Study of the $B^0_{(s)} \to \bar{D}^{(*)0} K K$ decays at LHCb

D. Ao, D. Decamp, H. Sazak, W. Qian, S. Ricciardi, V. Tisserand,
S. T'Jampens, Z. Wang, Z.Xu, Z. Yang, S. Zhang, X. Zhou

On behalf of the LHCb Collaboration

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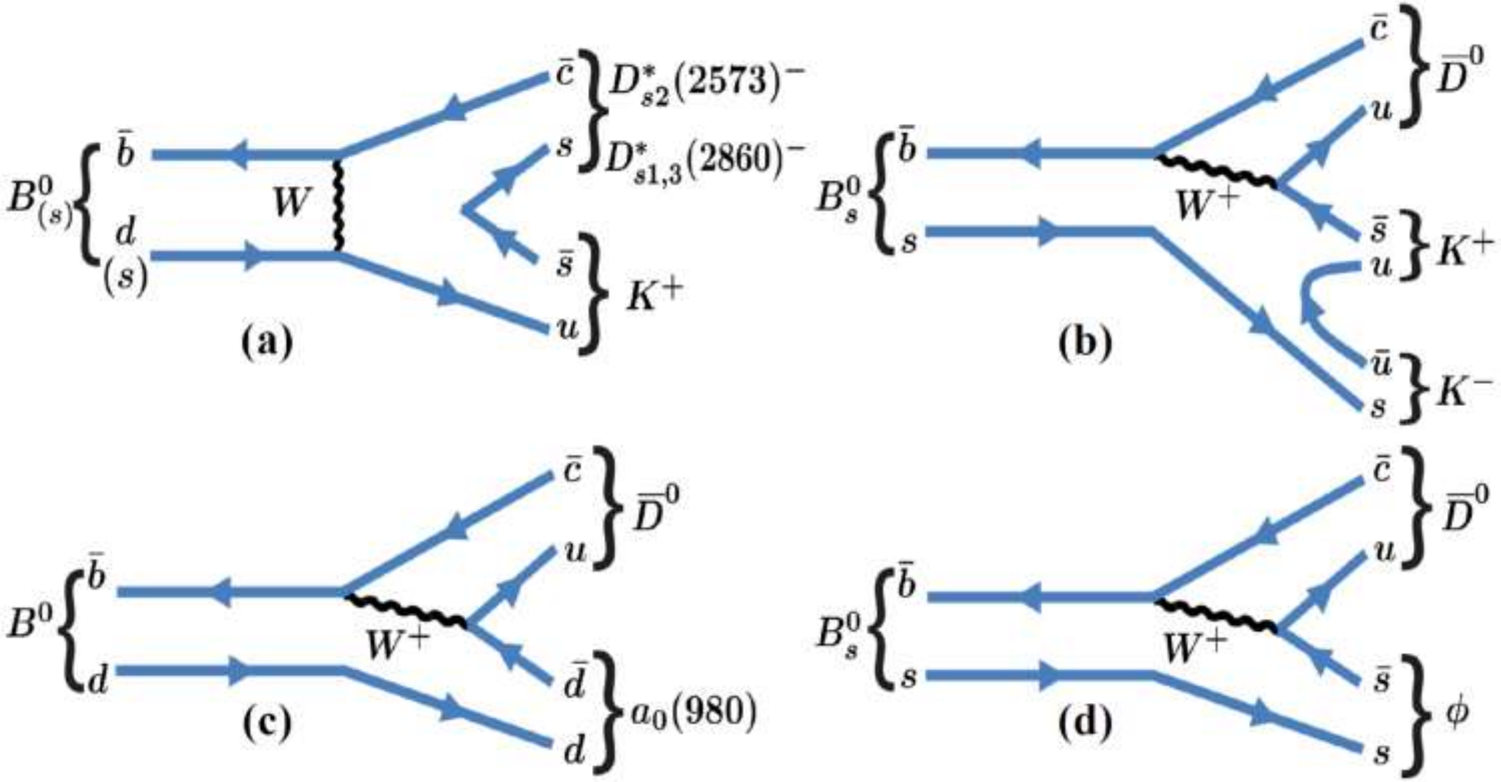
Content

- Motivation
- Improved measurements on $B^0_{(s)} \to \bar{D}^{(*)0}\phi$
- Measure γ via $B^0_s \to \bar{D}^{(*)0}\phi$ mode
- Observation of the decay $B^0_{(s)} \to D_{s1}(2536)^{\mp}K^{\pm}$
- Dalitz analysis of $B^0/B^0_{(s)} \to \bar{D}^0 KK$
- Summary

Physics with/of $B^0_{(s)} \to \bar{D}^0 KK$ decays

- **Time-Dependent Dalitz analyses** can be used to access CKM angles γ and to obtain clean determination of $\beta_{(s)}$ in $B_{(s)} - \bar{B}_{(s)}$ mixing (*Phys. Rev. D85(2012)114015*)
- **Rich phenomenology of Dalitz structures** are interesting for exited D_s** charmed B-decays spectroscopy studies

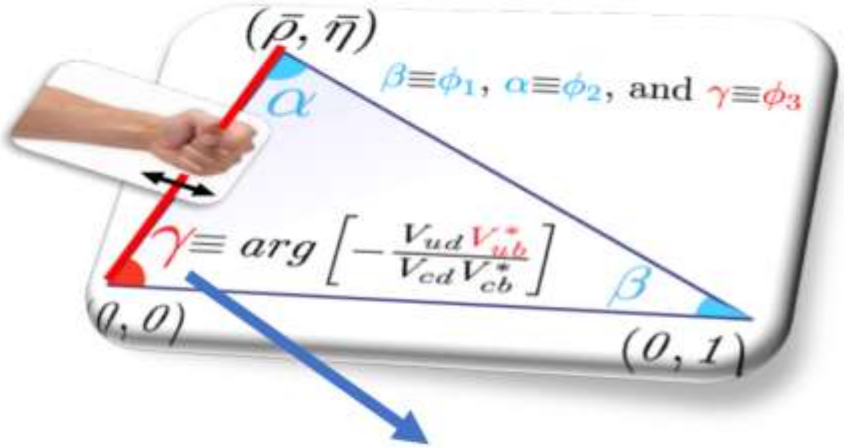


- Previous Studies:
  - Measurements performed with 3/fb (Run1:2011+2012): (*Phys. Rev. D98(2018)072006, 071103*)
  - γ sensitivity studies based on 9/fb (Run1+2): (*Chin. Phys. C45(2021) 023003*)

Precise measurement of the CKM angle γ

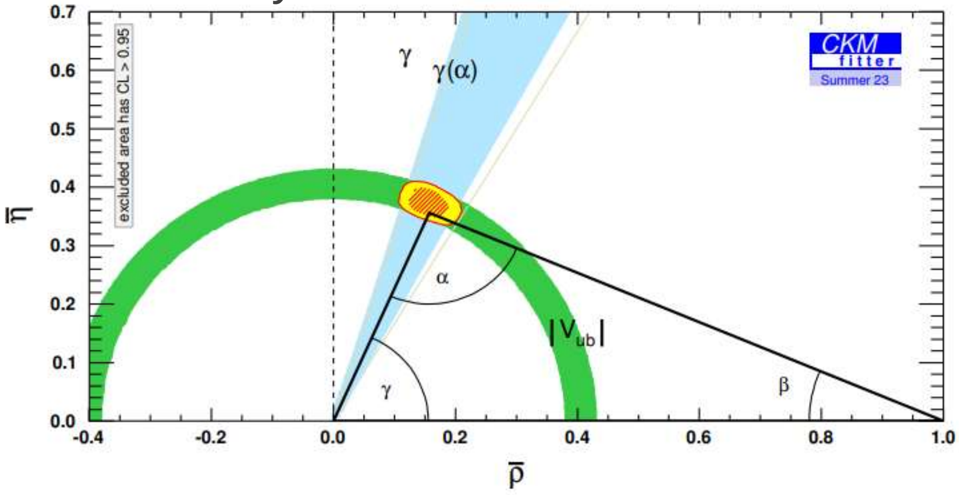
- Measure γ directly using **tree-level** decays
- Theoretically clean ($\delta\gamma/\gamma<10^{-7}$) (*JHEP 1401(2014)051*)
- HFLAV latest: $\gamma = (65.9^{+3.3}_{-3.5})^o$
- LHCb dominated: $\gamma = (63.8^{+3.5}_{-3.7})^o$(*LHCb-CONF-2022-003*)

- **Loop-level** (indirect measurement) is sensitive to New Physics
- CKMFitter latest: $\gamma = (66.3^{+0.7}_{-1.9})^o$

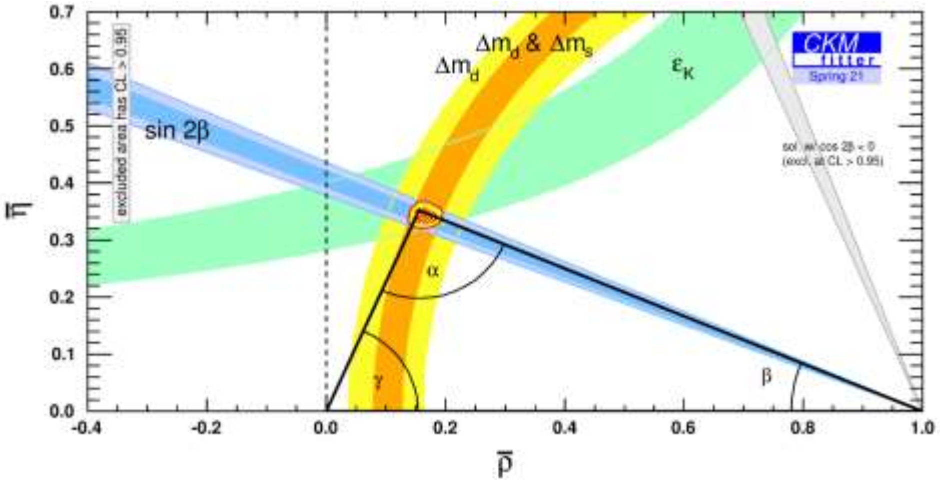


$$\gamma = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$$

Tree only



Loop only

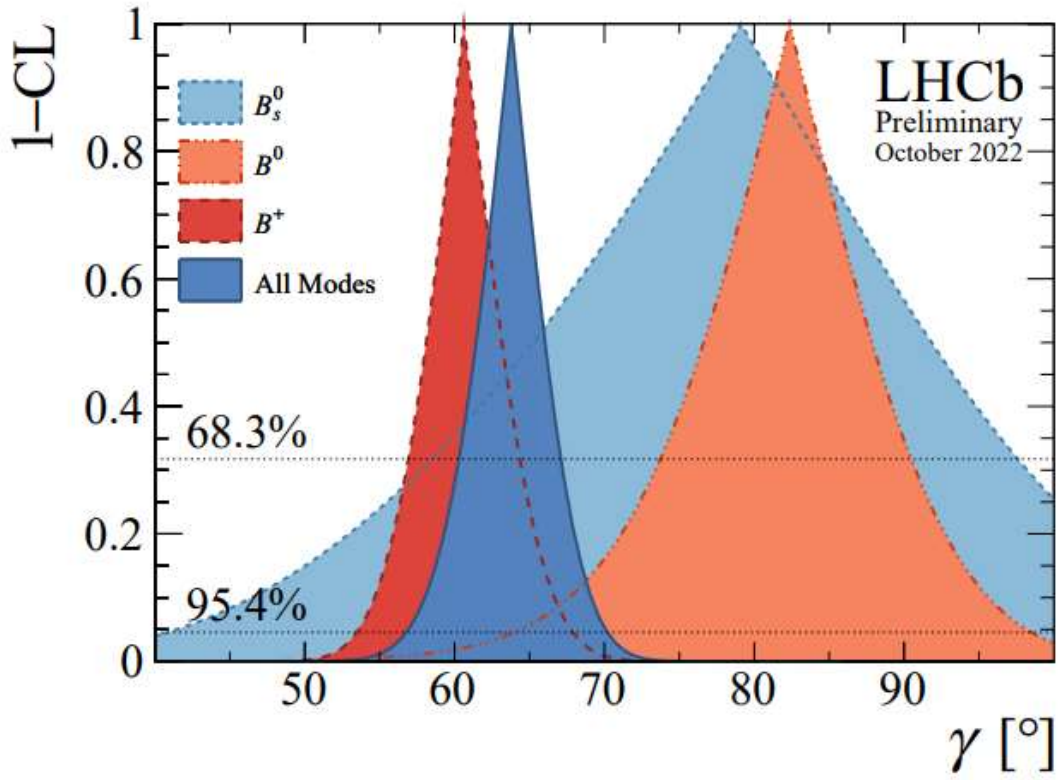


LHCb γ combination (LHCb-CONF-2022-003)

- Best knowledge of γ comes from combination of many measurements

- Largest uncertainty for γ in B_s^0 mode:
- $\boldsymbol{\gamma = (79^{+21}_{-24})^o}$
  - $B_s^0 \to D_s^{\mp} K^{\pm}$: $\gamma = (128^{+17}_{-22})^o$ (JHEP 03(2018)059)
  - **New!** Run2 result: $\gamma = (74 \pm 11)^o$ (LHCb-CONF-2023-004)
  - $B_s^0 \to D_s^{\mp} K^{\pm} \pi^{+} \pi^{-}$:$\gamma = (44 \pm 12)^o$ (JHEP 03(2021)137)

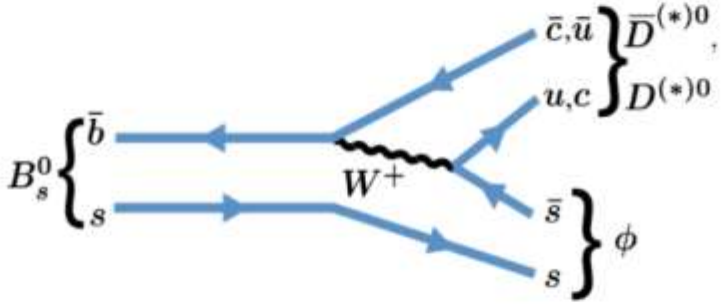
- Need more modes of B_s^0 constraint the γ errors in B_s^0 decay
  - γ sensitivity study in $B_s^0 \to D^{(*)0}\phi$: $8^o \sim 19^o$(9/fb) Chin. Phys. C45(2021) 023003



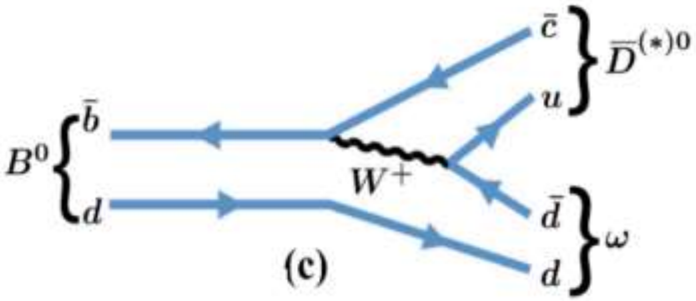
Improved measurements on $B^0_{(s)} \to D^{(*)0}\phi$

JHEP 10 (2023)123

Introduction of $B^0_{(s)} \to D^{(*)0}\phi$

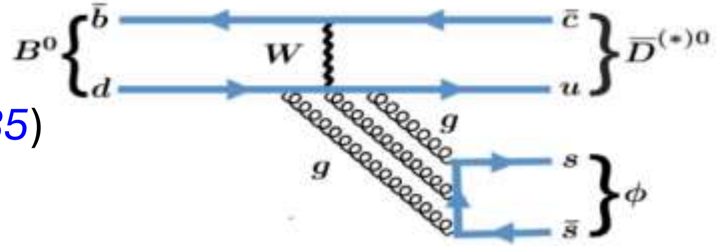


- $B^0_{(s)} \to D^{(*)0}\phi$ can proceed by $b \to c$ or $b \to u$ process:
  - Color suppressed and proportional to λ^3
  - Measuring longitudinal polarisation (f_L) is particular interest
  - Can be used to determine γ



- $B^0 \to \bar{D}^{(*)0}\phi$ can proceed by:
  - OZI suppress, W-exchange decay
  - Observed in charmonium decays (*Phys. Rev. D 99 (2019) 012015*)

    but not in b-hardon decays (*Chin. Phys. C45(2021) 043001*)
  - Theoretical predict $B(B^0 \to \bar{D}^0\phi) \sim 1.6 \times 10^{-6}$ (*Phys. Lett. B 666(2008) 185*)
  - Upper limit in previous work: $B(B^0 \to \bar{D}^0\phi) < 2.0(2.3) \times 10^{-6}$ at 90%(95%) CL
  - Help to extract $\omega - \phi$ mixing angle



Branching fraction measurements of $B^0_{(s)} \to \bar{D}^{(*)0}\phi$

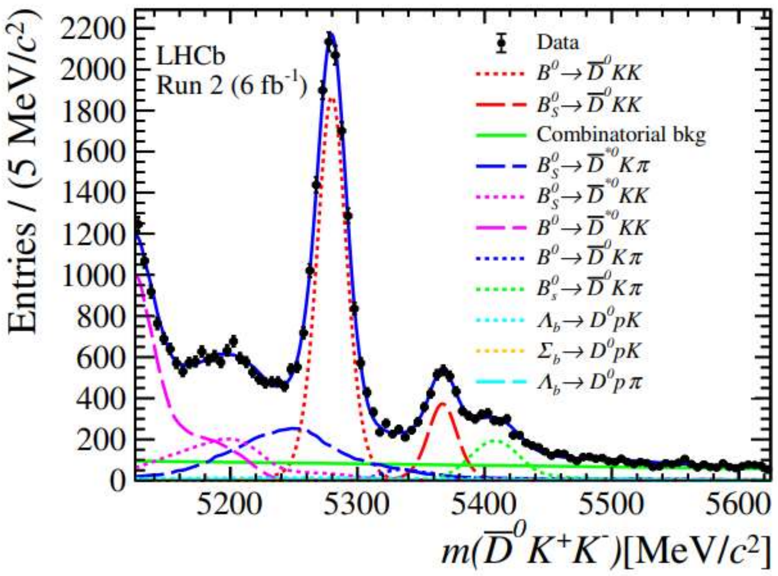
JHEP 10 (2023)123

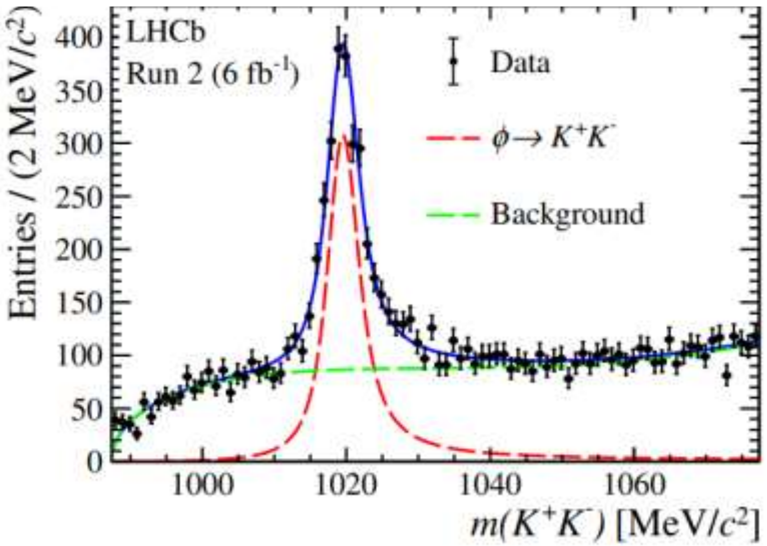
- All Run1+Run2 data (~9/fb) used

- $B^0 \to \bar{D}^0 KK$: normalized mode

- Very similar study strategy to the previous Run1 work (*Phys. Rev. D98(2018)072006, 071103*)
  - sPlot technique is used to extract ϕ signal
  - Partial reconstruction for $\bar{D}^{(*)0}$
  - Different shapes for transverse/longitudinal $D^{*0} \to \gamma/\pi^0 D^0$ from MC simulation

- Optimised the selection criteria → Efficiencies and yields improved ~30% with almost similar background level





Result of $B^0_{(s)} \to \overline{D}^{(*)0}\phi$

ArXiv: 2306.02768
JHEP accepted

- Evidence for $B^0 \to \overline{D}^{(*)0}\phi$ is reported

$$\mathcal{B}(B^0 \to \overline{D}^0\phi) = (7.7 \pm 2.1 \pm 0.7 \pm 0.7) \times 10^{-7}, \quad 3.6\sigma$$
$$\mathcal{B}(B^0 \to \overline{D}^{*0}\phi) = (2.2 \pm 0.5 \pm 0.2 \pm 0.2) \times 10^{-6}. \quad 4.3\sigma$$
$$\mathcal{B}(B^0_s \to \overline{D}^0\phi) = (2.30 \pm 0.10 \pm 0.11 \pm 0.20) \times 10^{-5},$$
$$\mathcal{B}(B^0_s \to \overline{D}^{*0}\phi) = (3.17 \pm 0.16 \pm 0.17 \pm 0.27) \times 10^{-5}.$$

- The fraction of longitudinal polarisation

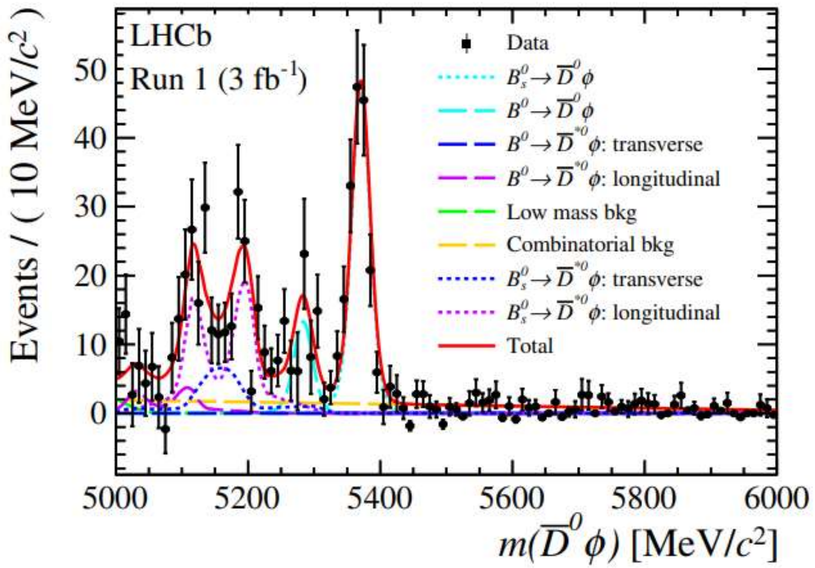
$$f_L(B^0_s \to \overline{D}^{*0}\phi) = (53.1 \pm 6.0 \pm 1.9)\%$$

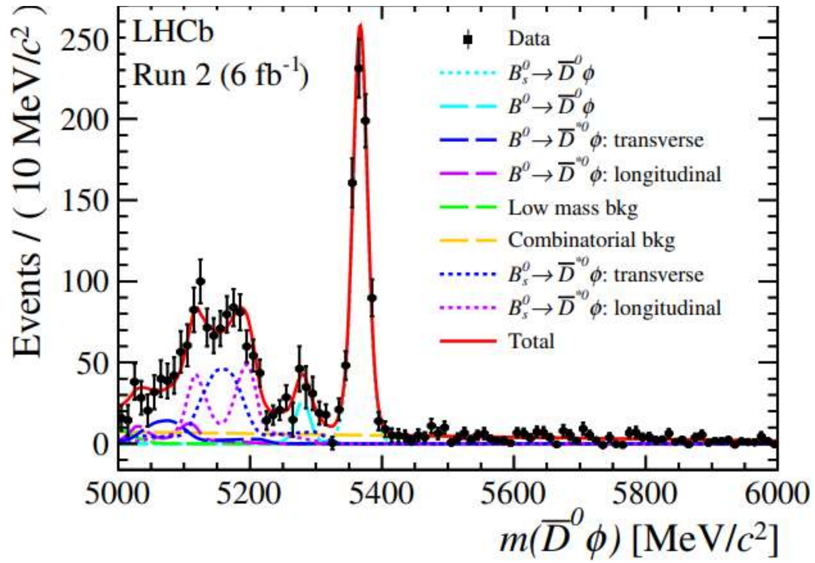
- Combining the branching fraction of $B^0 \to \overline{D}^{(*)0}\omega$, $\omega - \phi$ mixing angle determined:

$$\tan^2\delta = (3.6 \pm 0.7 \pm 0.4) \times 10^{-3}$$

Consistent with the theoretical prediction (*Phys. Lett. B 666(2008) 185*)

All the results are consistent with, and supersede the previous LHCb measurement



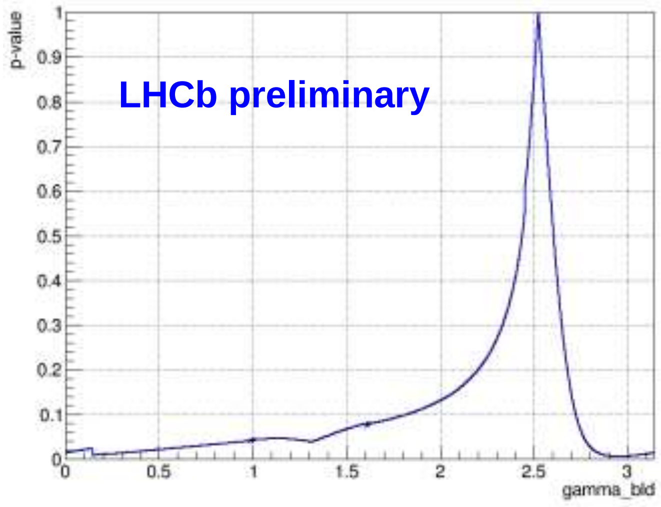


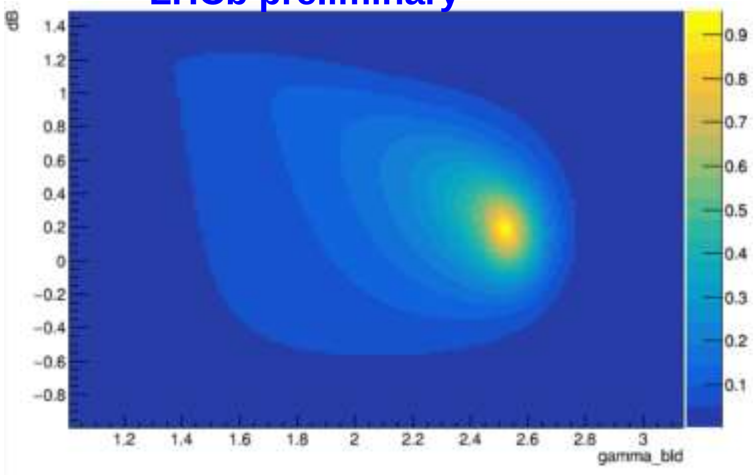
Measure γ via $B_s^0 \to \bar{D}^{(*)0}\phi$ mode (ongoing)

- Flavor mode: $D^0 \to K^-\pi^+/K^-\pi^+\pi^-\pi^+/K^-\pi^+\pi^0$
  - π^0 reconstruction is challenging in LHCb
- CP-even mode: $D^0 \to K^+K^-/\pi^+\pi^-$
  - $D^0 \to K_S^0 hh$ modes do not included due to lack of statistics
- More yields than expected due to optimisation
- Worse f_L, but dominated modes is $B_s^0 \to \bar{D}^0\phi$
- Blind analysis on-going , now only $B_s^0 \to \bar{D}^0\phi$ used

$$\gamma = (xxx^{+8}_{-16})^o$$

Consistent with the sensitivity study (*Chin. Phys. C45(2021) 023003*)





Search for the decay $B_{(s)}^0 \to D_{s1}(2536)^{\mp}K^{\pm}$

JHEP 10 (2023)106

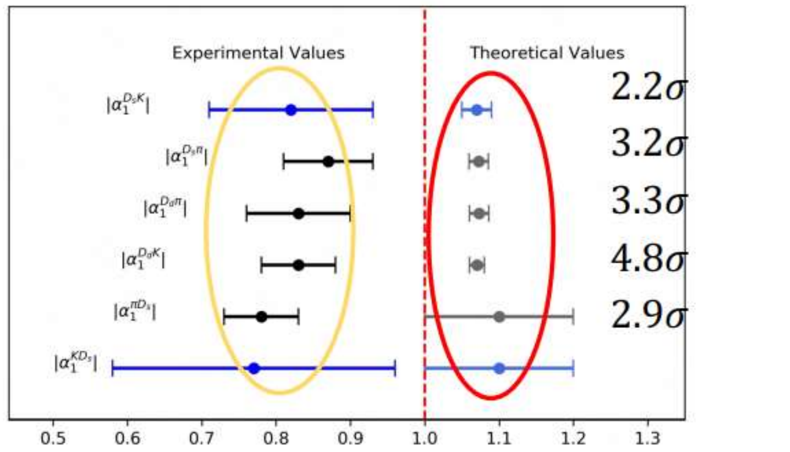
Search for the decay $B^0_{(s)} \to D_{s1}(2536)^{\mp} K^{\pm}$

- The puzzle in the decays $B^0 \to D^{(*)-}K^+$ and $B^0_s \to D^{(*)-}\pi^+$:
  - Their measured branching fractions smaller than those from calculation with QCD factorization. (*Phys. Rev. D 83 (2011) 014017*) (*Eur. Phys. J. C 80 (2020) 951*)

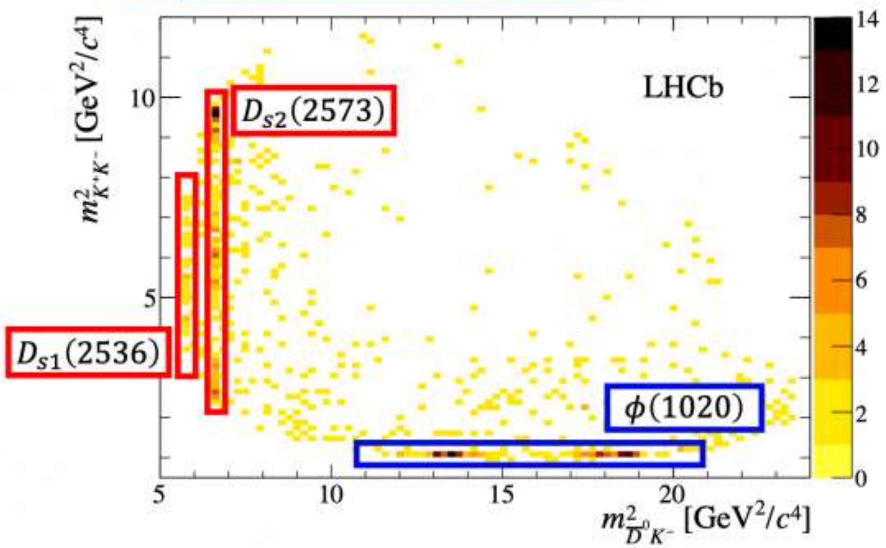
- An extension of previous $B^0_{(s)} \to \bar{D}^0 KK$ work
  - A significant peak corresponding to $D_{s1}(2536)$
  - $D_{s1}K$ decay mode not observed in $B^0_{(s)}$

- The B^0_s mode can process via both $b \to c$ and $b \to u$ transition – sensitive to CKM angle γ

- Probe γ from $B^0_s - \bar{B}^0_s$ mixing and decay, time dependent measurement



[Phys. Rev. D 106, 056004 (2022)]

[Phys. Rev. D98 072006 (2018)]


Observation of the decay $B^0_{(s)} \to D_{s1}(2536)^{\mp}K^{\pm}$

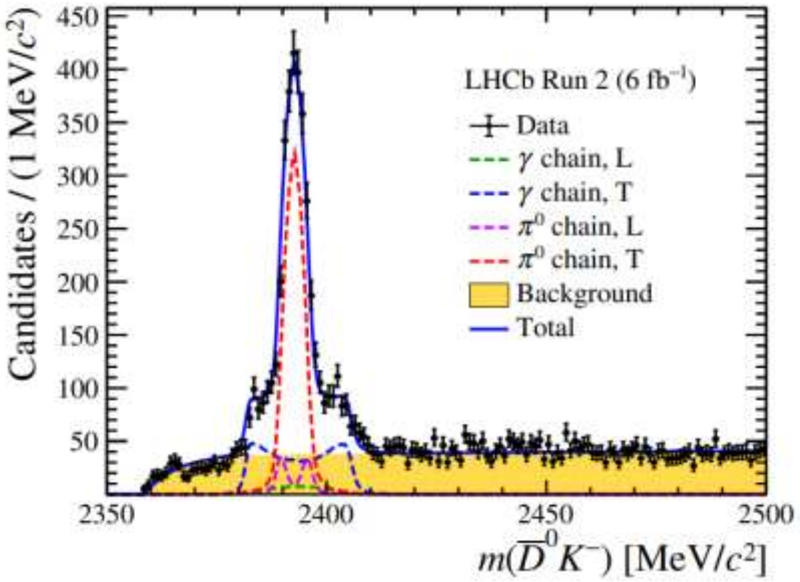
JHEP 10 (2023)106

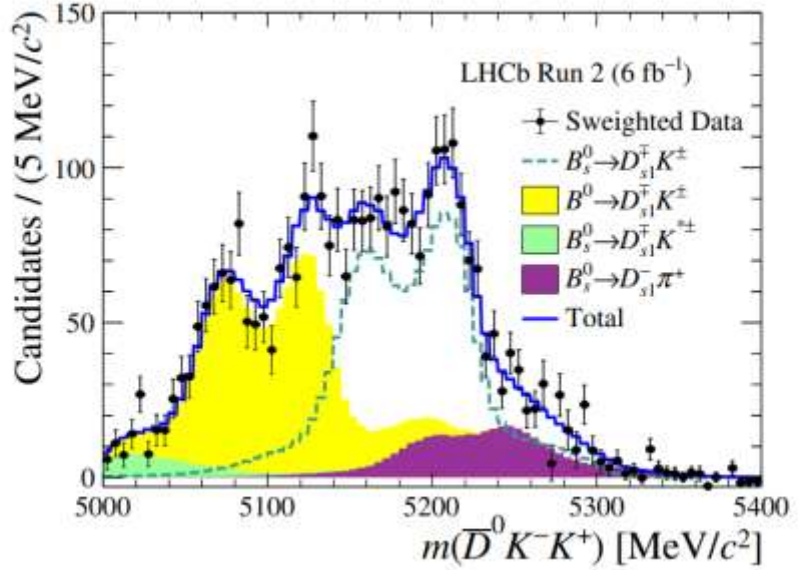
- All Run1+Run2 data (~9/fb) used
- sPlot technique is used to extract $D_{s1}(2536)$ signal
- Angular decay rates of signals are considered
- Simultaneous fit to Run1& Run2
- $B^0_{(s)} \to D_{s1}(2536)^{\mp}K^{\pm}$ observed:

$$\mathcal{B}(B^0_s \to D_{s1}(2536)^{\mp}K^{\pm}) \times \mathcal{B}(D_{s1}(2536)^- \to \overline{D}^*(2007)^0K^-) = (2.49 \pm 0.11 \pm 0.12 \pm 0.25 \pm 0.06) \times 10^{-5},$$

$$\mathcal{B}(B^0 \to D_{s1}(2536)^{\mp}K^{\pm}) \times \mathcal{B}(D_{s1}(2536)^- \to \overline{D}^*(2007)^0K^-) = (0.510 \pm 0.021 \pm 0.036 \pm 0.050) \times 10^{-5}.$$

- Helicity-related parameters, fractions of S-wave component, etc. are also determined



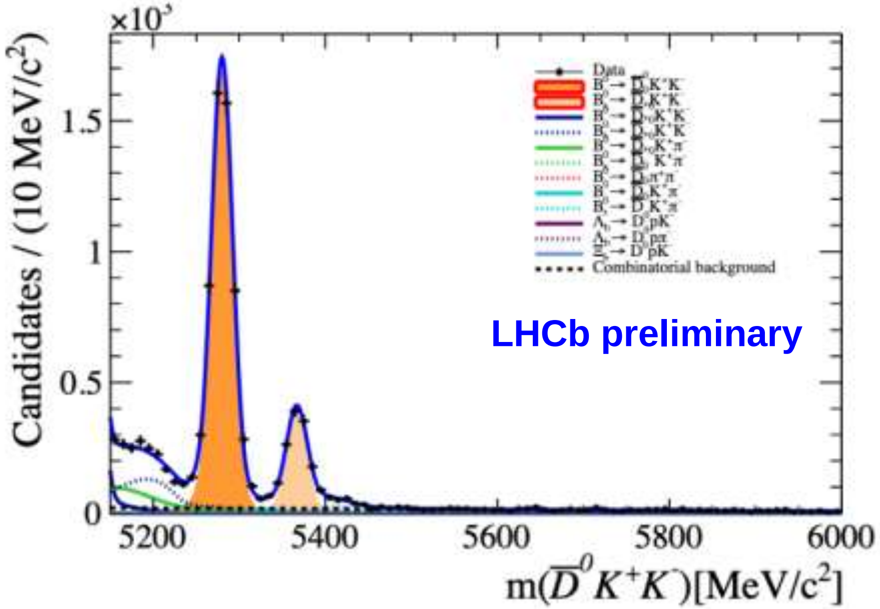


Dalitz analysis of $B^0/B^0_{(s)} \to \bar{D}^0 KK$ (ongoing)

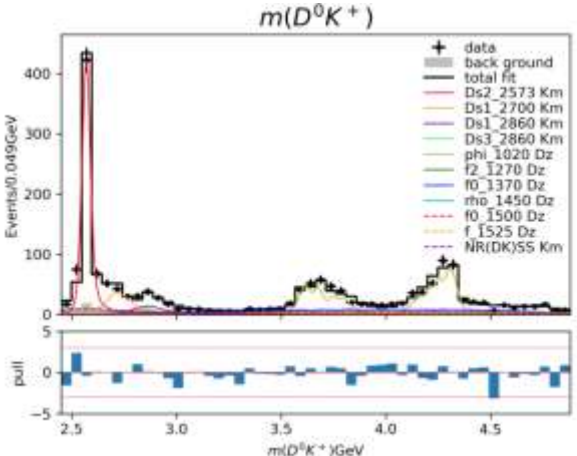
- Optimised the selection for high purity of signals (different optimizations for the two decay modes)
  - ~1500 signals with purity 83% for $B_s^0 \to \bar{D}^0 KK$
  - ~5000 signals with purity 93% for $B^0 \to \bar{D}^0 KK$

- Dalitz analyses of $B^0 \to \bar{D}^0 KK$ and $B_s^0 \to \bar{D}^0 KK$ are on-going

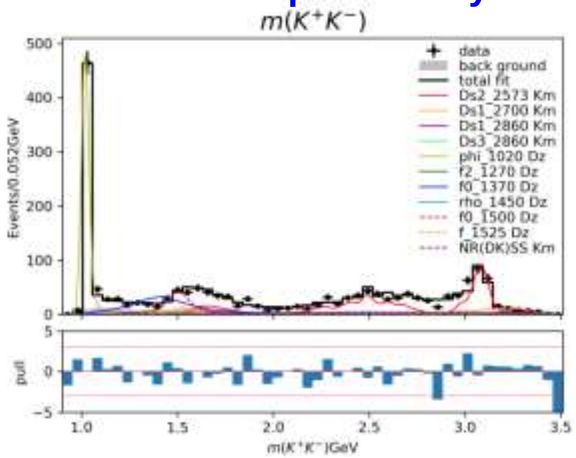
- $B_s^0 \to \bar{D}^0 KK$ for example:
  - $D^*_{s2}(2573)$, $D^*_{s1}(2700)$, $D^*_{s1}(2860)$, $D^*_{s3}(2860)$ and $\phi(1020)$ peaks are observed in the projection plots



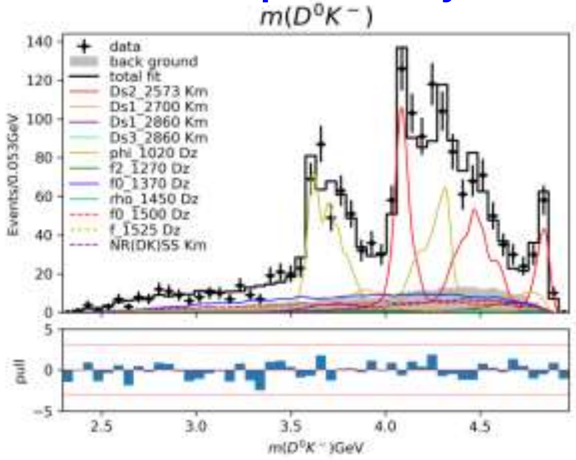
LHCb preliminary



LHCb preliminary



LHCb preliminary



Summary

- Two papers published in 2023 under FCPPL framework
  - Evidence for the decays $B^0 \to \overline{D}^{(*)0}\phi$ and updated measurement of the branching fractions of the $B_s^0 \to \overline{D}^{(*)0}\phi$ decays (*JHEP 10 (2023)123*)
  - Observation of the decay $B_{(s)}^0 \to D_{s1}(2536)^{\mp}K^{\pm}$ (*JHEP 10 (2023)106*)

- Work on-going on three analyses towards publication
  - Measure γ via $B_s^0 \to \overline{D}^{(*)0}\phi$ mode
  - Dalitz analyses of $B^0 \to \overline{D}^0 KK$
  - Dalitz analyses of $B_s^0 \to \overline{D}^0 KK$

- Future plan
  - Preparation and early study on Run3 data

Thank you!

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