

RECENT DEVELOPMENT IN $B_{(s)}^0 \rightarrow \bar{D}^{(*)0} KK$ DECAYS AT LHCb

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on behalf of the LHCb collaboration

April 24, 2019

FCPPL 2019



Science & Technology Facilities Council
Rutherford Appleton Laboratory



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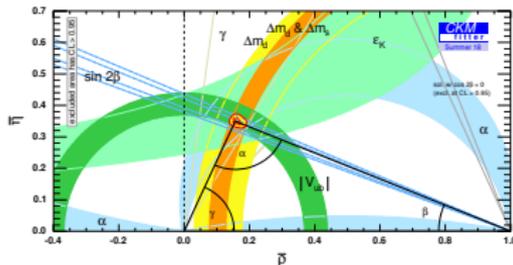
- CKM quark mixing matrix

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

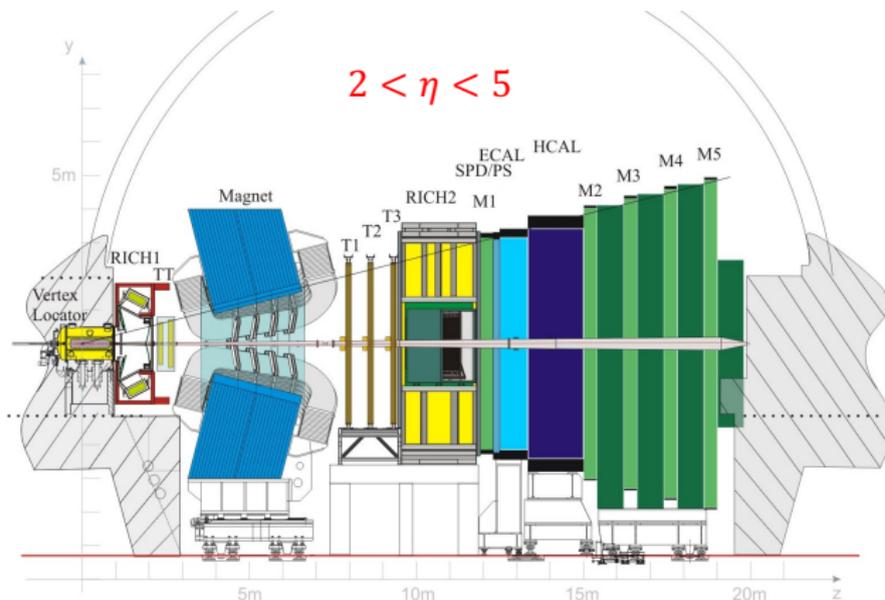
- Unitarity triangle: $\gamma = \arg \left[-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*} \right]$
- Current measurements

$\gamma_{\text{LHCb}} = (74.0^{+5.0}_{-5.8})^\circ$	}	LHCb dominates WA
$\gamma_{\text{WA}} = (71.1^{+4.6}_{-5.3})^\circ$		
$\gamma_{\text{ind.}} = (65.64^{+0.97}_{-3.42})^\circ$		

- A sub-degree precision of γ is needed to test SM and probe NP

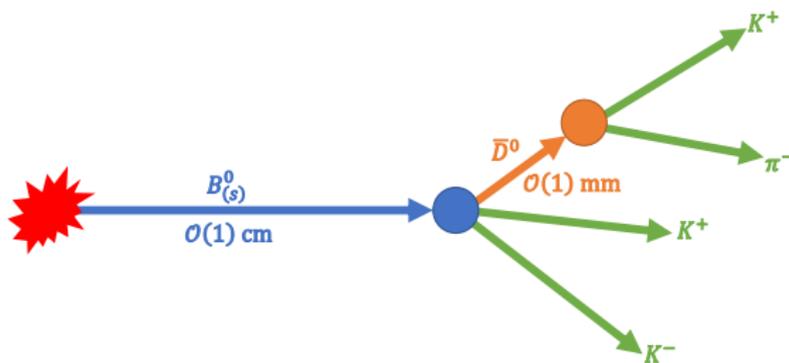


[CKMfitter, ICHEP 2018]

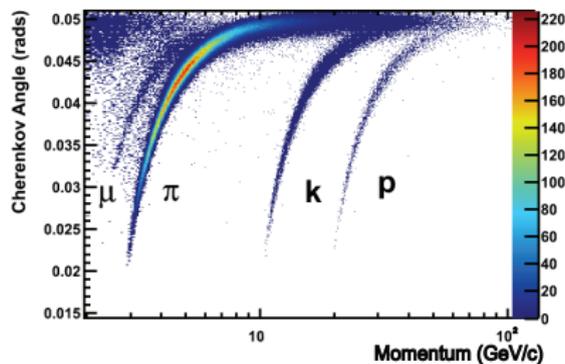


[JINST 3 (2008) S08005, Int. J. Mod. Phys. A 30 (2015) 1530022]

- High-precision tracking system, distinguish displaced vertices
- Efficient distinction for charged hadrons, high performance PID



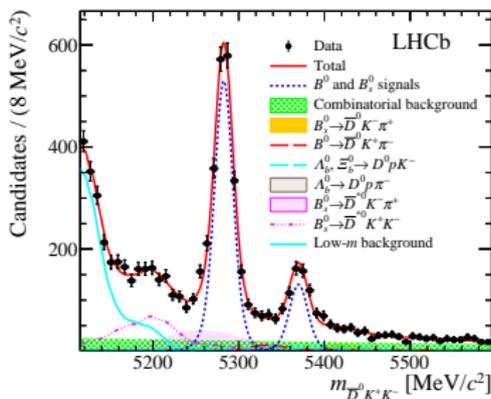
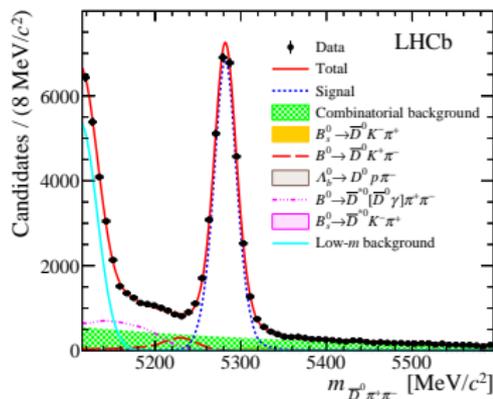
$\sigma \sim \mathcal{O}(10) \mu\text{m}$ [JINST 9 (2014) P09007]



[Eur.Phys.J. C73 (2013) 2431]

- Time-dependent $B_s^0 \rightarrow \bar{D}^0 K^+ K^-$ Dalitz analysis
 - Sensitive to γ and ϕ_s [Phys. Rev D85 (2012) 114015]
 - First observed by LHCb in 2018
 - Rich structures in Dalitz plot for charm spectroscopy study
- Untagged $B_s^0 \rightarrow \bar{D}^{(*)0} \phi$ measurement
 - Possible to extract γ [Phys. Lett. B253 (1991) 483]
 - $B_s^0 \rightarrow \bar{D}^{*0} \phi$ is observed in 2018
- Search for $B^0 \rightarrow \bar{D}^0 \phi$
 - Strongly suppressed in SM
 - Predicted branching fraction: [Phys. Lett. B 666 (2008) 185]
 $\mathcal{B}(B^0 \rightarrow \bar{D}^0 \phi) = (1.6 \pm 0.1) \times 10^{-6}$ [Phys. Rev. D 84 (2011) 112007]
 - Can be used to determine ω - ϕ mixing angle
- Observation of $B_s^0 \rightarrow D_{s1}(2536)K$ decays
 - Structures observed on $D^0 K^+$ spectrum
 - Could obtain γ with time-dependent analysis

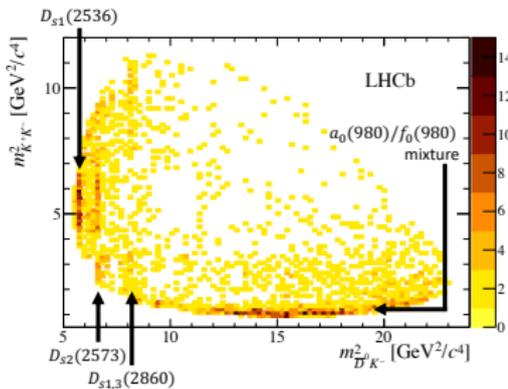
- LHCb run1 data used, $\sqrt{s} = 7(8) \text{ TeV}$, $\int \mathcal{L} = 1.0(2.0) \text{ fb}^{-1}$
- $B_{(s)}^0 \rightarrow \bar{D}^0 K^+ K^-$ could be mediated by multiple processes with many charm resonances
- A Dalitz plot analysis of $B_s^0 \rightarrow \bar{D}^0 K^+ K^-$ could increase the sensitivity to γ and ϕ_s



$$\mathcal{B}(B^0 \rightarrow \bar{D}^0 K^+ K^-) = (6.1 \pm 0.4 \pm 0.3 \pm 0.3) \times 10^{-5} \quad \text{most precise}$$

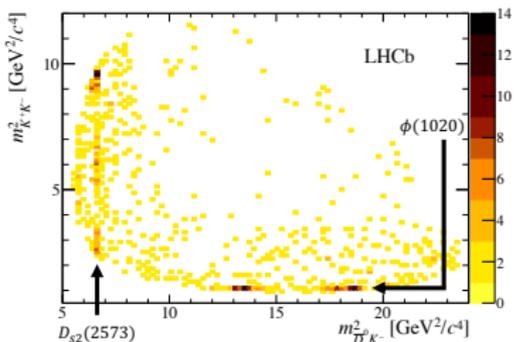
$$\mathcal{B}(B_s^0 \rightarrow \bar{D}^0 K^+ K^-) = (5.7 \pm 0.5 \pm 0.4 \pm 0.5) \times 10^{-5} \quad \text{first measured}$$

B^0 signal region



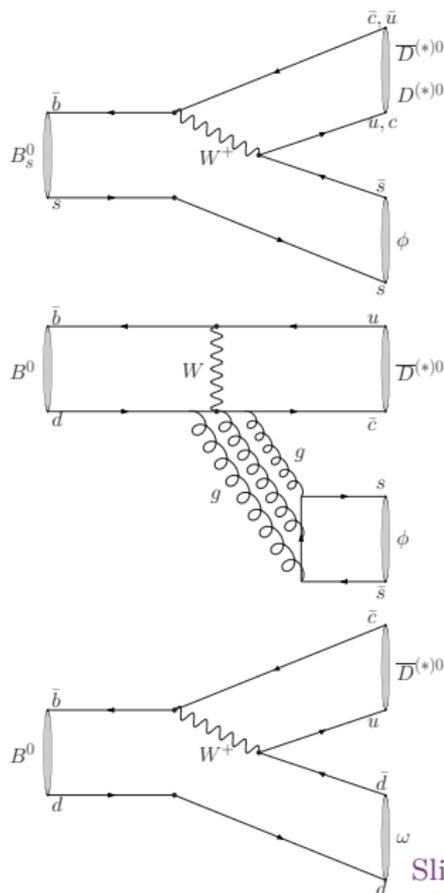
$$m_{\bar{D}^0 K^+ K^-} \in [5240, 5320] \text{ MeV}/c^2$$

B_s^0 signal region

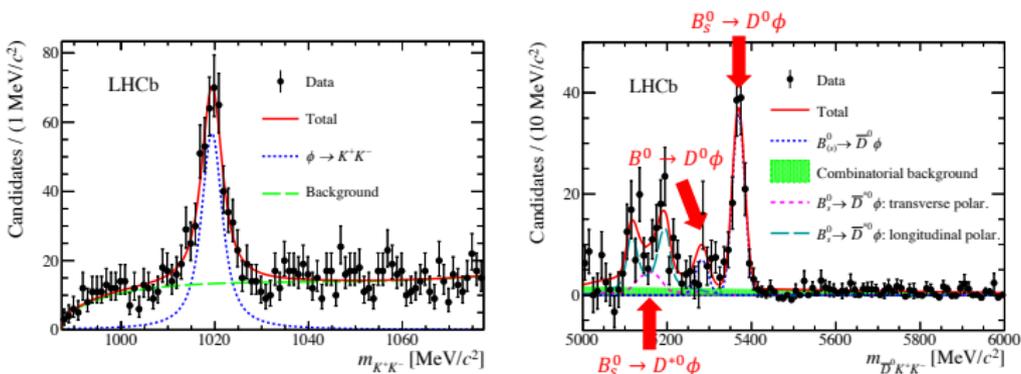


$$m_{\bar{D}^0 K^+ K^-} \in [5327, 5407] \text{ MeV}/c^2$$

- $B_s^0 \rightarrow \bar{D}^{(*)0} \phi$ mediated by $b \rightarrow cW$ or $b \rightarrow uW$ process
 - Both color-suppressed and proportional to λ^3
 - Could probe γ via GLW mode and flavour-specific D decays
 - Measuring longitudinal polarisation (f_L) of $B_s^0 \rightarrow \bar{D}^{*0} \phi$ helps to constrain QCD models
- $B^0 \rightarrow \bar{D}^0 \phi$ mediated by
 - W -exchange decay, suppressed by OZI rule
 - Color-suppressed $B^0 \rightarrow \bar{D}^0 \omega$ with ω - ϕ mixing, sensitive to mixing angle δ



- Selected candidates from $B_s^0 \rightarrow \bar{D}^0 K^+ K^-$ measurement
- $sPlot$ technique is adopted to extract ϕ signal
- Very clean $B_s^0 \rightarrow \bar{D}^0 \phi$ signal



$$\mathcal{B}(B_s^0 \rightarrow \bar{D}^0 \phi) = (3.0 \pm 0.3 \pm 0.2 \pm 0.2) \times 10^{-5} \quad \text{most precise}$$

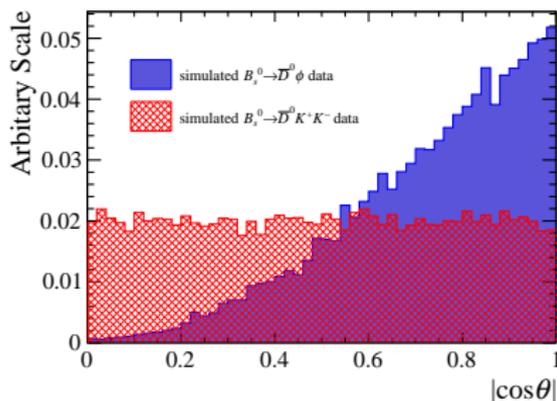
$$\mathcal{B}(B_s^0 \rightarrow \bar{D}^{*0} \phi) = (3.7 \pm 0.5 \pm 0.3 \pm 0.2) \times 10^{-5} \quad \text{first measured}$$

$$f_L = (73 \pm 15 \pm 4)\% \quad \text{consistent with others}$$

$$\mathcal{B}(B^0 \rightarrow \bar{D}^0 \phi) < 2.3 \times 10^{-6} \quad \text{and} \quad |\delta| < 5.5^\circ \quad \text{at 95\% CL}$$

$B_{(s)}^0 \rightarrow \bar{D}^0 \phi$ optimization

- Selection criteria for $\bar{D}^0 K^+ K^-$ now optimized for $\phi \rightarrow K^+ K^-$ resonance
- Expect higher signal significance with 10 ~ 20% increase in signal yields
- All data used: 3 fb^{-1} for 7&8 TeV, 6 fb^{-1} for 13 TeV
- Improved event selection
 - Pre-selection inherited from $\bar{D}^0 K^+ K^-$ analysis
 - BDT classifier with $B_s^0 \rightarrow \bar{D}^0 \phi$ simulation as input
 - PID variables included in training
 - Use of discriminating variables like ϕ helicity angle

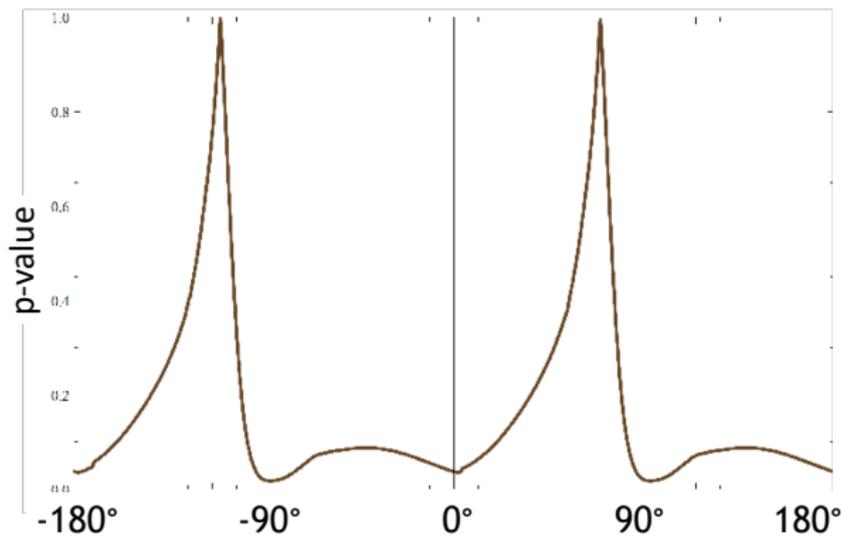


- Based on LHCb public note [[LHCb-PUB-2010-005](#)]
- Signal yields estimation
 - Extrapolated from previous run1 $B_s^0 \rightarrow [K\pi]_{D^{(*)}}\phi$ yields
 - Naively scale with luminosity, $\sim 5\times$ statistics
 - Relative efficiencies taken from $B^\pm \rightarrow [X]_D K^\pm$
 - More decays considered: $B_s^0 \rightarrow \bar{D}^{(*)0}\phi$ with
 $D^0 \rightarrow hh, K3\pi, K\pi\pi^0, K_S^0 hh$

Decay	$K\pi$	$K3\pi$	K^+K^-	$\pi^+\pi^-$	$K\pi\pi^0$	$K_S^0\pi^+\pi^-$	$K_S^0K^+K^-$
Events	1145	432	151	44	114	52	7~8

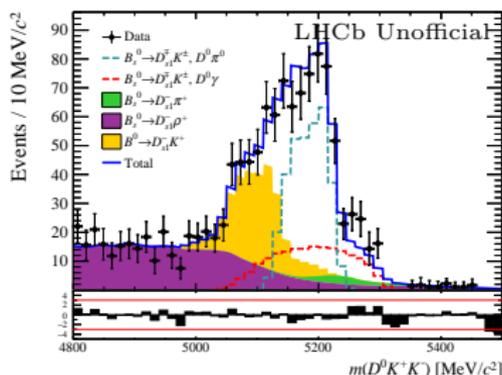
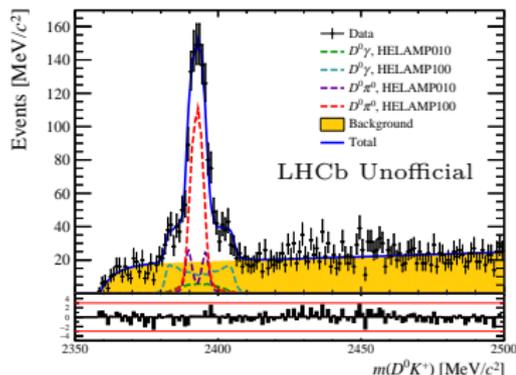
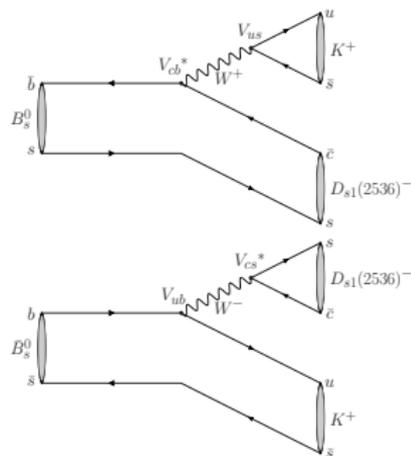
- Decay-time acceptance study
 - $B_s^0-\bar{B}_s^0$ oscillation will influence sensitivity to γ
 - Acceptance determined from simulation
 - Corrections relate to $y = \frac{\Delta\Gamma}{2\Gamma}$
 - Results in a reduction of total decay rate, adding $\sim 3^\circ$ to the uncertainty of γ

- Compute constraint on γ with expected yields
- Including $B_s^0 \rightarrow \bar{D}^{(*)0} \phi$, $D^0 \rightarrow hh$, $K3\pi$, $K\pi\pi^0$
- Fitted with CKMfitter package (**VERY PRELIMINARY!**)
- Stat. uncertainty on γ : $\sim 10 - 15^\circ$



Observation of $B_s^0 \rightarrow D_{s1}(2536)K$

- Studied by a partially reconstructed approach
- Decays sensitive to γ by interference in B_s^0 - \bar{B}_s^0 mixing and decays
- Current work with LHCb run1 data, plan to add run2
- Expect ~ 3 k signal yields with all LHCb collected data



- 2 paper published in 2018 under FCPPL framework
 - Observation of the decay $B_s^0 \rightarrow \bar{D}^0 K^+ K^-$
 - Observation of $B_s^0 \rightarrow \bar{D}^{*0} \phi$ and search for $B^0 \rightarrow \bar{D}^0 \phi$ decays
- $B_{(s)}^0 \rightarrow \bar{D}^0 K^+ K^-$ system provides lots of interesting physical topics
- Ongoing works, thanks to FCPPL program
 - Measuring γ by $B_s^0 \rightarrow \bar{D}^{(*)0} \phi$
 - A precision of $\sim 10^\circ$ can be obtained
 - Search for $B^0 \rightarrow \bar{D}^0 \phi$
 - $B_s^0 \rightarrow \bar{D}^0 K^+ K^-$ Dalitz analysis
 - Observation of $B_s^0 \rightarrow D_{s1}(2536)K$

Thanks

- Our project supported by FCCPL is also a micro working group in LHCb B to Open Charm Analysis Working Group
- Meetings: regular monthly phone meeting (Vidyo) since September 2018 + in person meetings at the LHCb Weeks at CERN, regular exchanges/travels Beijing/France/CERN facilitated by FCPPL
- Visit by Zhipeng Tang (Tsinghua) and Daniel Decamp (Annecy) in Clermont Ferrand: 1 week each in June 2018
- Visit by Vincent Tisserand (Clermont Ferrand) in Beijing: 1 week in November 2018 + 1 seminar in IHEP & 1 on Tsinghua
- Visit by Xiaokang Zhou (UCAS) in Clermont Ferrand after the LHCb December 2018 at CERN: 2 weeks