

Precise measurement of the CKM angle γ with a novel model-independent approach

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The CKM angle γ

Only UT angle measurable through **tree-level decays alone**.

$$\gamma \equiv \arg \left[-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*} \right]$$

Direct γ vs indirect CKM constraints (including loops)

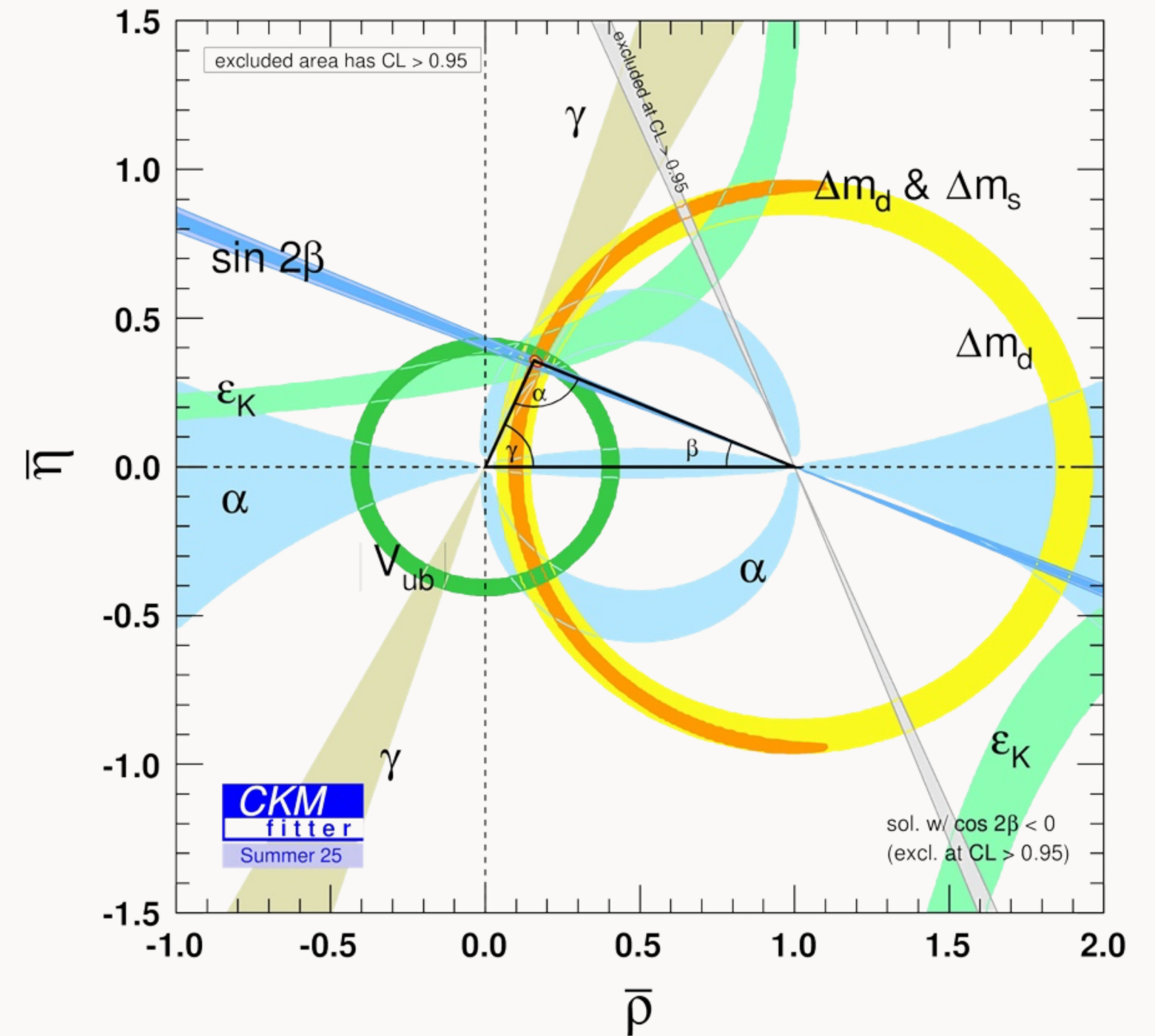
An indirect search for new physics.

The results agree, but direct measurements are less precise.

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

CKMfitter, Summer 2025: $\gamma = (66.2^{+0.7}_{-1.4})^\circ$

More precise direct γ measurements are needed.



Improving the precision of direct γ measurements

Use larger data samples

LHCb Run 3 (2024)

$$B^\pm \rightarrow Dh^\pm, D \rightarrow K_S^0 h'^+ h'^- \quad (h, h' = K, \pi)$$

JHEP 08 (2026) 037

Expand the γ + charm combination

$$\text{LHCb: } B^\pm \rightarrow D^* K^\pm, DK^{*\pm}$$

JHEP 02 (2024) 118; 02 (2025) 113

$$\text{BESIII: } D \rightarrow K_{S,L}^0 \pi^+ \pi^-$$

JHEP 06 (2025) 086

Study γ in b -baryon decays

$$\Lambda_b^0 \rightarrow DpK^-$$

Phys. Rev. D 89 (2014) 032001; 104 (2021) 112008

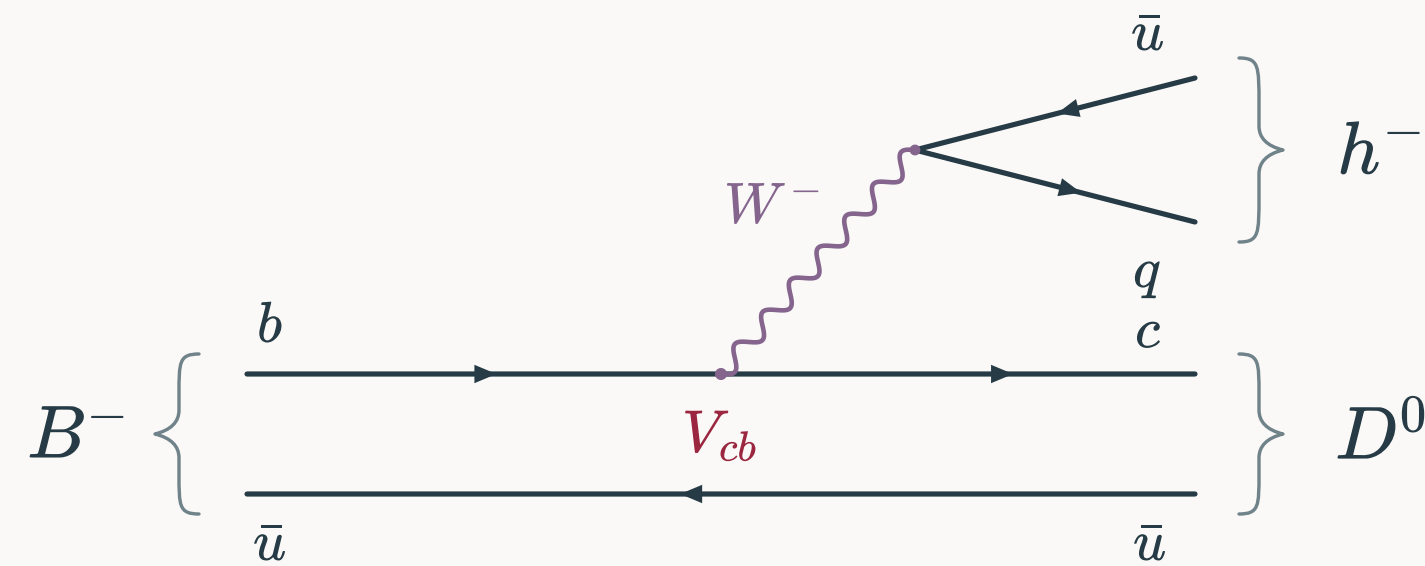
Optimise sensitivity per event

Optimal Fourier weights — This talk

$$B^\pm \rightarrow Dh^\pm, D \rightarrow K_S^0 h'^+ h'^-$$

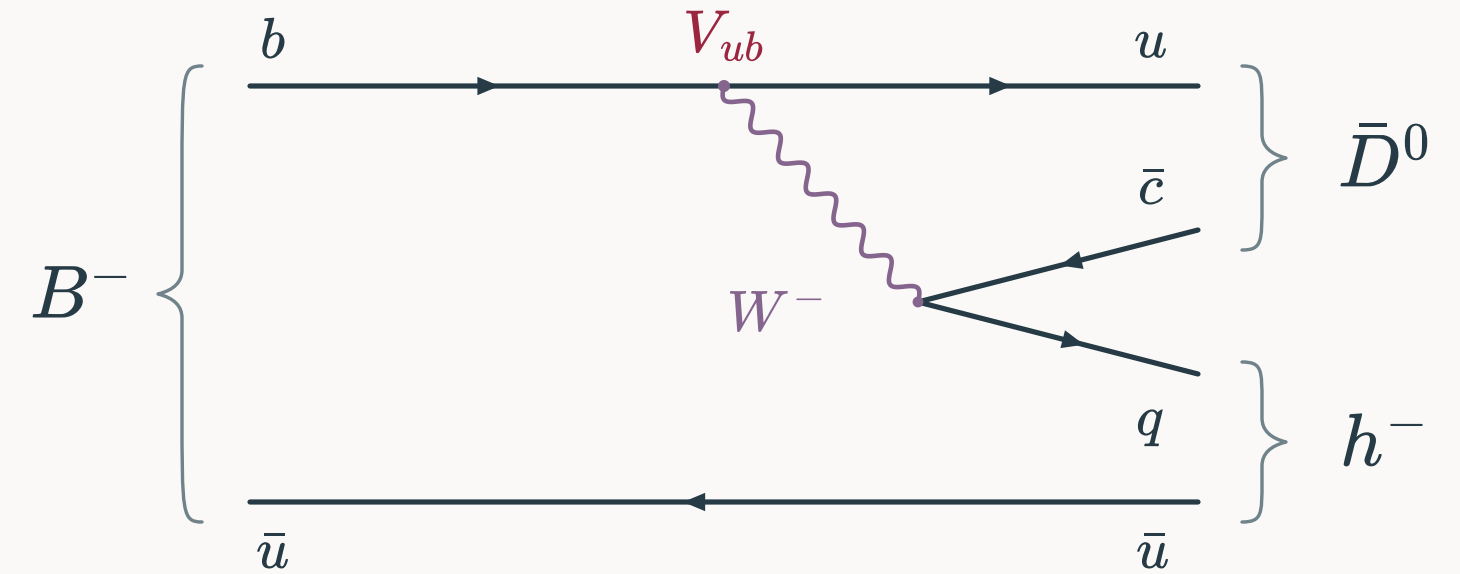
arXiv:2604.05712; arXiv:2604.05701

Measuring γ in $B^\pm \rightarrow Dh^\pm$ decays



$b \rightarrow c$ (favoured)

$q = s, d: h^- = K^-, \pi^-$



$b \rightarrow u$ (suppressed)

Amplitude ratio (suppressed / favoured): $r_B^{Dh} e^{i(\delta_B^{Dh} - \gamma)} = x_-^{Dh} + i y_-^{Dh}$

For B^+ : $r_B^{Dh} e^{i(\delta_B^{Dh} + \gamma)} = x_+^{Dh} + i y_+^{Dh}$

When D^0 and $\bar{D}^0$ decay to the same final state f , the $b \rightarrow c$ and $b \rightarrow u$ decay paths interfere, giving access to γ .

$$|A(B^- \rightarrow [f]_D h^-)|^2 \propto 1 + r_D^2 ((x_-^{Dh})^2 + (y_-^{Dh})^2) + 2r_D (x_-^{Dh} \cos \phi + y_-^{Dh} \sin \phi), \quad r_D e^{-i\phi} \equiv \frac{A(\bar{D}^0 \rightarrow f)}{A(D^0 \rightarrow f)}$$

r_B^{Dh}, r_D : amplitude ratios; δ_B^{Dh}, ϕ : strong-phase differences

Binned phase-space measurement

Multibody D decays: phase-space-dependent sensitivity to γ .

Local CP asymmetries can be much larger than the integrated asymmetry.

Phase-space binning retains local information.

Lower γ uncertainty than in a phase-space-integrated measurement.

$$N_i^\pm \propto F_{\mp i} + [(x_\pm^{Dh})^2 + (y_\pm^{Dh})^2] F_{\pm i} + 2\sqrt{F_i F_{-i}} (x_\pm^{Dh} c_i \mp y_\pm^{Dh} s_i).$$

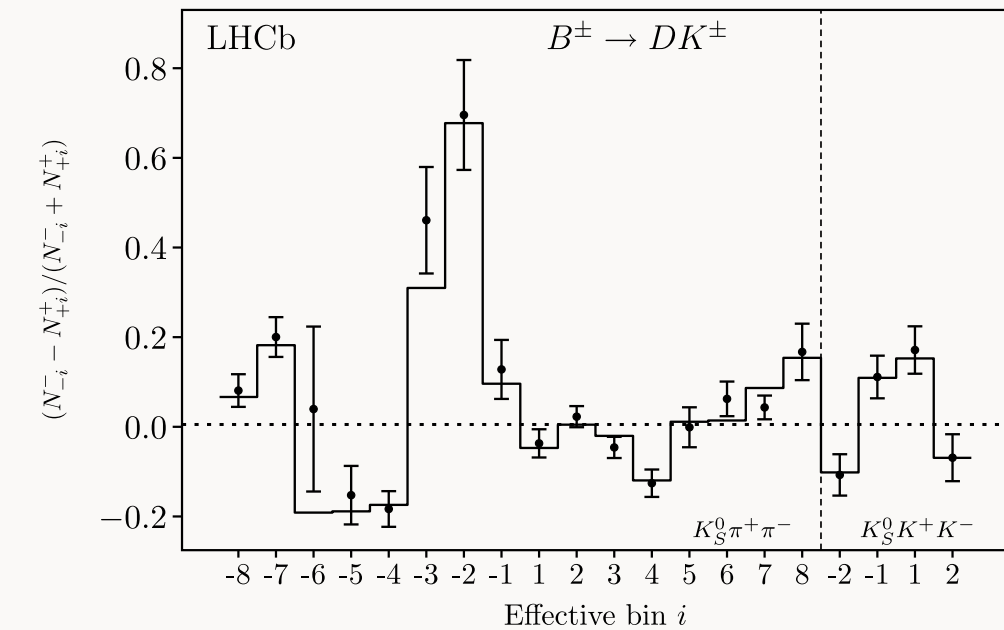
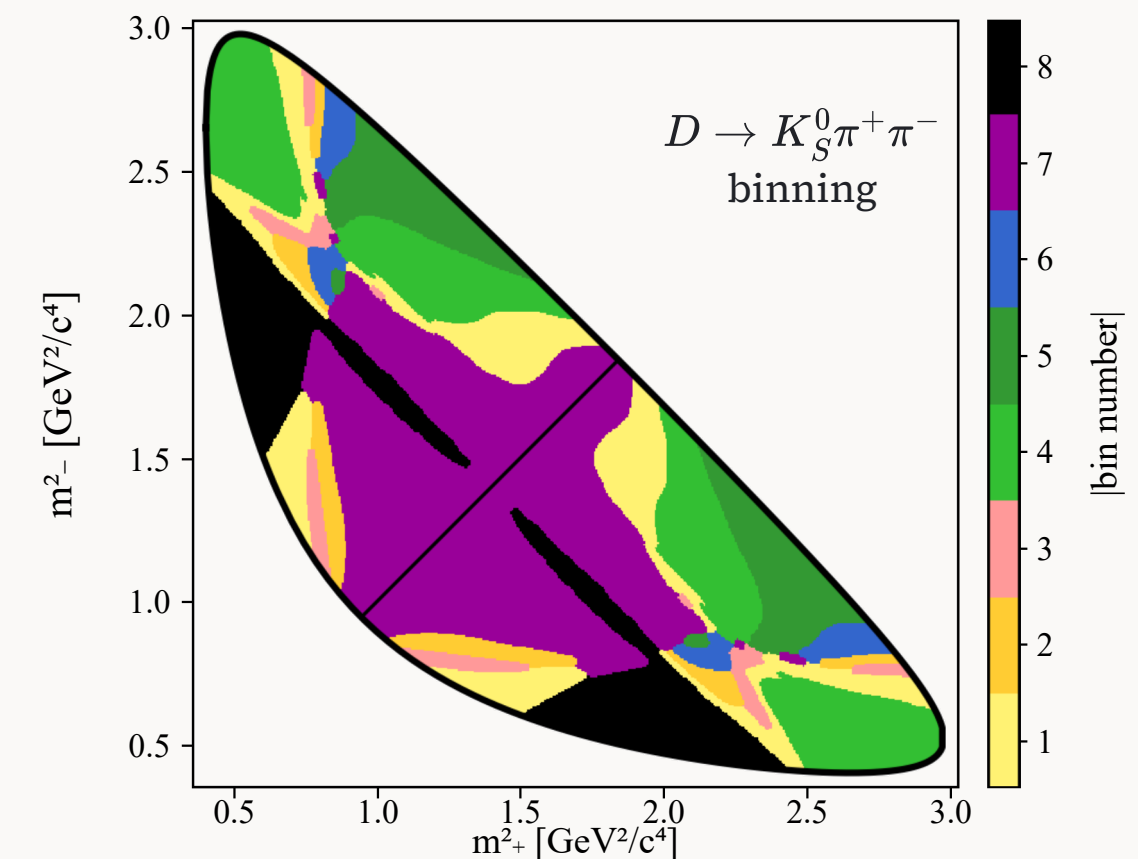
$F_{\pm i}$: D^0 -decay fractions; c_i, s_i : amplitude-weighted bin averages of $\cos \phi$ and $\sin \phi$.

c_i, s_i from BESIII and CLEO charm measurements.

Avoids uncertainty from the choice of strong-phase model.

Current binning schemes retain only about 85% of the sensitivity to γ .

A more sensitive, model-independent approach is needed.

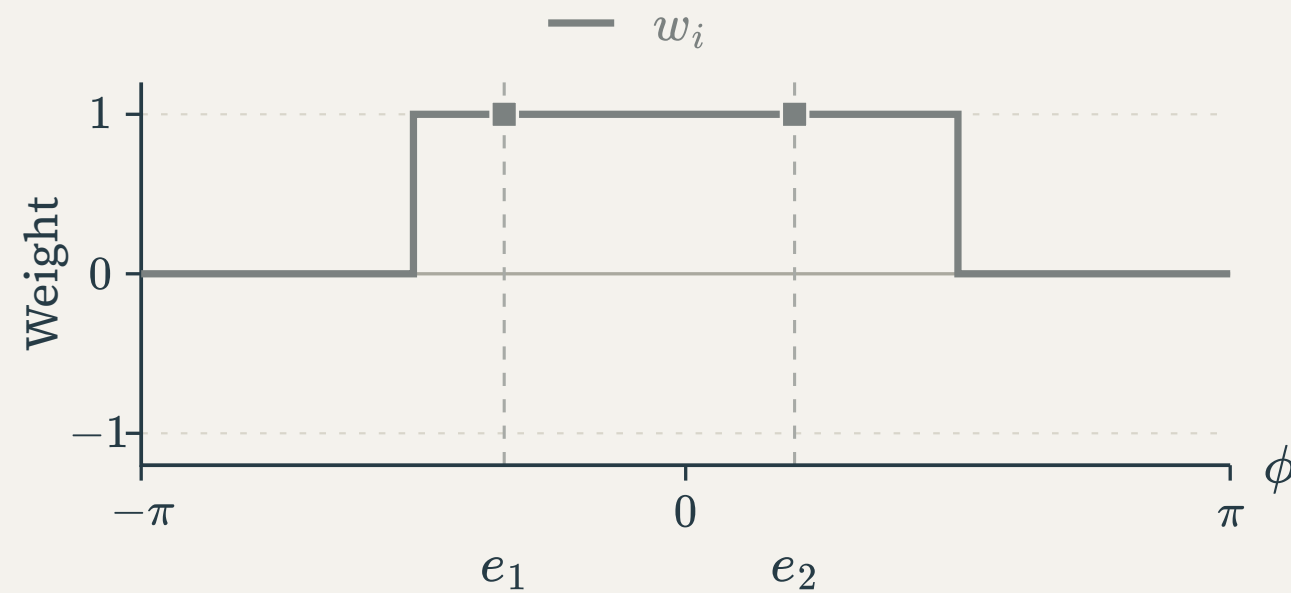


From binning to Fourier expansion

Binning

$$w_i(\mathbf{z}_j) = \begin{cases} 1, & \mathbf{z}_j \in \Omega_i, \\ 0, & \text{otherwise.} \end{cases}$$

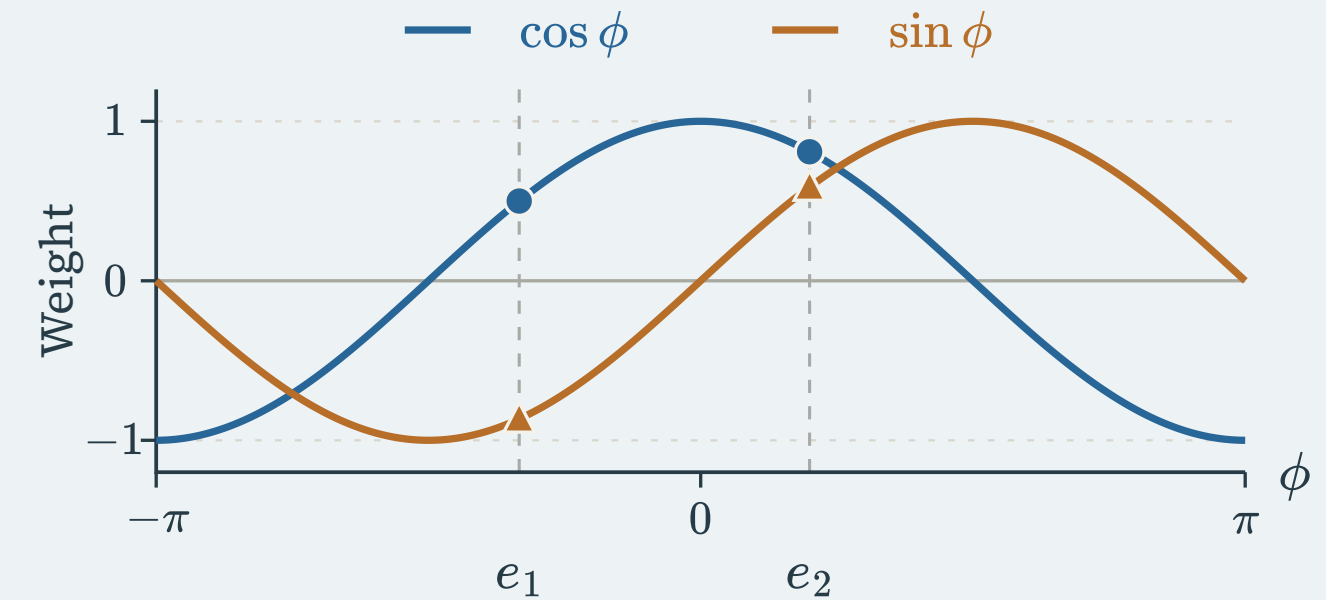
Equal weights within each bin.
Strong-phase variations averaged within bins.



Fourier expansion

$$w_n^{(M)}(\mathbf{z}_j) = \begin{cases} \cos[k\phi(\mathbf{z}_j)], & n = 2k, \\ \sin[k\phi(\mathbf{z}_j)], & n = 2k - 1. \end{cases}$$

Give each event sine/cosine weights up to order M .
Retains sensitivity to phase variation within bins.



$$\mathbf{z} \equiv (m_+^2, m_-^2), \quad m_\pm^2 \equiv m^2(K_S^0 h^\pm), \quad h = \pi, K$$

$\phi \equiv \phi_{\text{model}}(\mathbf{z})$: strong-phase difference from Belle/BaBar D -amplitude models.

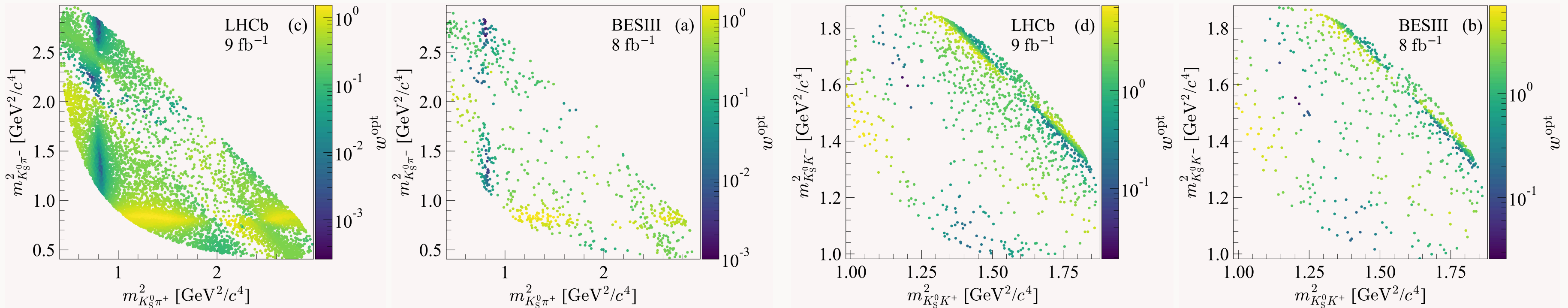
The optimal Fourier method

Sensitivity to γ also depends on the D -amplitude ratio r_D , efficiency and background.

To account for these effects, an optimal factor $w^{\text{opt}}(\mathbf{z})$ is introduced and weighted signal observables are formed:

$$w_n(\mathbf{z}_j) = w^{\text{opt}}(\mathbf{z}_j) w_n^{(M)}(\mathbf{z}_j), \quad \mathcal{N}_n^\pm \propto \sum_{j \in B^\pm \rightarrow Dh^\pm} w_n(\mathbf{z}_j).$$

Maximum Fourier orders: $M_\pi = 2$, $M_K = 1$.



w^{opt} for $D \rightarrow K_S^0 \pi^+ \pi^-$

w^{opt} for $D \rightarrow K_S^0 K^+ K^-$

Joint LHCb–BESIII measurement

LHCb

9 fb^{-1} of pp data · Run 1+2

$$B^\pm \rightarrow DK^\pm, D\pi^\pm$$

$$D \rightarrow K_S^0 \pi^+ \pi^-, K_S^0 K^+ K^-$$

BESIII

8 fb^{-1} at $\psi(3770)$

$$\psi(3770) \rightarrow D^0 \bar{D}^0$$

$$D \rightarrow K_{S/L}^0 \pi^+ \pi^-, K_{S/L}^0 K^+ K^-$$

Joint fit

Fit both sets of weighted observables with their covariance matrices.

$$\chi_{\text{joint}}^2 = \chi_{\text{LHCb}}^2(\theta_{CP}; \mathbf{C}_n, \mathbf{S}_n) + \chi_{\text{BESIII}}^2(\mathbf{C}_n, \mathbf{S}_n)$$

$$\theta_{CP} = (x_-^{DK}, y_-^{DK}, x_+^{DK}, y_+^{DK}, x_\xi^{D\pi}, y_\xi^{D\pi})$$

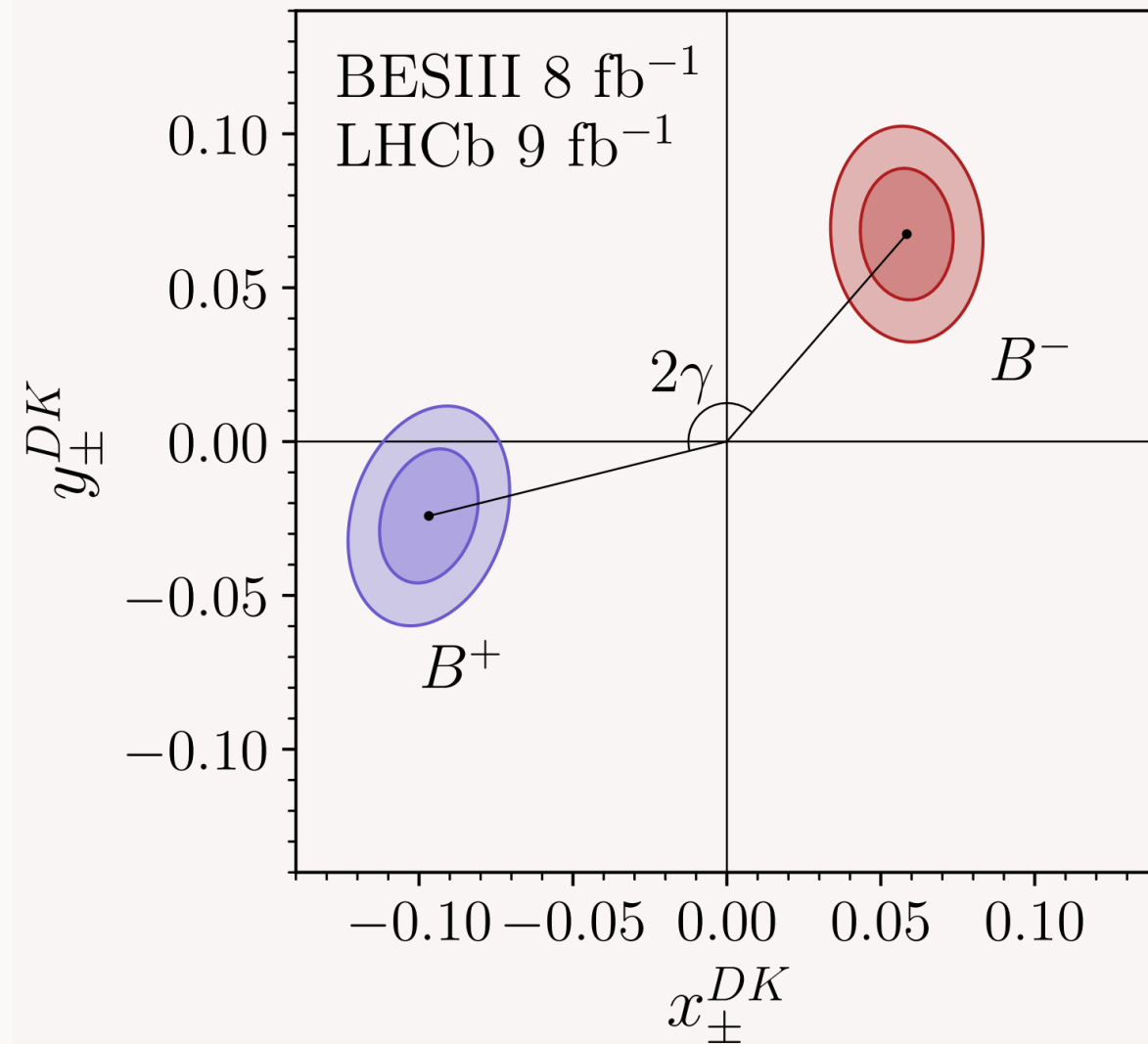
$$x_\xi^{D\pi} + iy_\xi^{D\pi} = \frac{r_B^{D\pi}}{r_B^{DK}} e^{i(\delta_B^{D\pi} - \delta_B^{DK})}$$

$\mathbf{C}_n, \mathbf{S}_n$: charm strong-phase moments for w_n

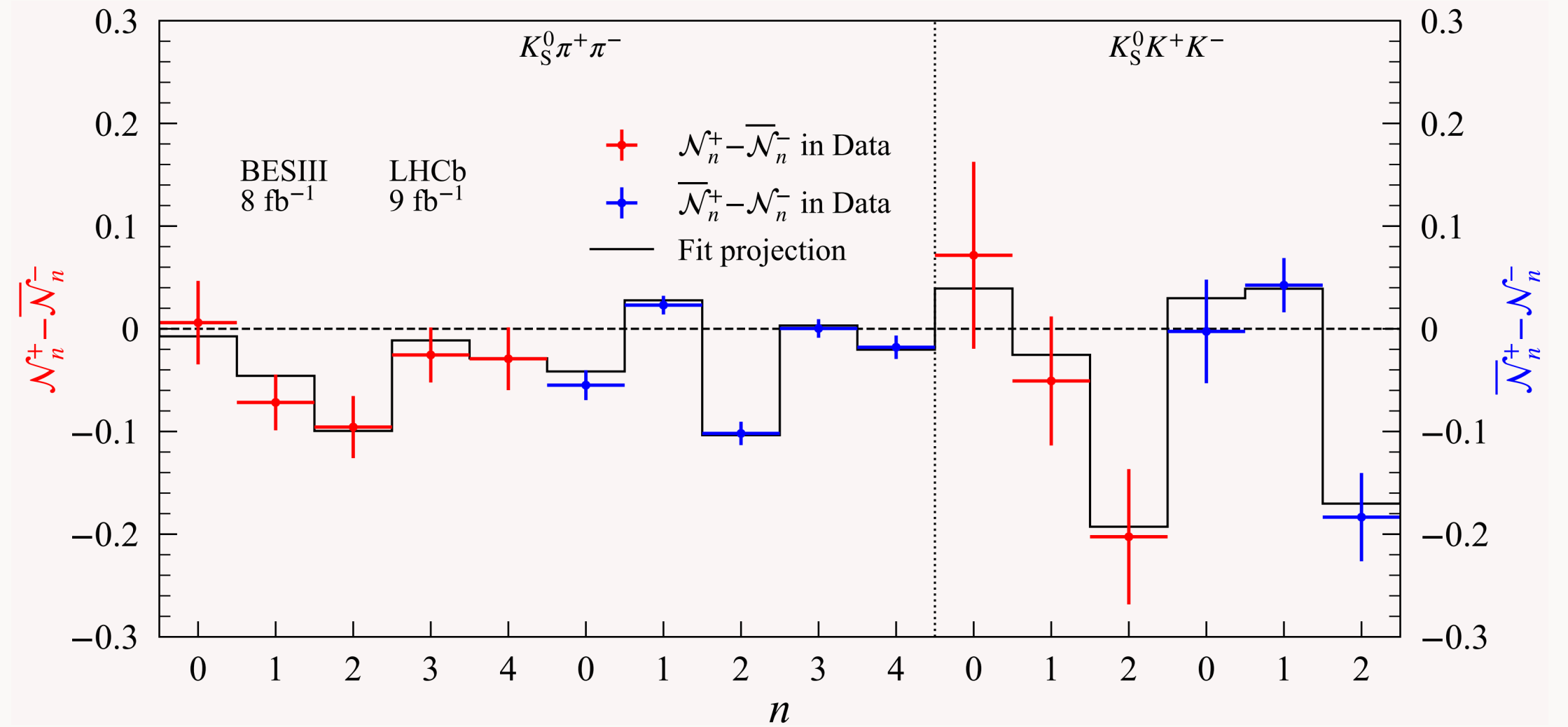
Fit CP observables to extract γ and hadronic parameters.

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

Results of the joint measurement



$$\gamma = (71.3 \pm 5.0)^\circ$$



$$r_B^{DK} = 0.0949_{-0.0085}^{+0.0086}$$

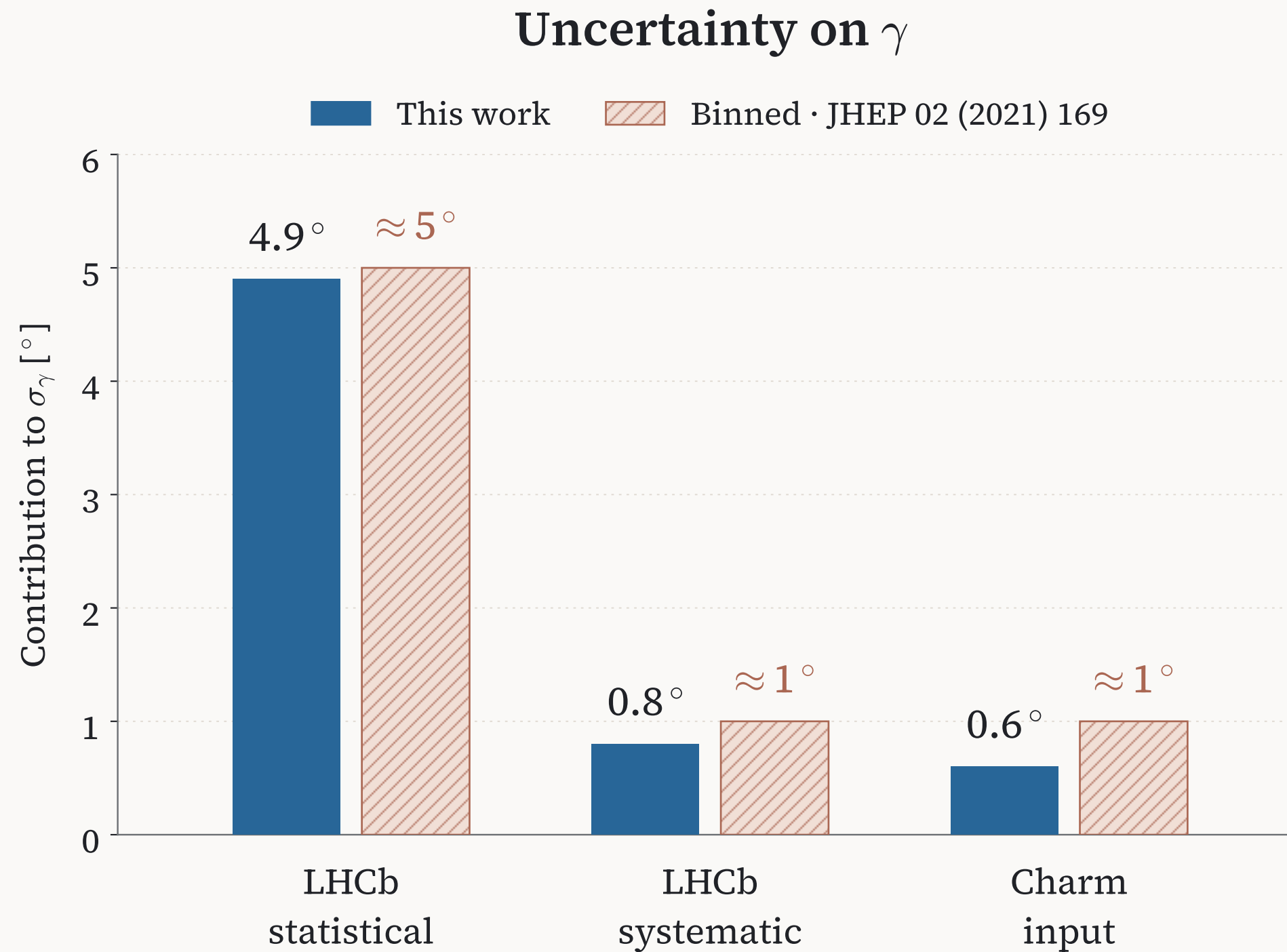
$$\delta_B^{DK} = (121.6_{-5.9}^{+5.6})^\circ$$

$$r_B^{D\pi} = 0.0064_{-0.0019}^{+0.0021}$$

$$\delta_B^{D\pi} = (311_{-20}^{+17})^\circ$$

This is the **most precise single direct measurement of γ** and agrees with world averages.

Comparison with previous binned work



- 5% smaller statistical uncertainty
vs the same-sample binned refit
- Comparable LHCb systematics
- Smaller charm-input uncertainty
BESIII Data: $3 \rightarrow 8 \text{ fb}^{-1}$

Summary and outlook



This work

$$\gamma = (71.3 \pm 5.0)^\circ$$

LHCb 9 fb^{-1} + BESIII 8 fb^{-1}

Optimal Fourier weights



Full-sample projection

$$\sigma_\gamma \approx 2.2^\circ$$

LHCb 37 fb^{-1} + BESIII 20 fb^{-1}

Current Fourier orders



Further gains

$$\sigma_\gamma < 2.2^\circ ?$$

Same LHCb and BESIII data

Higher Fourier orders/other methods?

Thank you for your attention!

References

BESIII and LHCb, Precise γ measurement with a novel approach.
[arXiv:2604.05712](#)

BESIII and LHCb, γ in $B^\pm \rightarrow D(K_S^0 h'^+ h'^-) h^\pm$ with a novel approach.
[arXiv:2604.05701](#)

LHCb, Measurement of the CKM angle γ in $B^\pm \rightarrow DK^\pm$ and $B^\pm \rightarrow D\pi^\pm$ decays with $D \rightarrow K_S^0 h^+ h^-$.
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Uncertainty breakdown: S. Malde, RAL seminar (2020), p. 64

J. Brod and J. Zupan, Ultimate theoretical error on γ from $B \rightarrow DK$.
[JHEP 01 \(2014\) 051](#) · [arXiv:1308.5663](#)

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LHCb, γ in partially reconstructed $B^\pm \rightarrow D^* h^\pm$ decays.
[JHEP 02 \(2024\) 118](#) · [arXiv:2311.10434](#)

LHCb, γ in $B^\pm \rightarrow DK^{*\pm}$ decays.
[JHEP 02 \(2025\) 113](#) · [arXiv:2410.21115](#)

LHCb, CP asymmetry in $B_s^0 \rightarrow D_s^\mp K^\pm$.
[JHEP 03 \(2025\) 139](#) · [arXiv:2412.14074](#)

CKM constraints: LHCb-CONF-2025-003.
Value: [A. Bertolin, DIS2026, p. 9](#) · Plot: [CKMfitter 2025 status](#)

LHCb recorded luminosity: J. He, DPS overview (12 Jan. 2026); LHCb run summary (27 May 2026).
[Overview, p. 3](#) · [Official run summary](#)

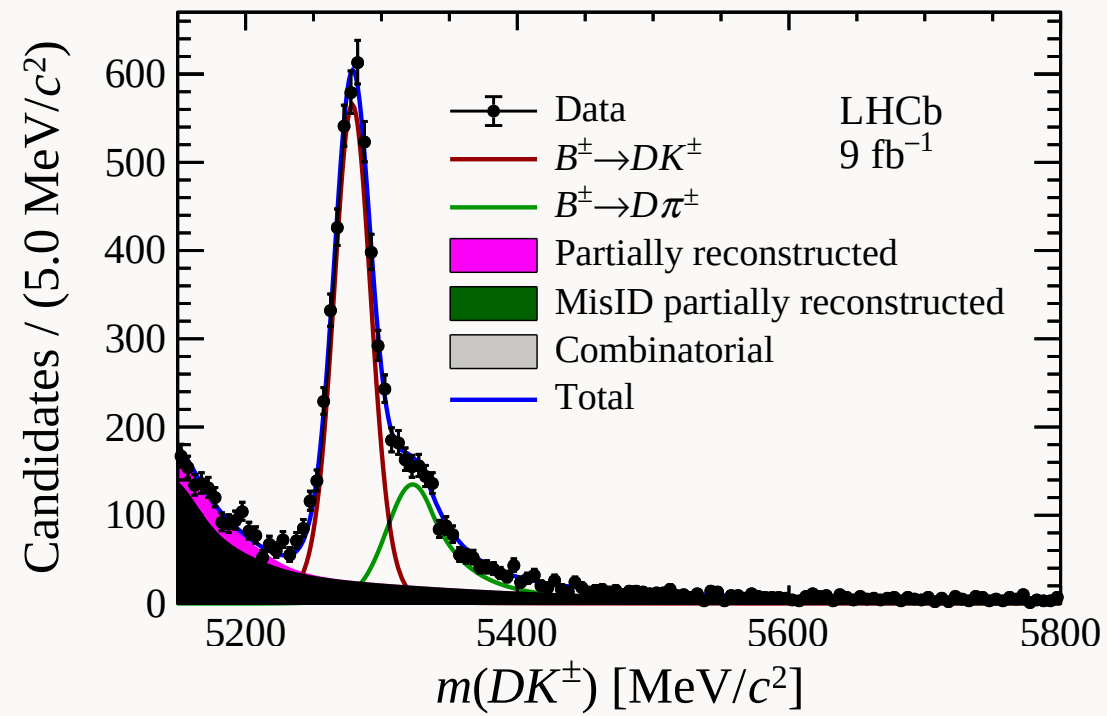
BESIII, Luminosity of e^+e^- data taken at $\sqrt{s} = 3.773$ GeV.
[arXiv:2406.05827](#)

Backup

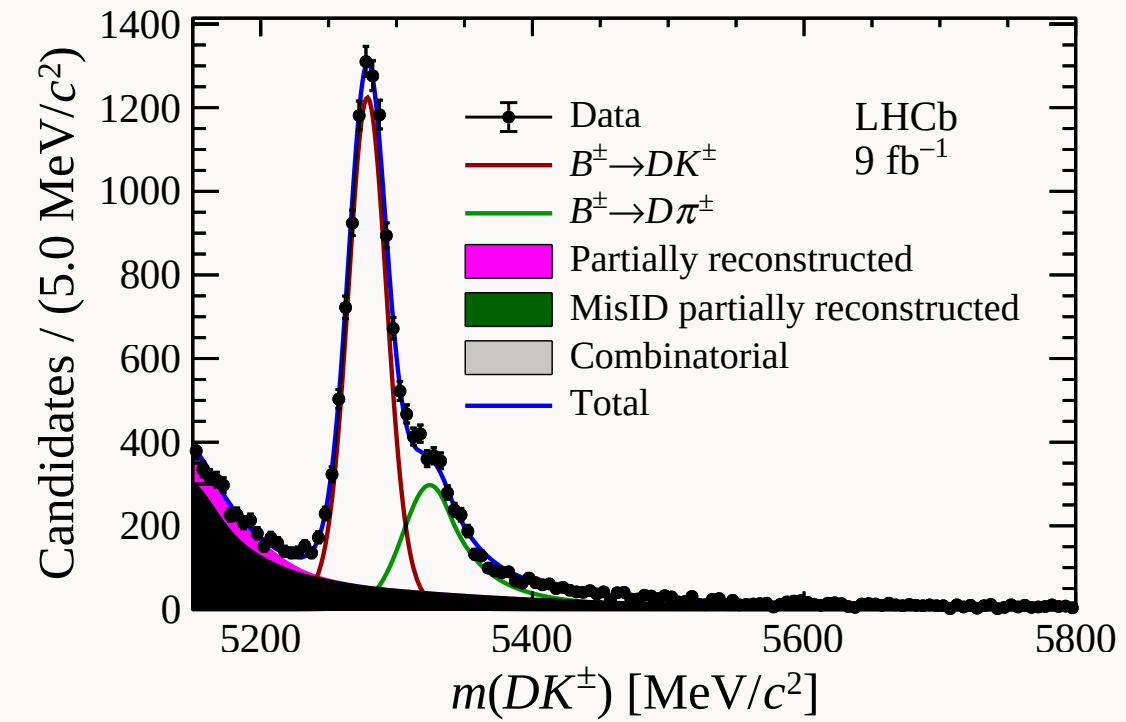
LHCb signal extraction

LHCb $9 \text{ fb}^{-1} \cdot B^{\pm} \rightarrow DK^{\pm}$

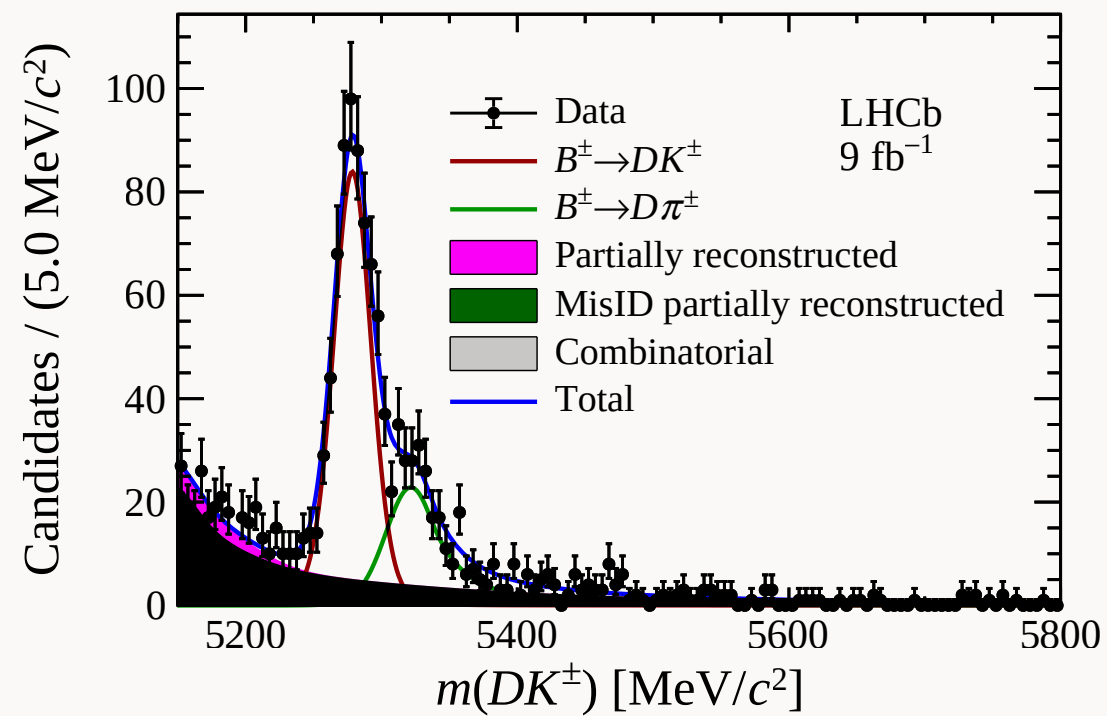
$D \rightarrow K_S^0 \pi^+ \pi^- \cdot \text{Long}$



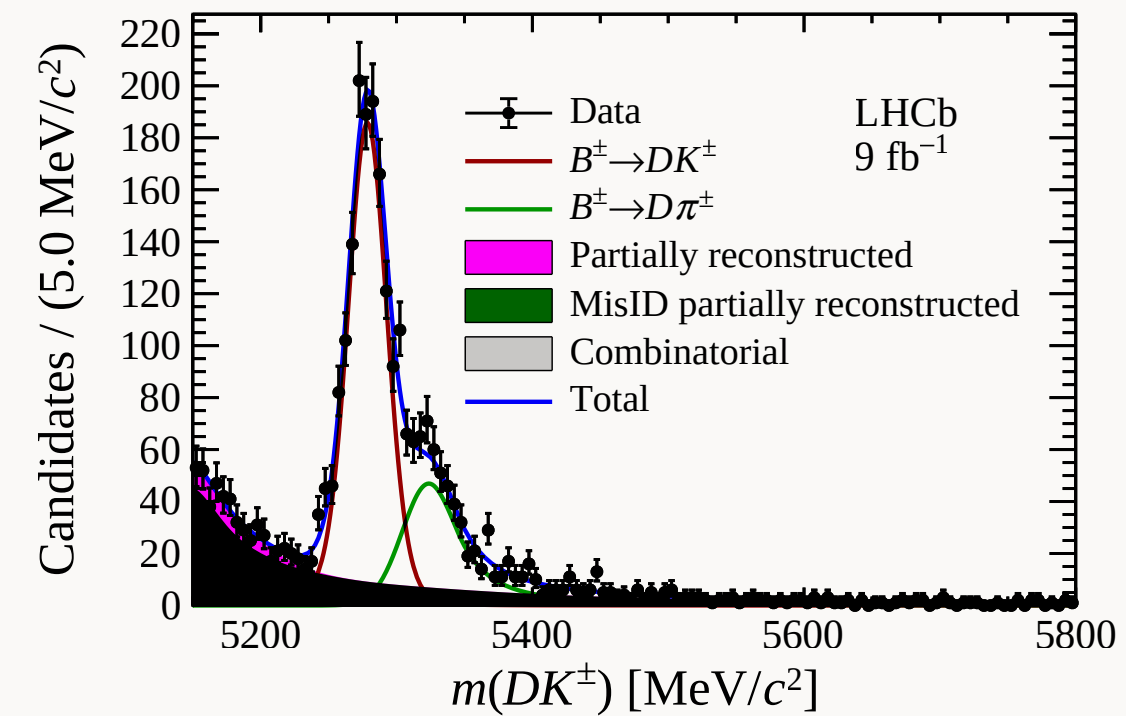
$D \rightarrow K_S^0 \pi^+ \pi^- \cdot \text{Downstream}$



$D \rightarrow K_S^0 K^+ K^- \cdot \text{Long}$

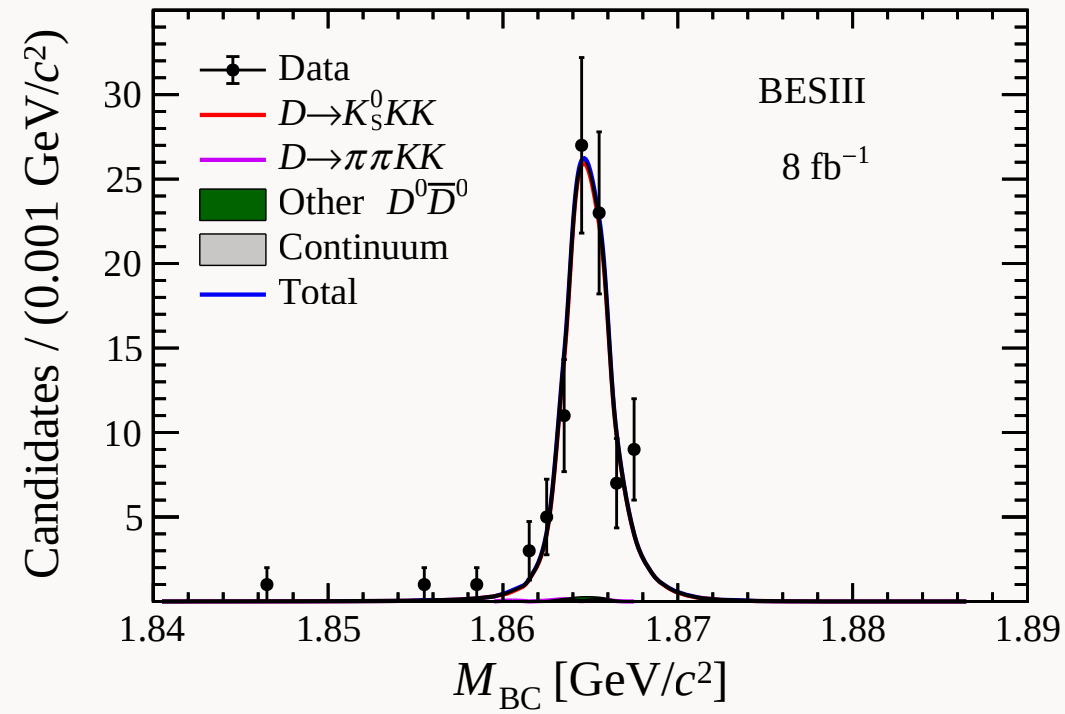
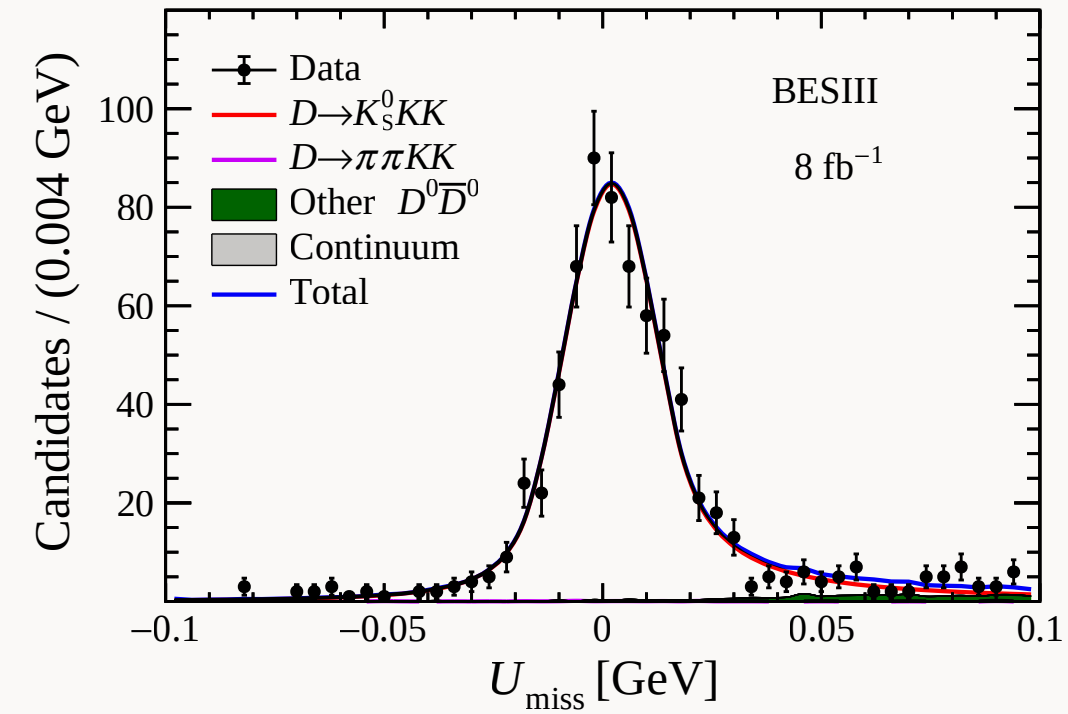
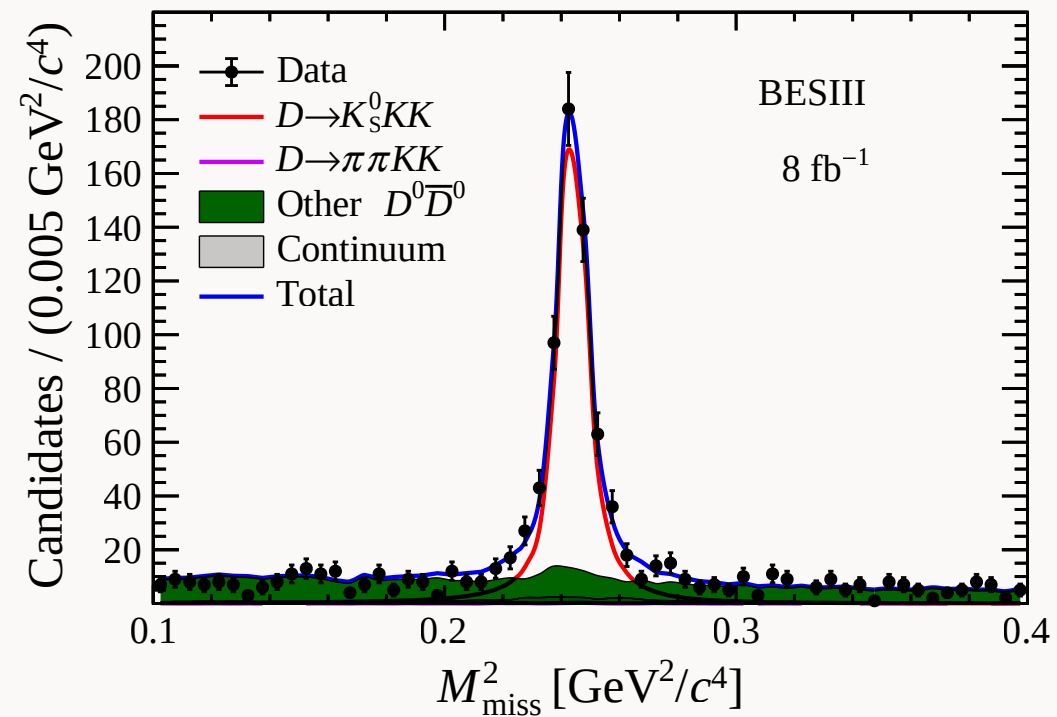
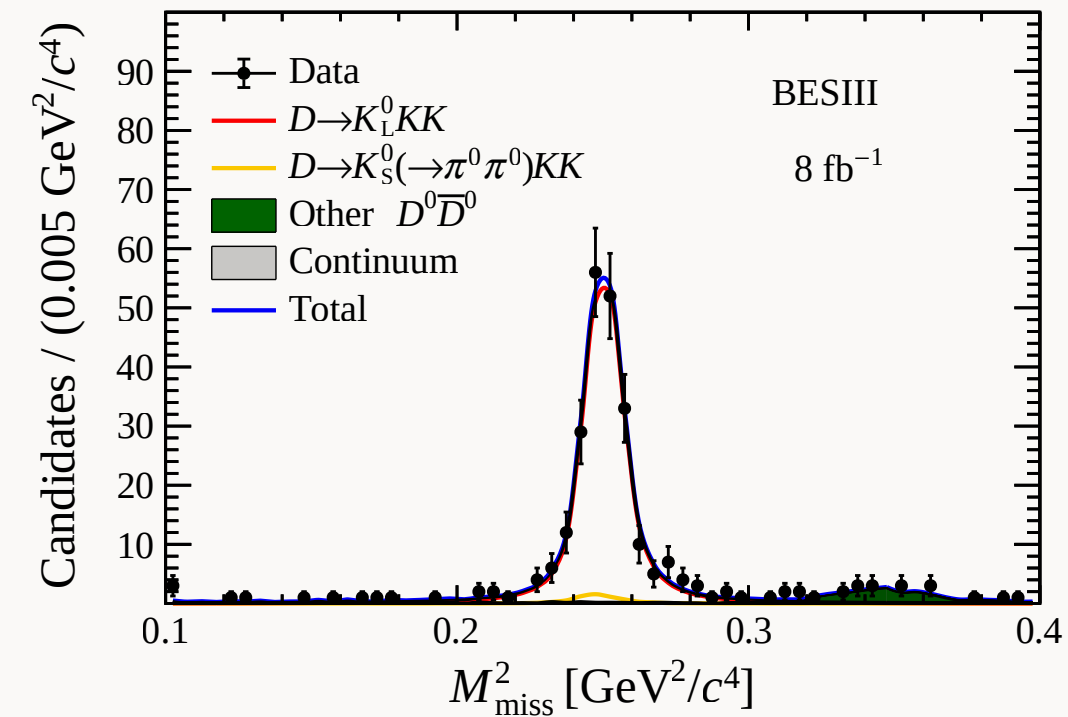


$D \rightarrow K_S^0 K^+ K^- \cdot \text{Downstream}$

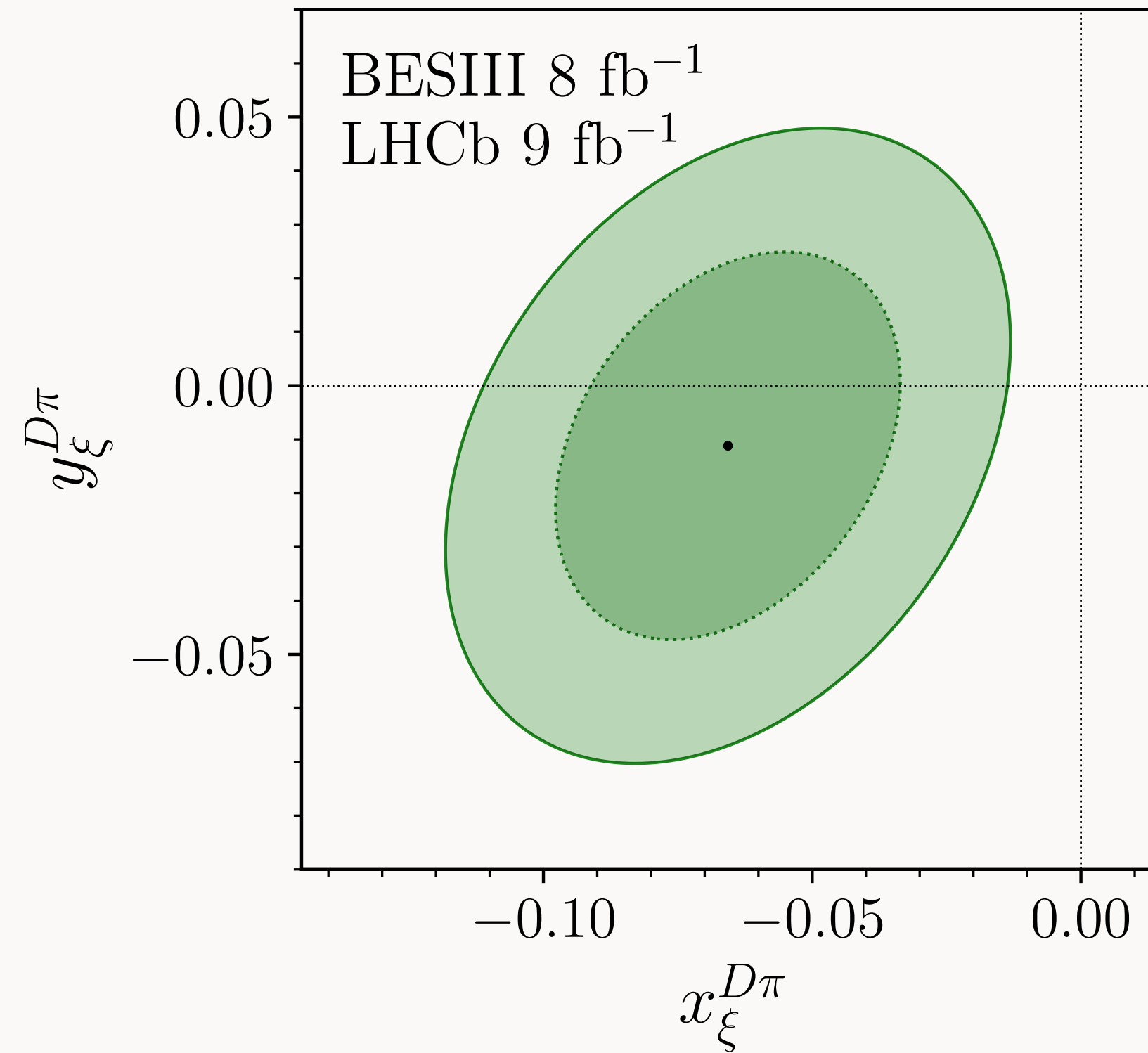


BESIII signal extraction

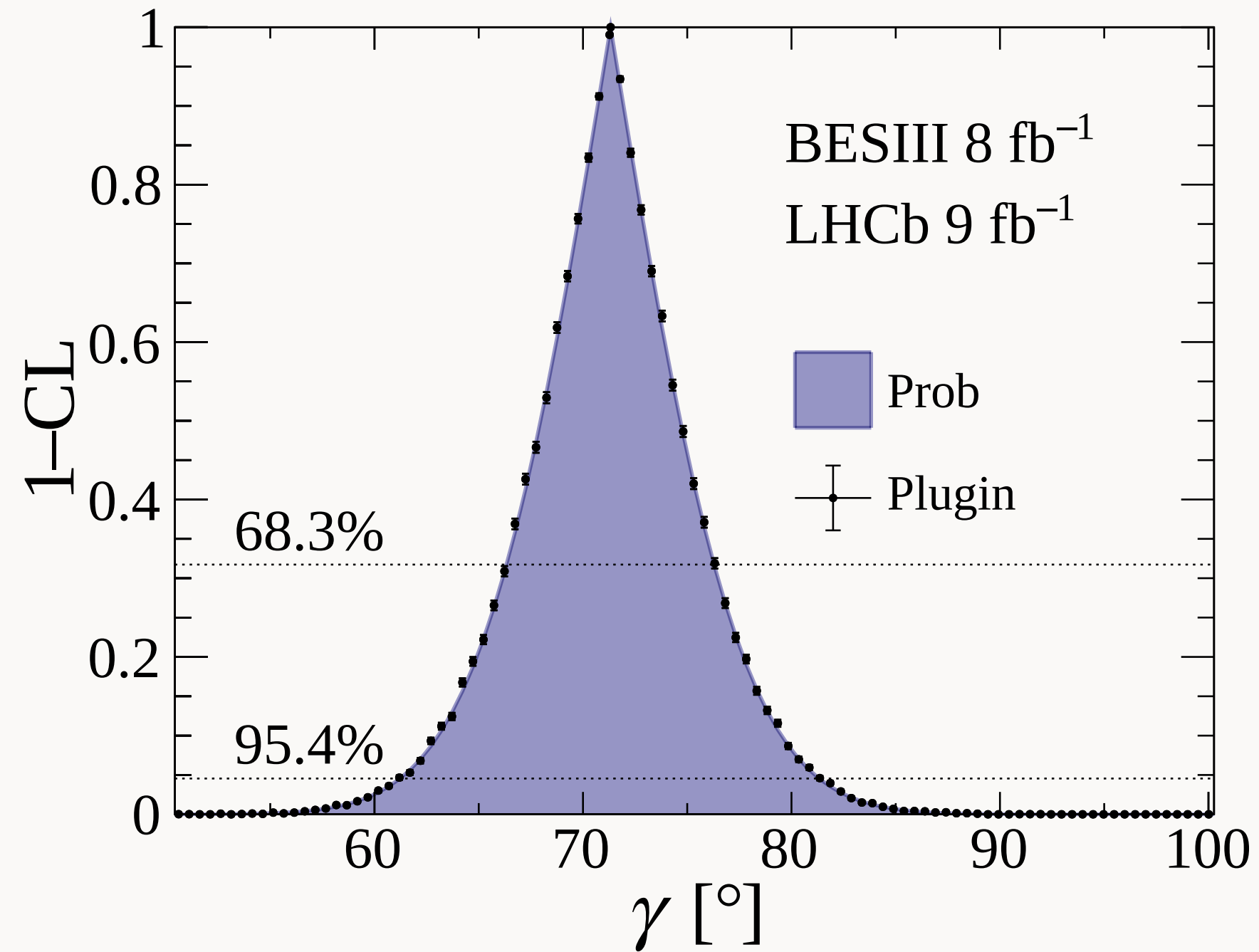
BESIII 8 fb^{-1} · Representative double-tag samples



The $D\pi/DK$ amplitude ratio

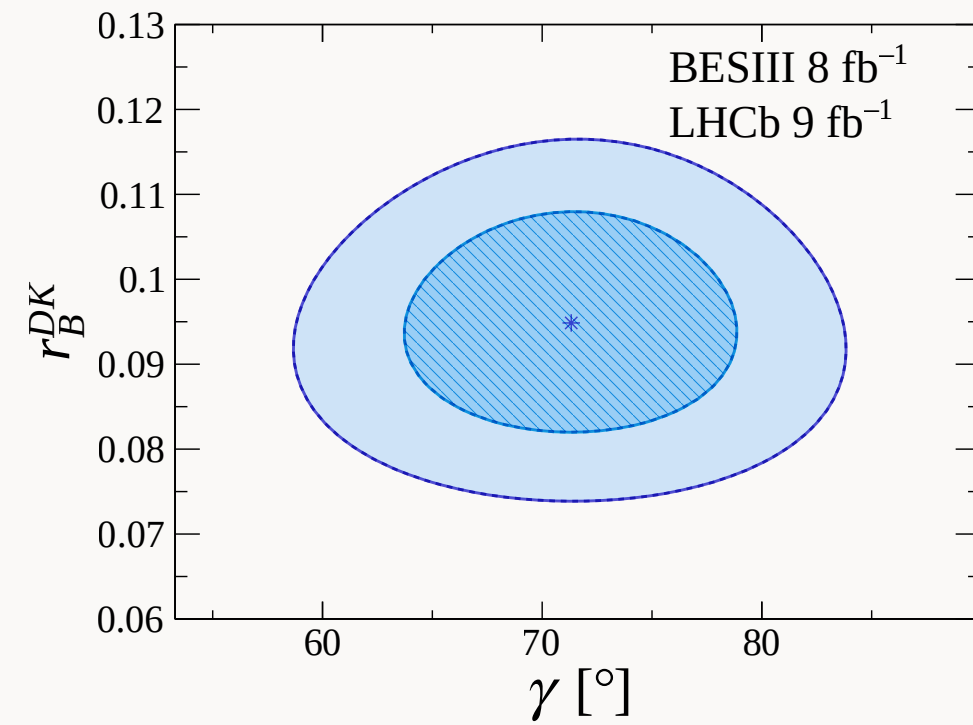
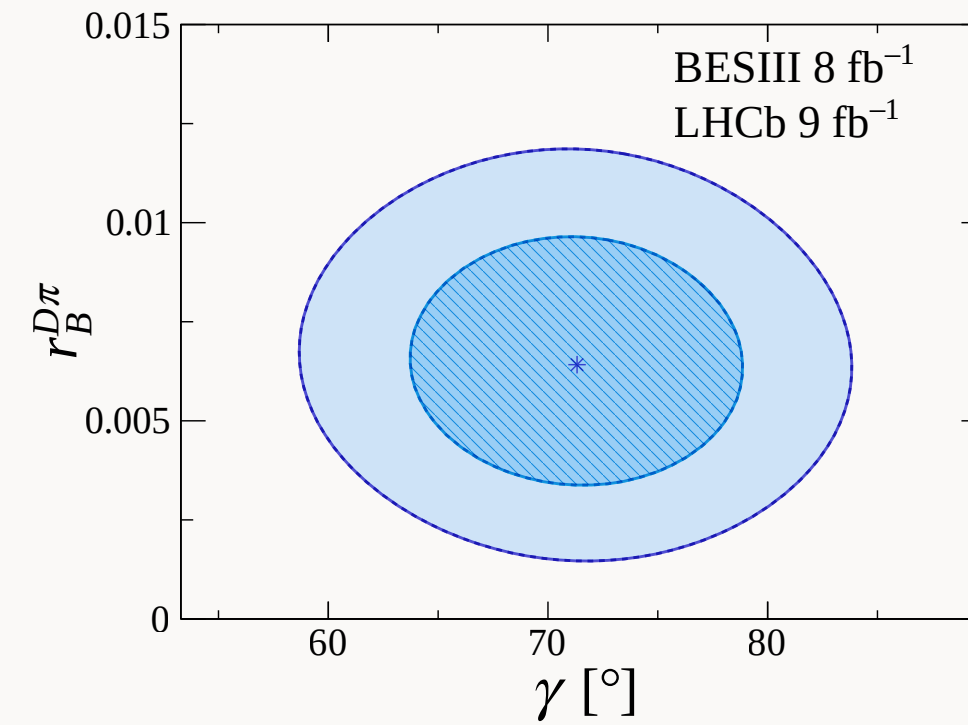
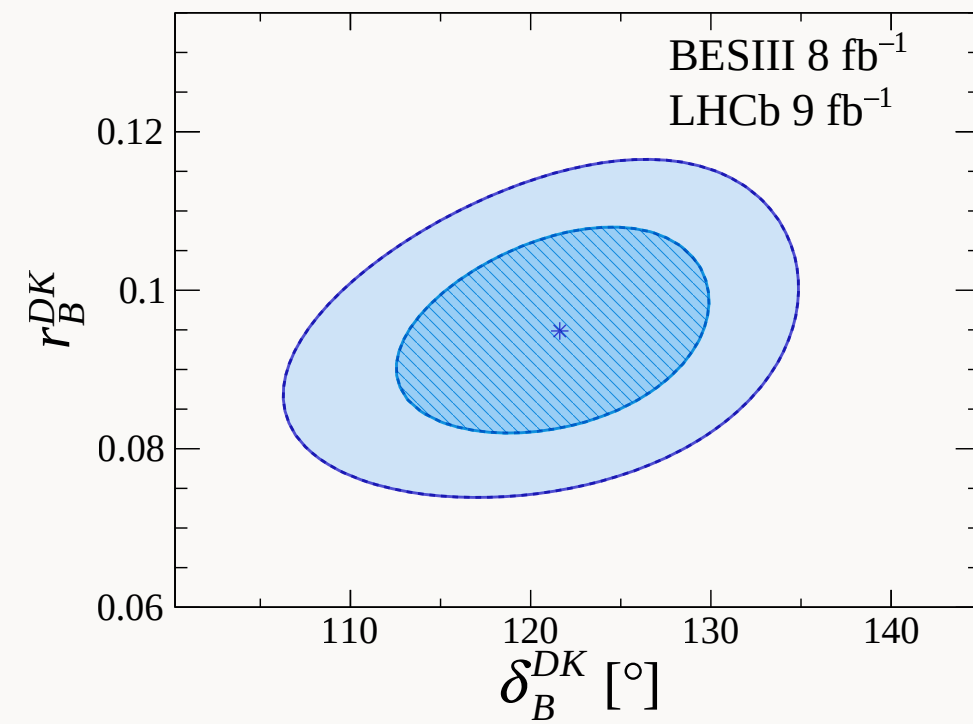
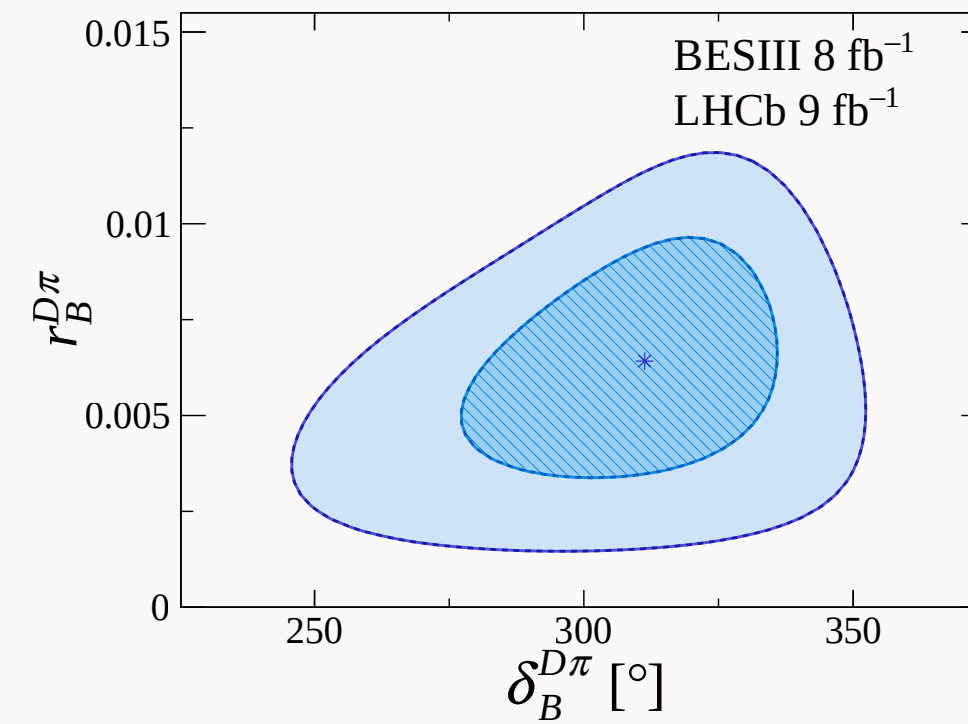


Confidence interval for γ



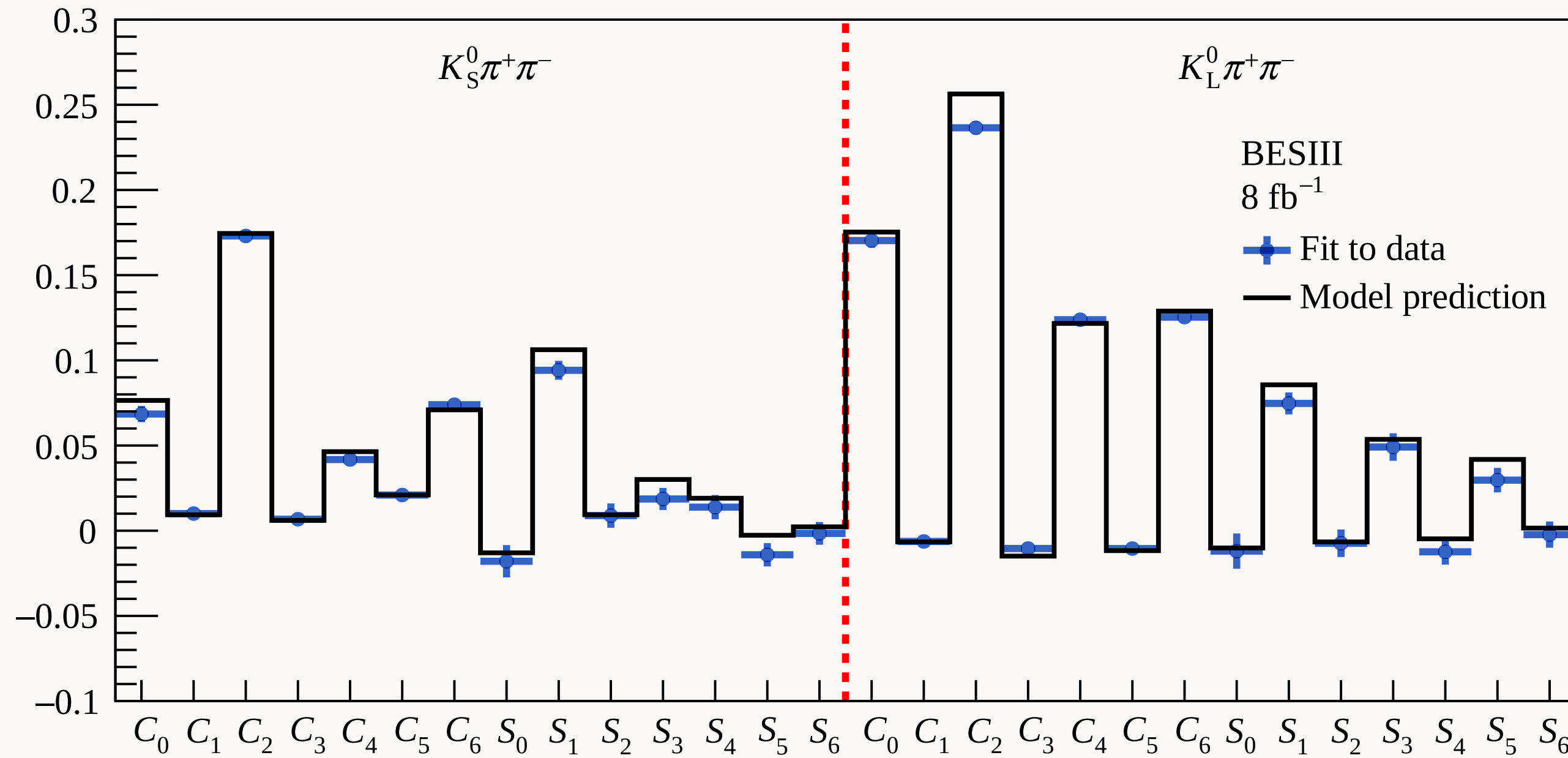
Correlations and hadronic parameters

68% and 95% confidence regions



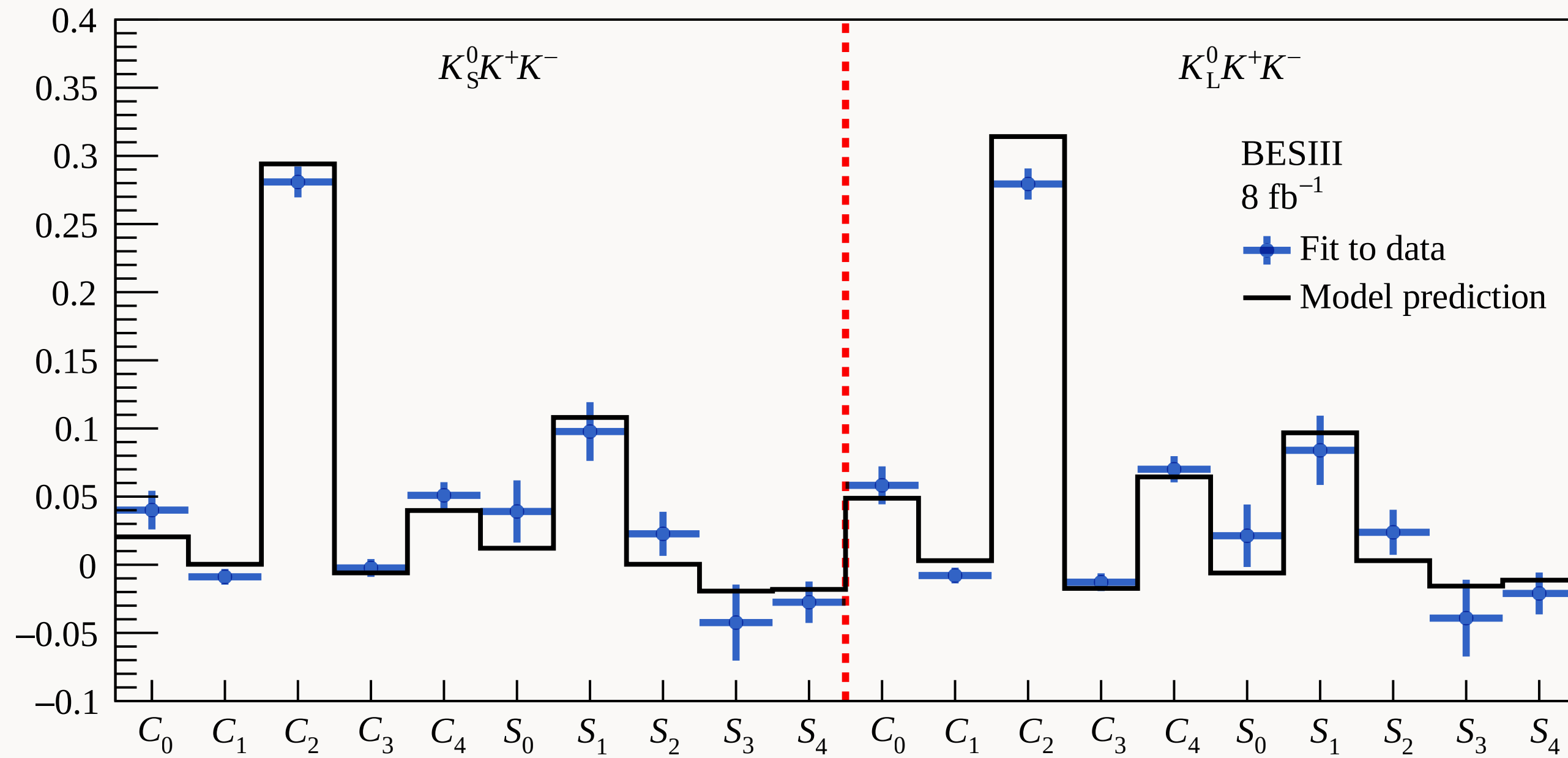
Charm strong-phase moments: $\pi\pi$

BESIII-only fit $\cdot M_\pi = 3, M_K = 2$



Charm strong-phase moments: KK

BESIII-only fit $\cdot M_\pi = 3, M_K = 2$



Results at different Fourier orders

LHCb statistical uncertainties only

