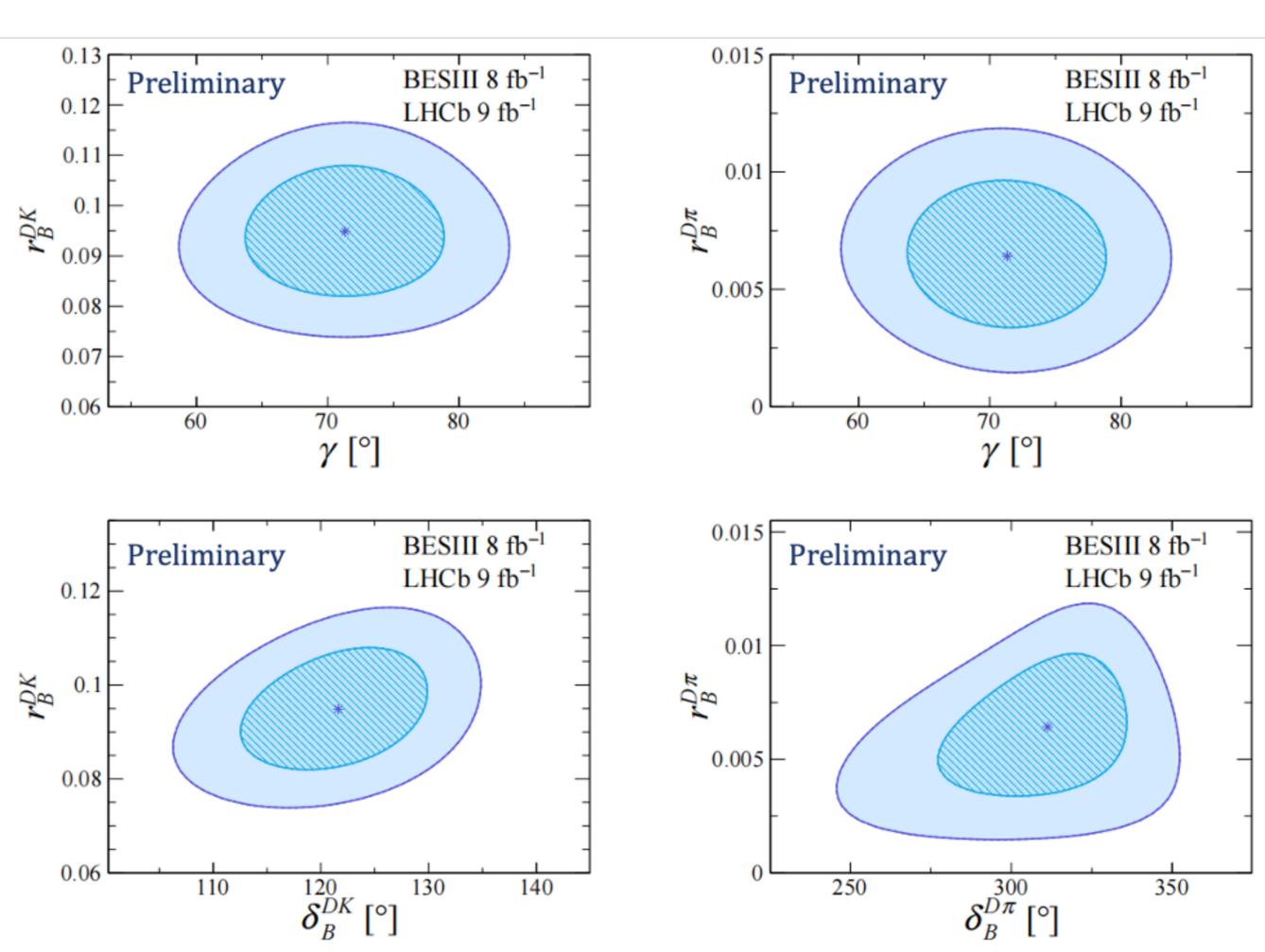
→ Inputs from charm sector

D decay	Observable(s)	Ref.	Dataset	Status since Ref. [16]
$D^0 \rightarrow h^+ h^-$	ΔA_{CP}	[44–46]	Run 1&2	<i>As before</i>
$D^0 \rightarrow K^+ K^-$	$A_{CP}(K^+ K^-)$	[46–48]	Run 2	<i>As before</i>
$D^0 \rightarrow h^+ h^-$	$y_{CP} - y_{CP}^{K^- \pi^+}$	[49, 50]	Run 1&2	<i>As before</i>
$D^0 \rightarrow h^+ h^-$	ΔY	[51–54]	Run 1&2	<i>As before</i>
$D^0 \rightarrow K^\pm \pi^\mp$ (double tag)	$R^\pm, (x'^\pm)^2, y'^\pm$	[21, 27]	Run 1&2	Updated
$D^0 \rightarrow K^\pm \pi^\mp$ (single tag)	$R_{K\pi}, A_{K\pi}, c_{K\pi}^{(l)}, \Delta c_{K\pi}^{(\sim)(l)}$	[55, 56]	Run 1&2	<i>As before</i>
$D^0 \rightarrow K^\pm \pi^\mp \pi^+ \pi^-$	$r, \kappa y', (x^2 + y^2)/4$	[28]	Run 1	<i>As before</i>
$D^0 \rightarrow K^\pm \pi^\mp \pi^+ \pi^-$	$r_i^\pm, (\kappa y'^\pm)_i, x^{2\pm} + y^{2\pm}$	[22]	Run 2	New
$D^0 \rightarrow K_S^0 \pi^+ \pi^-$	x, y	[57]	Run 1	<i>As before</i>
$D^0 \rightarrow K_S^0 \pi^+ \pi^-$	$x_{CP}, y_{CP}, \Delta x, \Delta y$	[58]	Run 1	<i>As before</i>
$D^0 \rightarrow K_S^0 \pi^+ \pi^-$	$x_{CP}, y_{CP}, \Delta x, \Delta y$	[59, 60]	Run 2	<i>As before</i>
$D^0 \rightarrow \pi^+ \pi^- \pi^0$	ΔY^{eff}	[61]	Run 2	<i>As before</i>

Unbinned of the CKM angle γ in $B^\pm \rightarrow D(\rightarrow K_S^0 h'^+ h'^-) h^\pm$ decays with a novel approach

NEW

◆ The result of the CP-violating observables: $\gamma, r_B^{DK}, \delta_B^{DK}, r_B^{D\pi}, \delta_B^{D\pi}$



$$\begin{aligned} \gamma &= (71.3 \pm 5.0)^\circ, \\ r_B^{DK} &= 0.0949_{-0.0085}^{+0.0086}, \\ \delta_B^{DK} &= (121.6_{-5.9}^{+5.6})^\circ, \\ r_B^{D\pi} &= 0.0064_{-0.0019}^{+0.0021}, \\ \delta_B^{D\pi} &= (311_{-20}^{+17})^\circ. \end{aligned}$$

• Results of extracted CP observables (uncertainties statistical only)

Preliminary

Configuration	γ ($^\circ$)	r_B^{DK} (10^{-2})	δ_B^{DK} ($^\circ$)	$r_B^{D\pi}$ (10^{-2})	$\delta_B^{D\pi}$ ($^\circ$)
Binned (refitted)	67.7 ± 5.1	$9.61_{-0.77}^{+0.78}$	$118.6_{-5.6}^{+5.2}$	0.53 ± 0.19	286_{-28}^{+24}
$M_\pi = 2, M_K = 1$ (baseline)	71.3 ± 4.9	9.48 ± 0.81	$121.6_{-5.5}^{+5.3}$	0.64 ± 0.20	311_{-20}^{+16}
$M_\pi = 2, M_K = 2$	$71.6_{-4.8}^{+4.7}$	$9.58_{-0.80}^{+0.81}$	$122.5_{-5.4}^{+5.1}$	$0.62_{-0.19}^{+0.20}$	309_{-20}^{+17}
$M_\pi = 3, M_K = 1$	71.0 ± 4.9	$9.36_{-0.79}^{+0.80}$	$120.7_{-5.6}^{+5.2}$	$0.64_{-0.19}^{+0.20}$	311_{-20}^{+16}
$M_\pi = 3, M_K = 2$	$71.3_{-4.9}^{+4.8}$	$9.46_{-0.79}^{+0.80}$	$121.5_{-5.5}^{+5.1}$	$0.63_{-0.20}^{+0.19}$	309_{-20}^{+17}

- ◆ Novel approach shows $\sim 5\%$ improvement in the statistical precision of γ compared to the binned phase-space analysis
- ◆ Optimising the analysis strategy can enhance the precision of γ with the current data set.
- ◆ Including higher-order Fourier terms shows robust agreement with the nominal results.



First evidence of CP violation in beauty baryon to charmonium decays

- ✓ Measurement of the difference in the CP asymmetries ΔA_{CP} between $\Lambda_b^0 \rightarrow J/\psi p \pi^-$ and $\Lambda_b^0 \rightarrow J/\psi p K^-$
- ✓ Analysis performed based pp data collected in the years of 2016-2018, corresponding to an integrated luminosity of 6 fb^{-1}

First evidence of CP violation in beauty baryon to charmonium decays

- First evidence in B meson decay to charmonium in 2024 by LHCb experiment

$$A_{CP}(B^+ \rightarrow J/\psi\pi^+) - A_{CP}(B^+ \rightarrow J/\psi\rho K^+) = (1.29 \pm 0.49 \pm 0.08) \% \quad (3.2\sigma)$$

- The difference between governed by $b \rightarrow c\bar{c}q$ ($q = d, s$) transitions. Constrain on the $b \rightarrow c\bar{c}s$ by $b \rightarrow c\bar{c}d$ enable to extract the weak phase 2β through penguin enhanced processes

- The enhancement in the penguin diagram and large weak phase lead to sizable CPV

- **CP-asymmetry difference** ΔA_{CP} measured between $\Lambda_b^0 \rightarrow J/\psi\rho\pi^-$ and $\Lambda_b^0 \rightarrow J/\psi\rho K^-$ (Run2)

- A_{raw} determined from the invariant-mass fit ($J/\psi\rho h$), to subtract π^\pm/K^\pm using the correction detection asymmetries :

$$\Delta A_{CP} = A_{raw}(\lambda_b^0 \rightarrow J/\psi\rho\pi^-) - A_{raw}(\lambda_b^0 \rightarrow J/\psi\rho K^-) + A_D(K^-) - A_D(\pi^-)$$

$$\Delta A_{CP} \equiv A_{CP}(\lambda_b^0 \rightarrow J/\psi\rho\pi^-) - A_{CP}(\lambda_b^0 \rightarrow J/\psi\rho K^-) = (4.03 \pm 1.18 \pm 0.23) \%$$

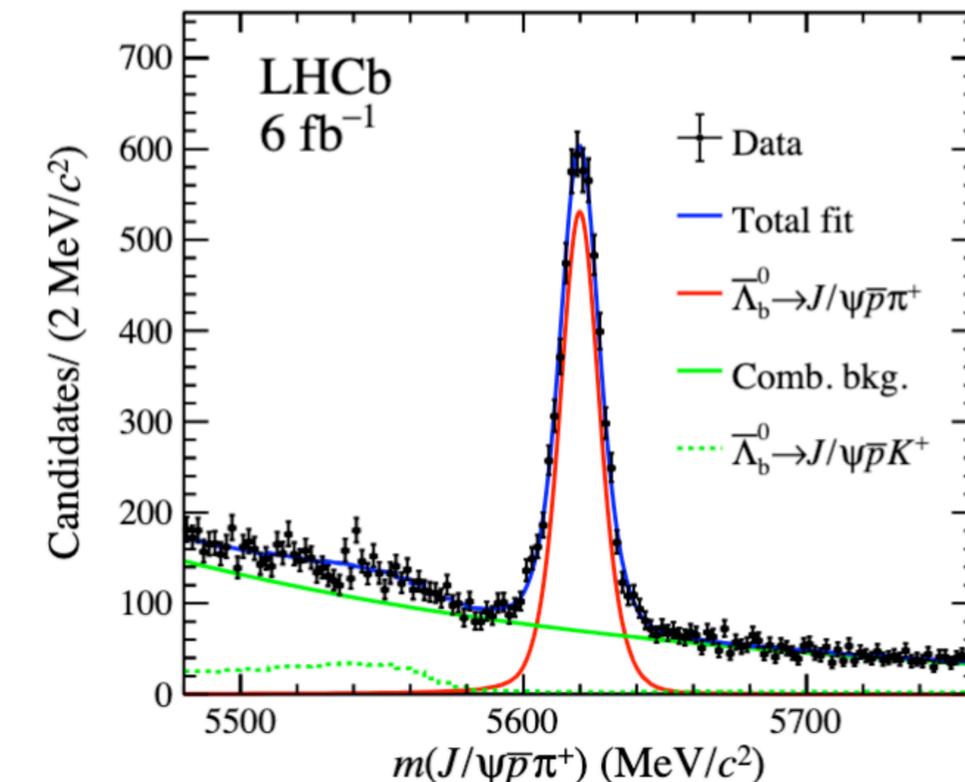
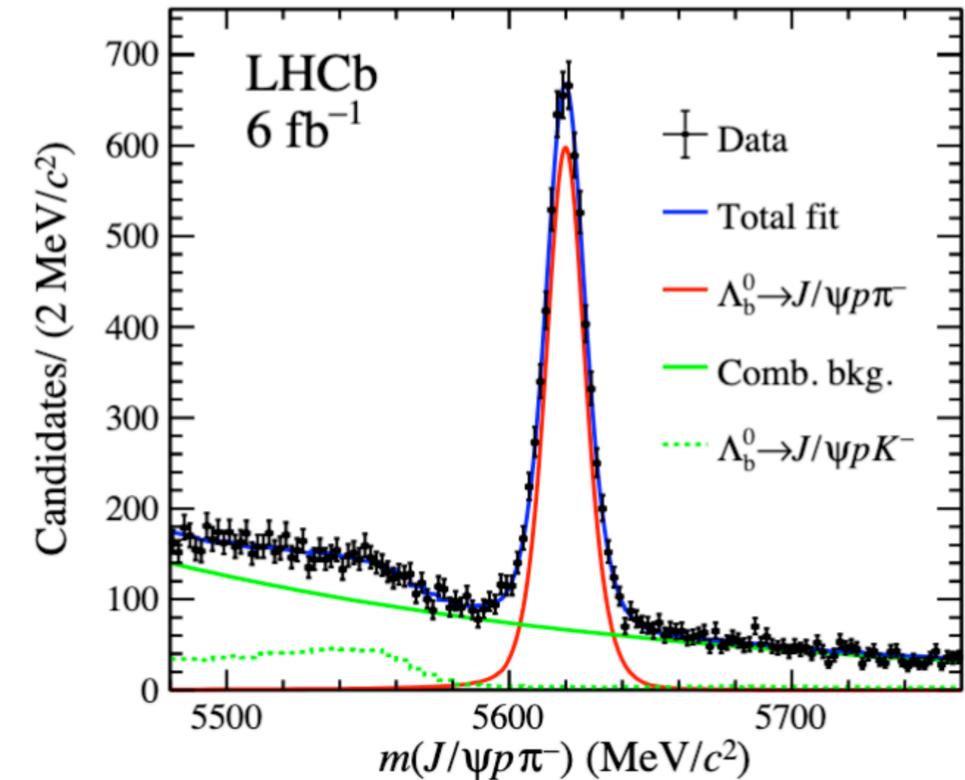
- Combined with Run1(2011-2012) result $(5.7 \pm 2.4 \pm 1.2)\%$

$$\Delta A_{CP} = (4.31 \pm 1.06 \pm 0.28) \%$$

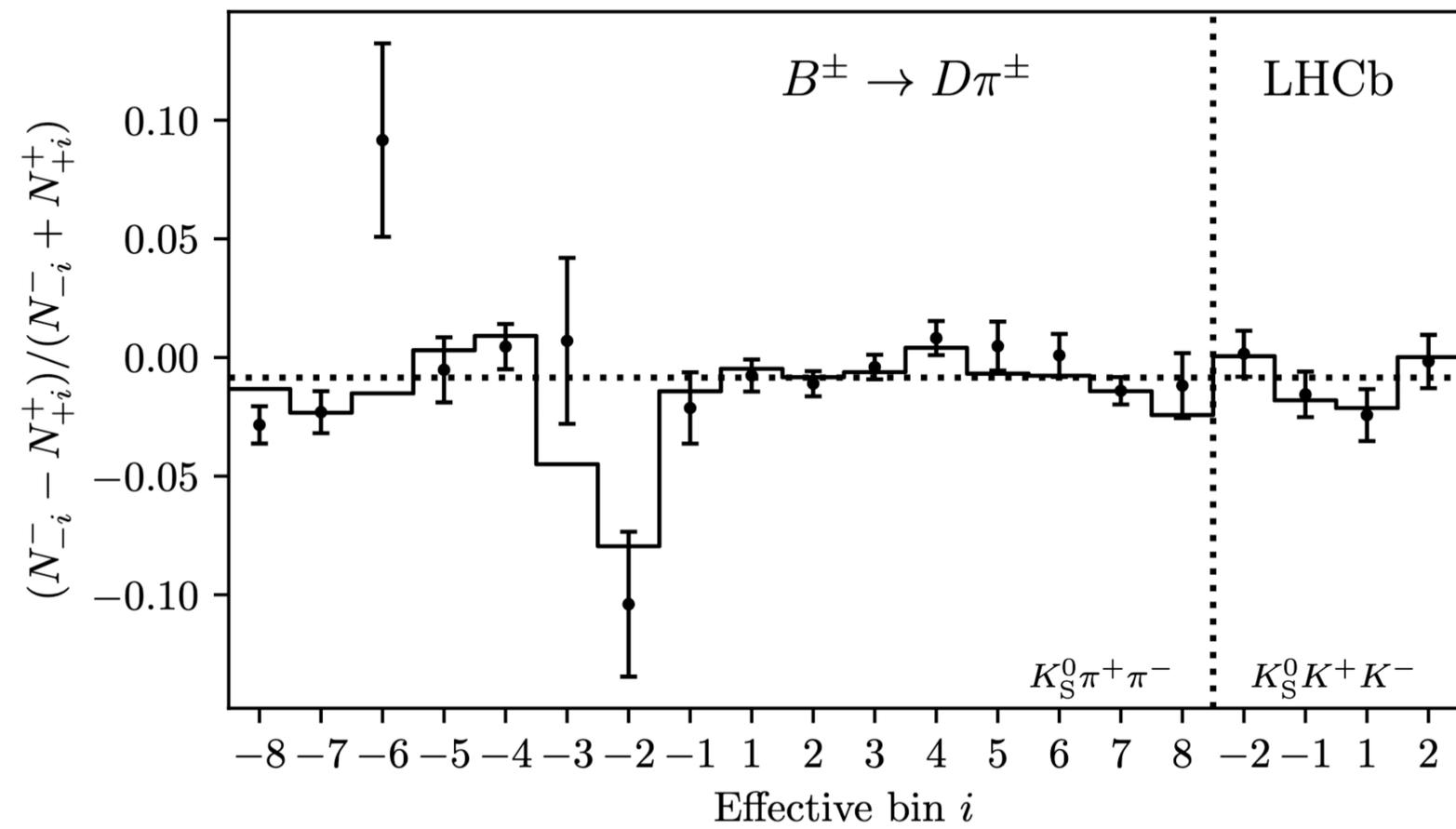
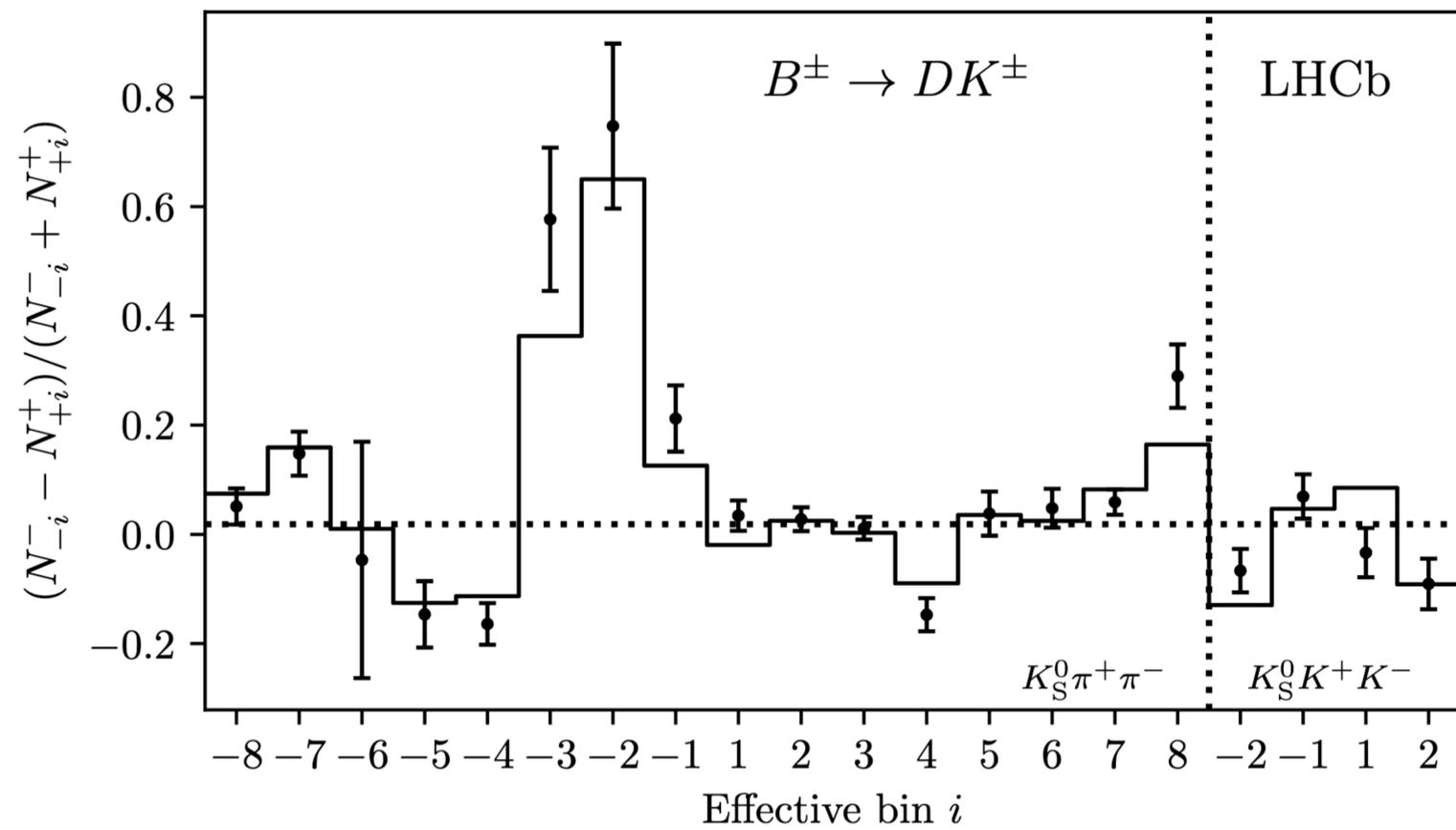
- The phase-space triplet product asymmetry measured for $\Lambda_b^0 \rightarrow J/\psi\rho\pi^-$

$$A_{T-odd}(\lambda_b^0 \rightarrow J/\psi\rho\pi^-) = (-1.37 \pm 1.15 \pm 0.21) \%$$

- No significant variations observed



Measurement of γ using $B^\pm \rightarrow DK^\pm$ and $B^\pm \rightarrow D\pi^\pm$ decays with $D \rightarrow K_S^0\pi^+\pi^-$ and $D \rightarrow K_S^0K^+K^-$

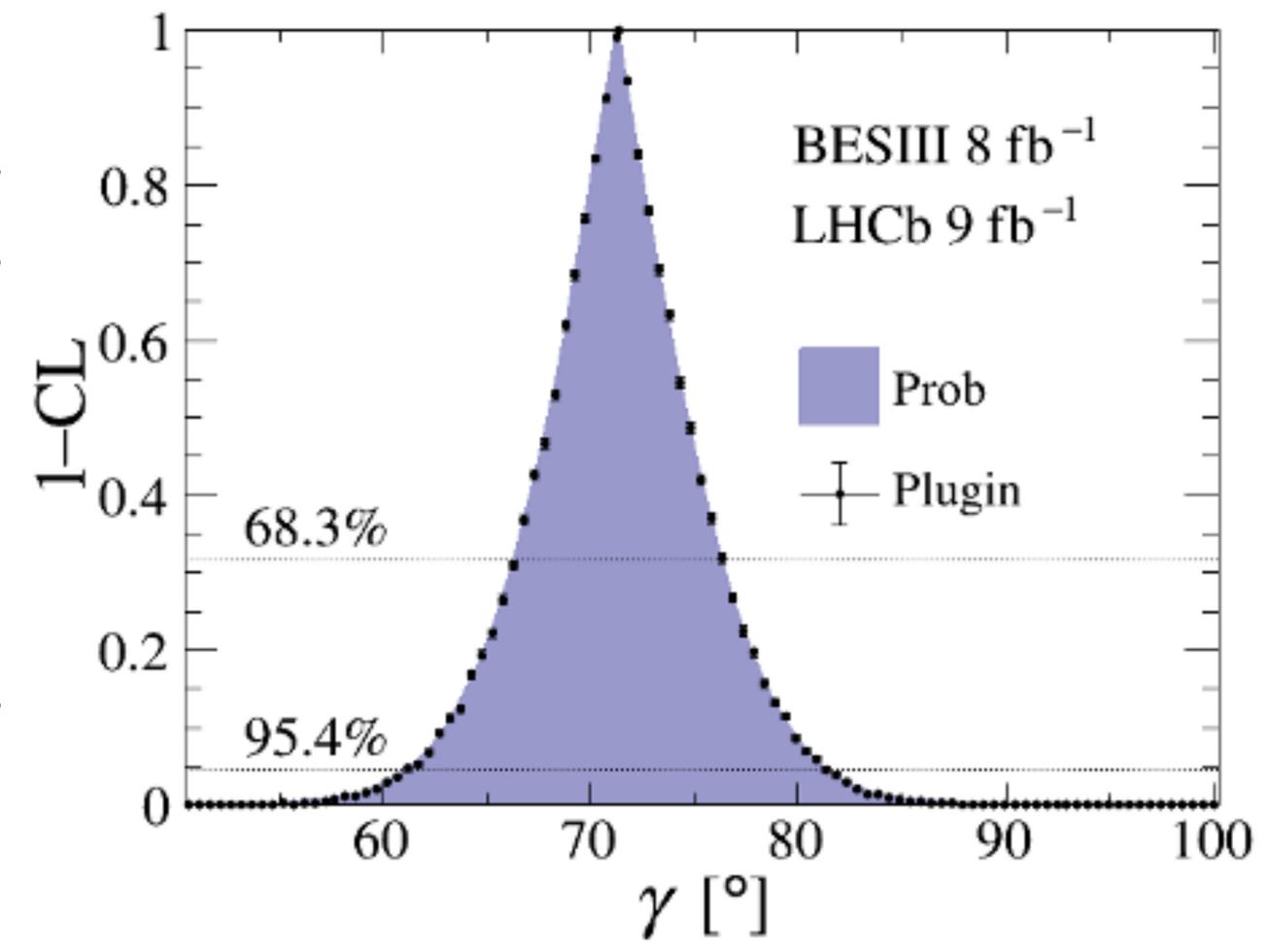


Unbinned of the CKM angle γ in $B^\pm \rightarrow D(\rightarrow K_S^0 h'^+ h'^-) h^\pm$ decays with a novel approach

◆ The result of the physics parameters: $\gamma, r_B^{DK}, \delta_B^{DK}, r_B^{D\pi}, \delta_B^{D\pi}$

Preliminary

Configuration	γ ($^\circ$)
Binned (refitted)	67.7 ± 5.1
$M_\pi = 2, M_K = 1$ (baseline)	71.3 ± 4.9
$M_\pi = 2, M_K = 2$	$71.6^{+4.7}_{-4.8}$
$M_\pi = 3, M_K = 1$	71.0 ± 4.9
$M_\pi = 3, M_K = 2$	$71.3^{+4.8}_{-4.9}$



$$\begin{aligned} \gamma &= (71.3 \pm 5.0)^\circ, \\ r_B^{DK} &= 0.0949^{+0.0086}_{-0.0085}, \\ \delta_B^{DK} &= (121.6^{+5.6}_{-5.9})^\circ, \\ r_B^{D\pi} &= 0.0064^{+0.0021}_{-0.0019}, \\ \delta_B^{D\pi} &= (311^{+17}_{-20})^\circ. \end{aligned}$$

- ◆ Novel approach shows $\sim 5\%$ improvement in the statistical precision of γ compared to the binned phase-space analysis
- ◆ Optimising the analysis strategy can enhance the precision of γ with the current data set.
- ◆ Including higher-order Fourier terms shows robust agreement with the nominal results.



LHCb-PAPER-2025-029

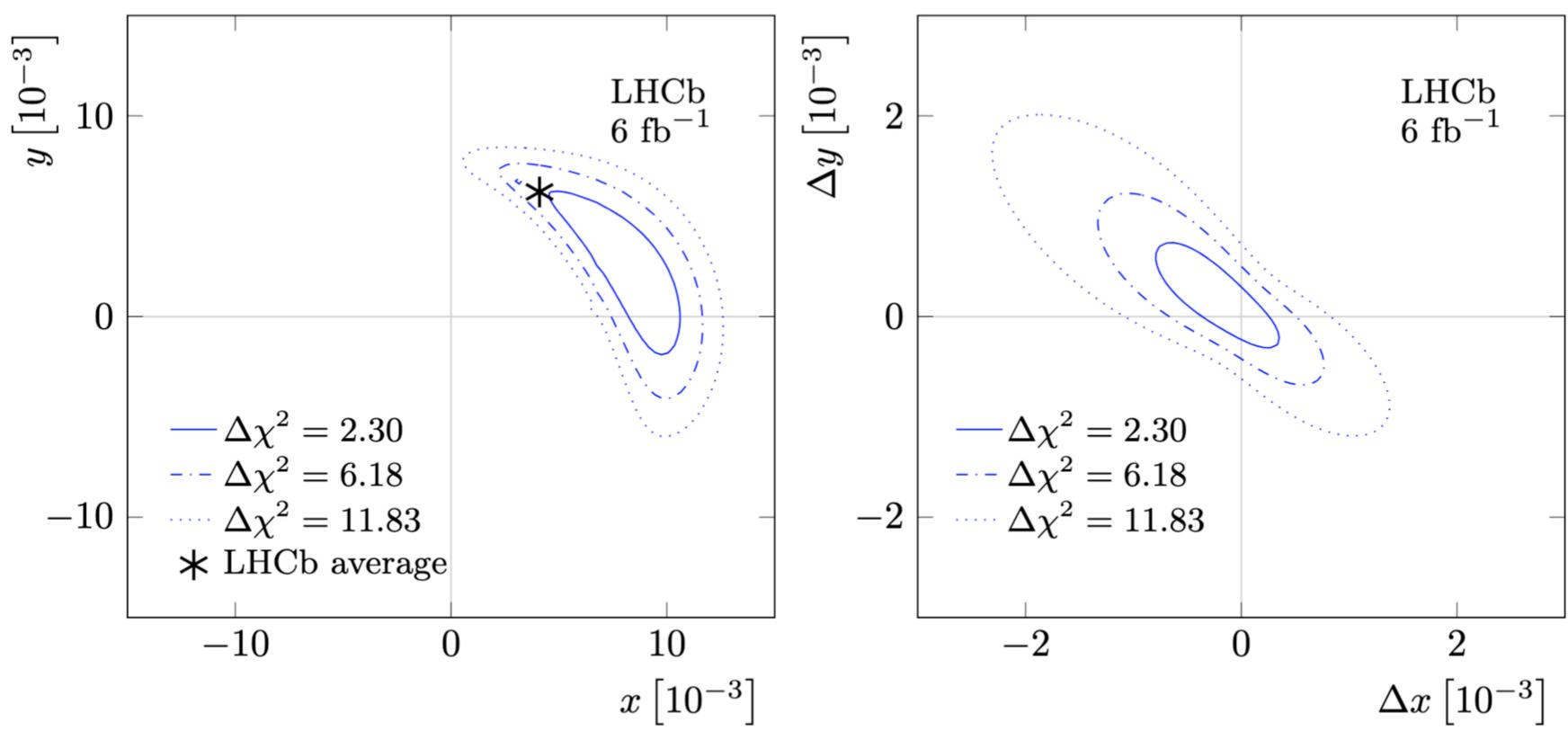
[arxiv:2510.04963](https://arxiv.org/abs/2510.04963)

[JHEP12\(2025\)153](https://arxiv.org/abs/2510.04963)

Study of charm mixing and CP violation with $D^0 \rightarrow K^\pm \pi^\mp \pi^\pm \pi^\mp$ decays

- ✓ Analysis based on data collected by the LHCb at $\sqrt{s} = 13\text{TeV}$ Run2 (2015-2018) corresponding to an integrated luminosity of 6 fb^{-1}
- ✓ Signal yields variation analysis across the D decay phase space

Study of charm mixing and CP violation with $D^0 \rightarrow K^\pm \pi^\mp \pi^\pm \pi^\mp$ decays



- Performed a study of charm mixing and CP-violation in $D^0 \rightarrow K^\pm \pi^\mp \pi^\pm \pi^\mp$:
- Charm-mixing observables measured: inclusive & four bins of phase space

- Alternative analysis performed: hadronic parameters from external inputs used to extract charm-mixing parameters

$$r = (5.49 \pm 0.02) \times 10^{-2} \quad \kappa = 0.430^{+0.043}_{-0.039} \quad \delta = (163.3^{+13.8}_{-14.8})$$

- Mixing parameters from external inputs (BESIII, CLEO-C) constraint on hadronic parameters

$$x = (0.85^{+0.15}_{-0.24}) \% \quad \Delta x = (-0.02 \pm 0.04) \%$$

$$y = (0.21^{+0.29}_{-0.27}) \% \quad \Delta y = (0.02^{+0.04}_{-0.03}) \%$$

- Consistent with prior results and CP-symmetry

$$x = (0.74^{+0.18}_{-0.25}) \%$$

$$y = (0.34^{+0.25}_{-0.29}) \%$$

- ◆ Charm-mixing limited by hadronic parameters of $D^0 \rightarrow K^\pm \pi^\mp \pi^\pm \pi^\mp$
- ◆ Larger BESIII charm-threshold data will enhance sensitivity
- ◆ Upgraded LHCb collecting more data enables higher-precision studies



LHCb-PAPER-2025-036

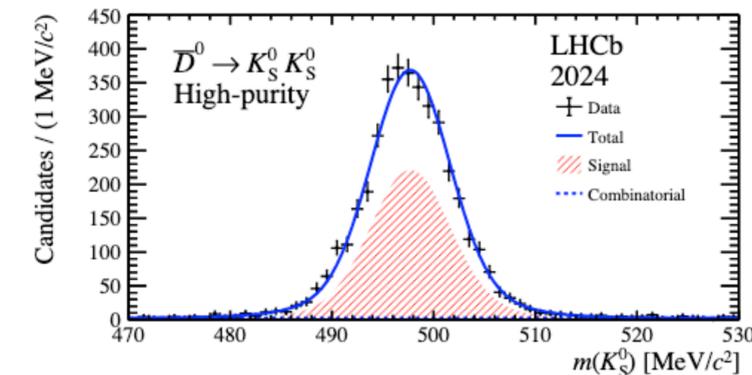
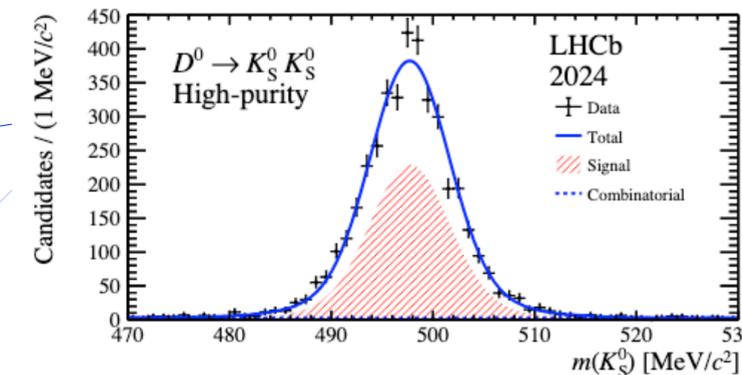
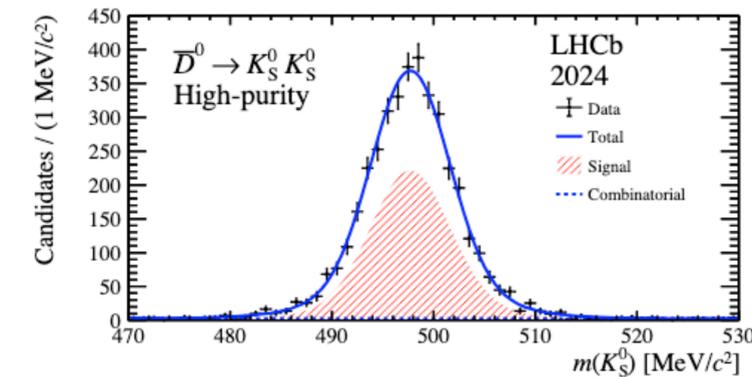
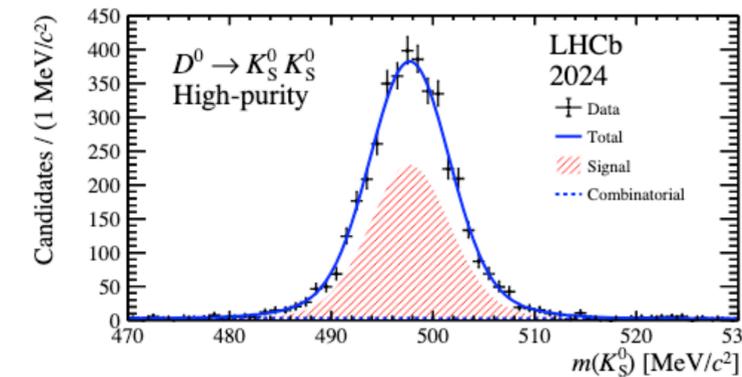
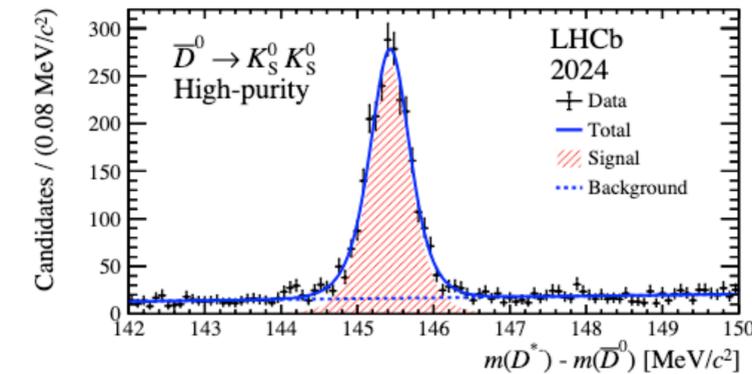
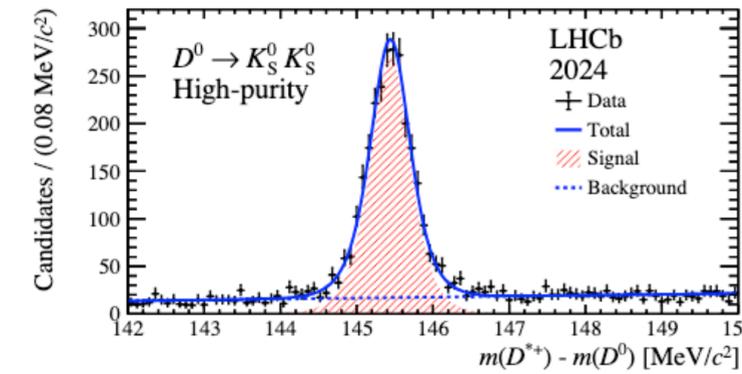
[JHEP02\(2026\)253](#), [arXiv:2510.14732](#)

Measurement of CP asymmetry in $D^0 \rightarrow K_S^0 K_S^0$ decays with Run 3 data

- ✓ Measurement of the time-integrated CP-asymmetry $A_{CP}(K_S^0 K_S^0)$ for $D^0 \rightarrow K_S^0 K_S^0$
- ✓ Analysis based on 2024 data collected by the upgraded LHCb experiment with a total integrated luminosity of 6.2 fb^{-1}

Measurement of CP asymmetry in $D^0 \rightarrow K_S^0 K_S^0$ decays with Run 3 data

- $D^0 \rightarrow K_S^0 \pi \pi$, Cabibbo-suppressed decay sensitive to CP-violation
- In SM, potentially larger $A_{CP}(K_S^0 K_S^0)$ than in $D^0 \rightarrow \pi^+ \pi^-$ and $D^0 \rightarrow K^+ K^-$
- First measurement with 2024 data, improved trigger with software based K_S^0 selection
- A_{CP} determined from a maximum-likelihood fit to Δ_m and $m(K_S^0)$
- Fit projection for the total data sample passing the high and low purity selections.
- Event weights from calibration sample $D^0 \rightarrow K_S^0 \pi \pi$ to cancel production and detection asymmetries



- ◆ The most precise single measurement to date : $A_{CP}(K_S^0 K_S^0) = (1.86 \pm 1.04 \pm 0.41) \%$
- ◆ In agreement with CP symmetry and previous averages
- ◆ Better precision thanks to the improved trigger efficiency with Run 3!

(JHEP02(2026)253, arXiv:2510.14732)



LHCb-PAPER-2025-016

[arxiv:2508.17836](https://arxiv.org/abs/2508.17836)

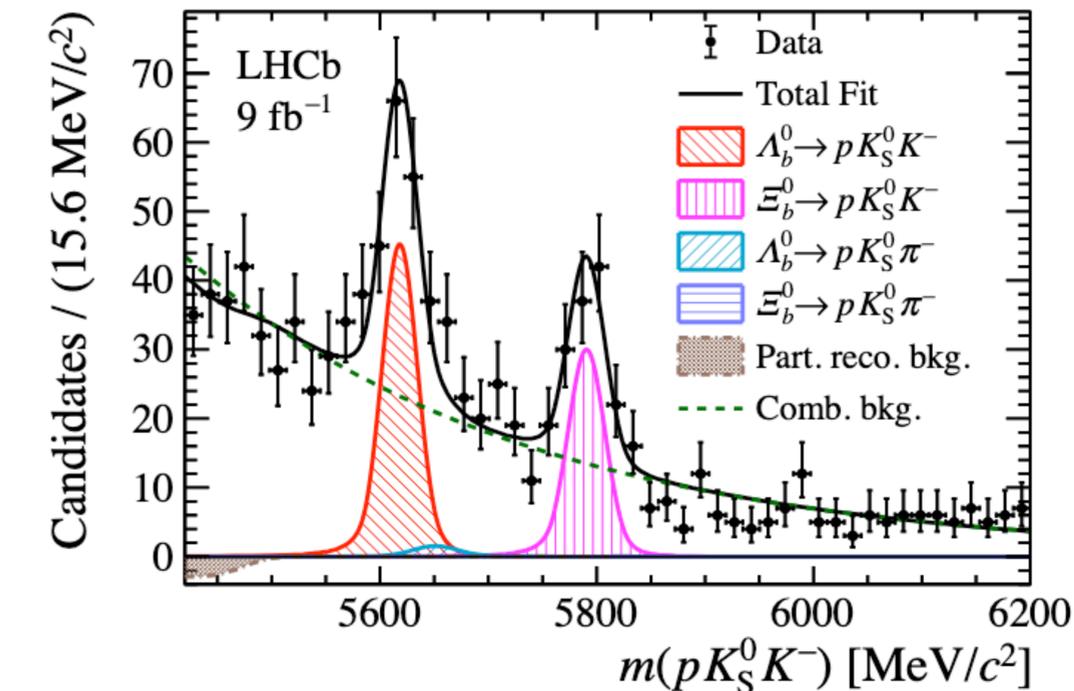
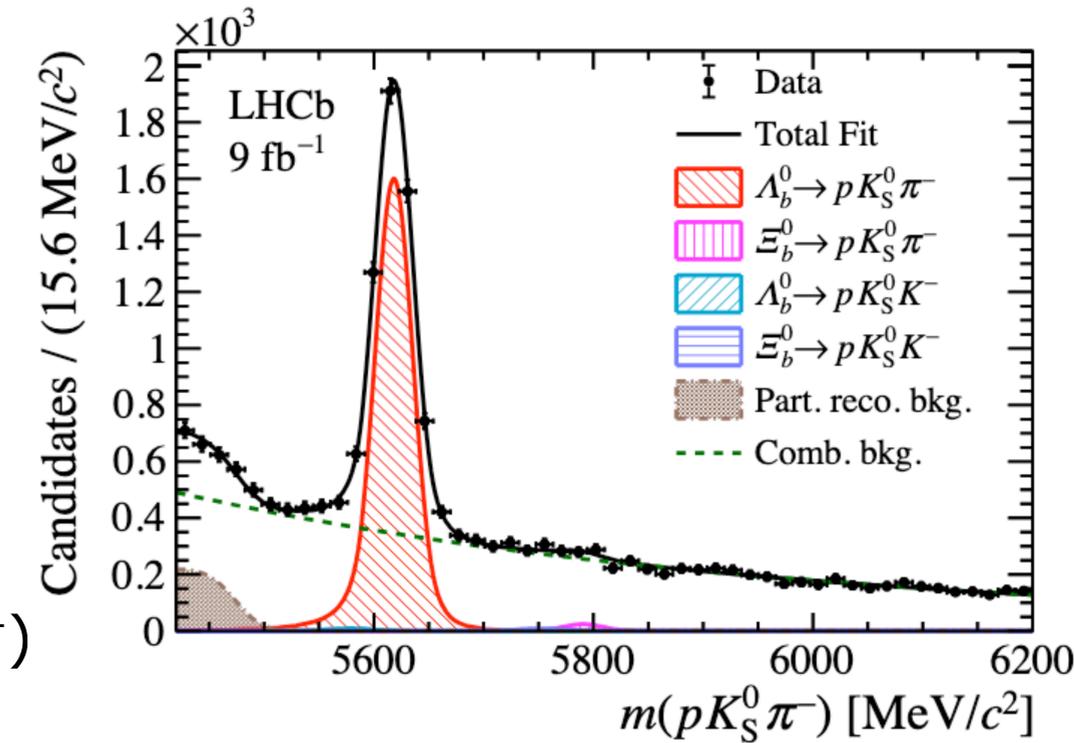
[JHEP10\(2025\)169](https://arxiv.org/abs/2508.17836)

Measurement of branching fractions and CP asymmetries in $\Lambda_b^0(\Xi_b^0) \rightarrow pK_S^0 h^-$ decays

- ✓ Measurement of the branching fractions and the CP-violating observables of the charmless $\Lambda_b^0(\Xi_b^0) \rightarrow pK_S^0 h^-$
- ✓ Analysis based on data samples Run1&2 corresponding to an integrated luminosity of $9fb^{-1}$ of pp collision at center-of-mass energy $\sqrt{s} = 7,8$ and 13 TeV

Measurement of branching fractions and CP asymmetries in $\Lambda_b^0(\Xi_b^0) \rightarrow pK_S^0 h^-$ decays

- Charmless $\Lambda_b^0(\Xi_b^0) \rightarrow pK_S^0 h^-$ ($h = K, \pi$) decays with contribution from both tree & penguin diagrams
- Possible asymmetry due to interference
- Yields determination from extended maximum-likelihood fit ($m(pK_S^0 \pi^-)$)
- CP asymmetries across different Dalitz regions of $\Lambda_b^0 \rightarrow pK_S^0 \pi^-$ decays : fit performed, split in four bins of Dalitz space according to the observed resonances
- Nuisance asymmetries largely canceled via control channel ($\Lambda_b^0 \rightarrow \Lambda_c^+ (\rightarrow pK_S^0) \pi^-$)
- **First observation : $\Lambda_b^0 \rightarrow pK_S^0 K^-$ and $\Xi_b^0 \rightarrow pK_S^0 K^-$ decays with 8σ significance**
- No evidence of CP violation in the studied decays.



	Result [%]	$m(p\pi^-)$	$m(K_S^0\pi^-)$	Yield	\mathcal{A}^{CP} [%]
$\mathcal{A}^{CP}(\Lambda_b^0 \rightarrow pK_S^0\pi^-)$	$3.4 \pm 1.9 \pm 0.9$	Bin 1	$< 1.1 \text{ GeV}/c^2$	821 ± 34	$-0.6 \pm 4.0 \pm 1.9$
$\mathcal{A}^{CP}(\Lambda_b^0 \rightarrow pK_S^0K^-)$	$2 \pm 13 \pm 9$	Bin 2	$[1.1, 1.7] \text{ GeV}/c^2$	870 ± 40	$12.4 \pm 4.2 \pm 1.8$
$\mathcal{A}^{CP}(\Xi_b^0 \rightarrow pK_S^0\pi^-)$	$22 \pm 15 \pm 11$	Bin 3	$\leq 2.4 \text{ GeV}/c^2$	2200 ± 50	$0.5 \pm 2.4 \pm 1.1$
$\mathcal{A}^{CP}(\Xi_b^0 \rightarrow pK_S^0K^-)$	$22 \pm 15 \pm 11$	Bin 4	$> 2.4 \text{ GeV}/c^2$	840 ± 50	$3.3 \pm 5.5 \pm 2.0$

- ◆ CP asymmetry in $K^*(892)$ significantly far below 20% expectation
- ◆ More data needed to probe CP violation mechanisms in baryon decays.

JHEP10(2025)169 arxiv:2508.17836