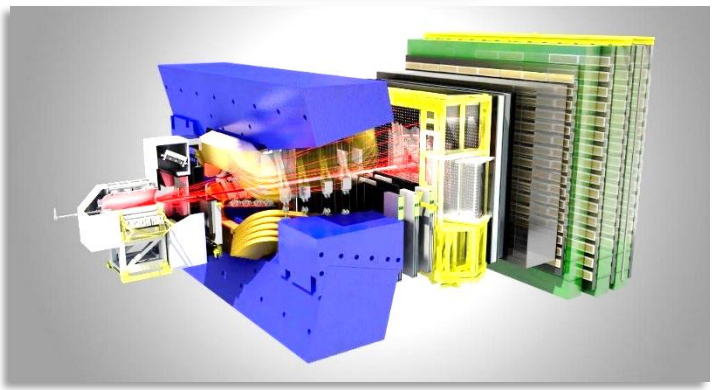
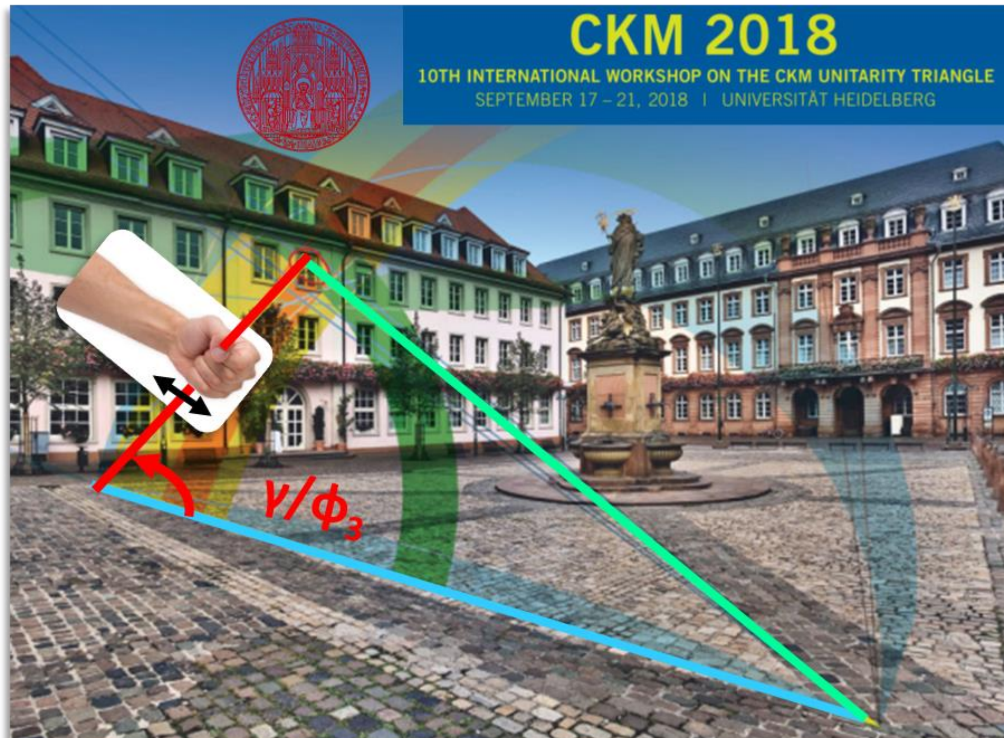
Latest results on $B^0_{(s)} \to \bar{D}^{(*)0} K^+ K^-$ from LHCb

V. Tisserand, LPC-Clermont FD
on behalf of the LHCb Collaboration





Talk based on 2 recent publications:

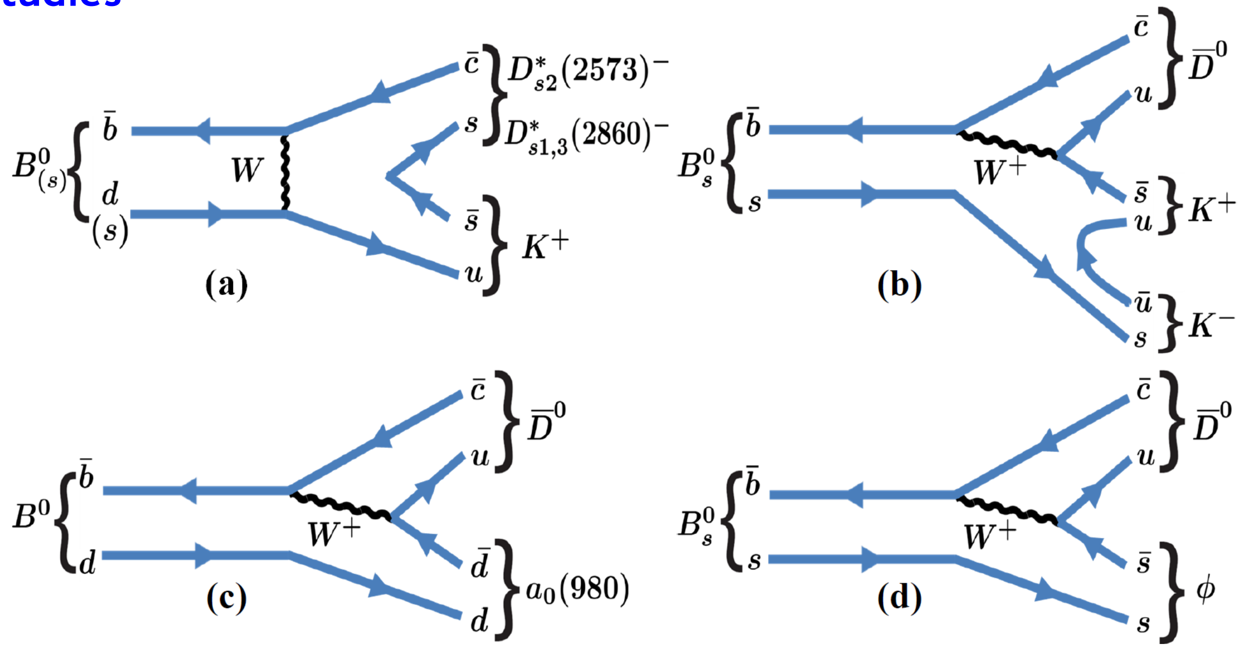
- ✓ LHCb-PAPER-2018-014: arXiv:1807.01891 Submitted to Phys. Rev. D
- ✓ LHCb-PAPER-2018-015: arXiv:1807.01892 Submitted to Phys. Rev. Lett.

arXiv:1807.01891

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

✓ Time-Dependent Dalitz analyses can be used to access CKM angles γ and to obtain clean (i.e. tree decays) 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



First steps:

✓ Analysis already performed with early LHCb dataset (0.6/fb) : observation of B^0 channel and only evidence for B^0_s mode (Phys. Rev. Lett. 109 (2012) 131801)

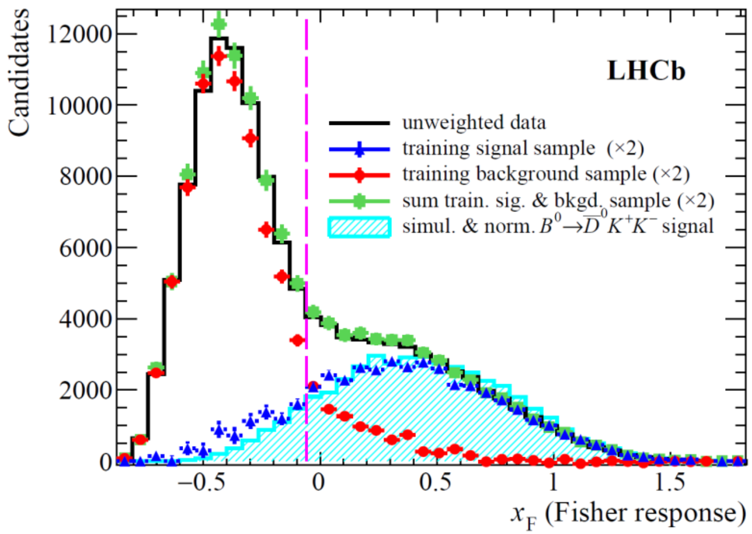
✓ Updated measurements performed with 3/fb (Run1: 2011+2012) ➔ new analysis

- Improved background treatment (e.g. : $B^0_{(s)} \to \bar{D}^0 K^- \pi^+$ and $\Lambda_b \to D^0 p K^-$)
- control/norm. mode: $B^0 \to \bar{D}^0 \pi^+ \pi^-$

arXiv:1807.01891

Selection of $B^0_{(s)} \to \bar{D}^0 K^+ K^-$ decays

- ✓ $\bar{D}^0$ reconstructed in $K^+\pi^-$ decay
- ✓ Kinematic and topological discriminating variables
- ✓ Charmless B decays rejected by requiring the D meson vertex to be downstream of the B meson vertex
- ✓ Veto of $B^0 \to D^*(2010)^-\pi^+$, $D^*(2010)^- \to \bar{D}^0\pi^-$
- ✓ Combinatorial background rejected with robust MVA Fisher discriminant optimised on data with $B^0 \to \bar{D}^0\pi^+\pi^-$ using sPlot technique



- ✓ Selections for $B^0_{(s)} \to \bar{D}^0 K^+ K^-$ signal and $B^0 \to \bar{D}^0\pi^+\pi^-$ normalisation modes differ only on the PID of the h^+h^- pair (use of RICHs)
- ✓ One candidate/event only

arXiv:1807.01891

invariant mass fit of $B^0_{(s)} \to \bar{D}^0 h^+ h^-$ decays

- ✓ **Signals modelled with 2 Crystal Ball functions** (tails params. fixed from simulation) and mass difference between B^0 and B^0_s for DK^+K^- fixed to PDG2018 value (87.35 MeV/c²)
- ✓ **Surviving combinatorial background modelled with exponential function**
- ✓ **Mis-identified and partially reconstructed b-hadron decays modelled from simulation** with corrections to match data
- ✓ **Specific treatment of $\Lambda_b \to D^0 p\pi^-$, $\Lambda_b \to D^0 pK^-$ and $\Xi_b \to D^0 pK^-$ backgrounds constrained from data**

Likelihood function:

$$\mathcal{L}_{\bar{D}^0 h^+ h^-} = \frac{v^n}{n!} e^{-v} \prod_{i=1}^{n} \mathcal{P}_\theta^{\rm tot}(m_{i,\bar{D}^0 h^+ h^-})$$

v is the sum of the yields and *n* the number of observed candidates

- **$B^0 \to \bar{D}^0 \pi^+ \pi^-$ (7 background components):**

$$\mathcal{P}_\theta^{\rm tot}(m_{\bar{D}^0\pi^+\pi^-}) = N_{\bar{D}^0\pi^+\pi^-} \times \mathcal{P}_{\rm sig}^{B^0}(m_{\bar{D}^0\pi^+\pi^-}) + \sum_{j=1}^{7} N_{j,{\rm bkg}} \times \mathcal{P}_{j,{\rm bkg}}(m_{\bar{D}^0\pi^+\pi^-})$$

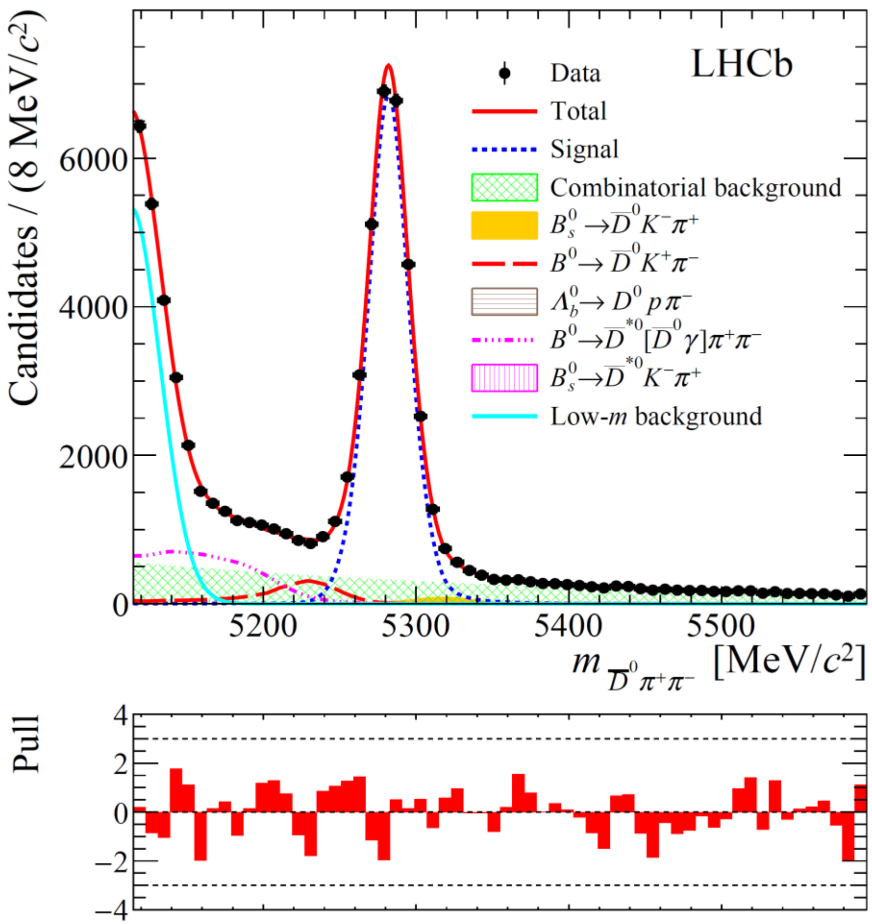
- **$B^0_{(s)} \to \bar{D}^0 K^+ K^-$ (2 signal + 9 background components):**

$$\begin{aligned}\mathcal{P}_\theta^{\rm tot}(m_{\bar{D}^0K^+K^-}) &= N_{B^0\to\bar{D}^0K^+K^-} \times \mathcal{P}_{\rm sig}^{B^0}(m_{\bar{D}^0K^+K^-}) \\ &+ N_{B^0_s\to\bar{D}^0K^+K^-} \times \mathcal{P}_{\rm sig}^{B^0_s}(m_{\bar{D}^0K^+K^-}) \\ &+ \sum_{j=1}^{9} N_{j,{\rm bkg}} \times \mathcal{P}_{j,{\rm bkg}}(m_{\bar{D}^0K^+K^-}).\end{aligned}$$

arXiv:1807.01891

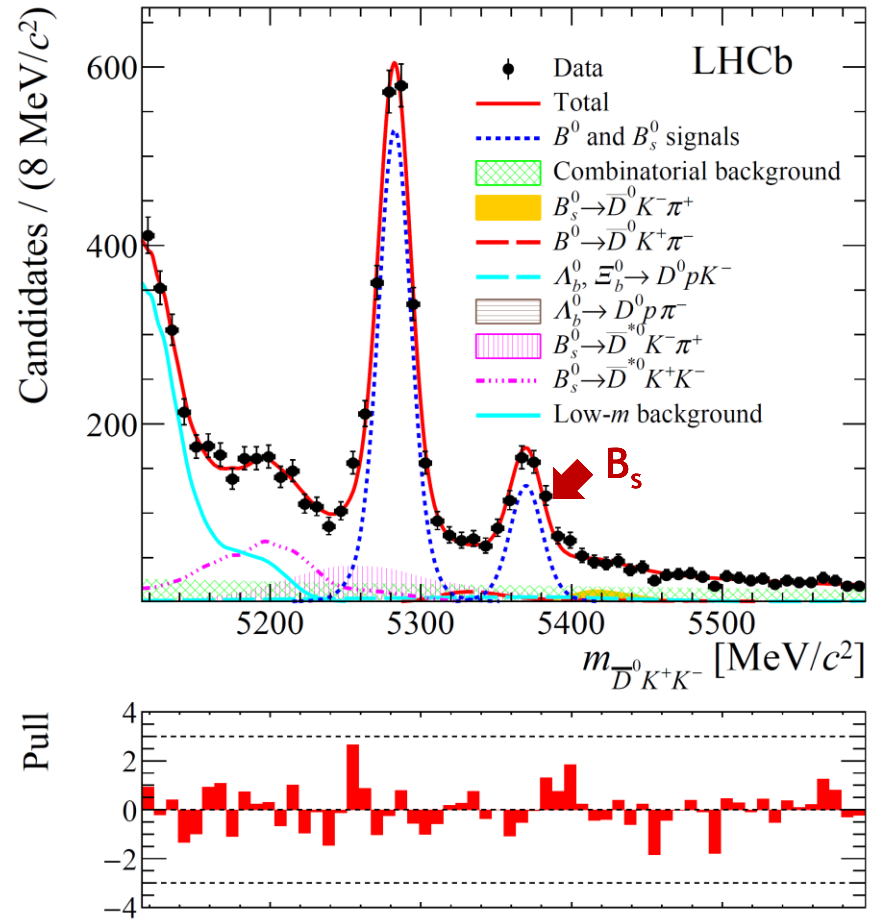
invariant mass fit of $B^0_{(s)} \to \bar{D}^0 h^+ h^-$ decays

$B^0 \to \bar{D}^0 \pi^+ \pi^-$



29 943 ± 243

$B^0_{(s)} \to \bar{D}^0 K^+ K^-$



1918 ± 74 B^0 & NEW → 473 ± 33 B^0_s
Observed for the 1st time!

ratio of yields $r_{B^0_s/B^0}$=(24.7±1.7)%

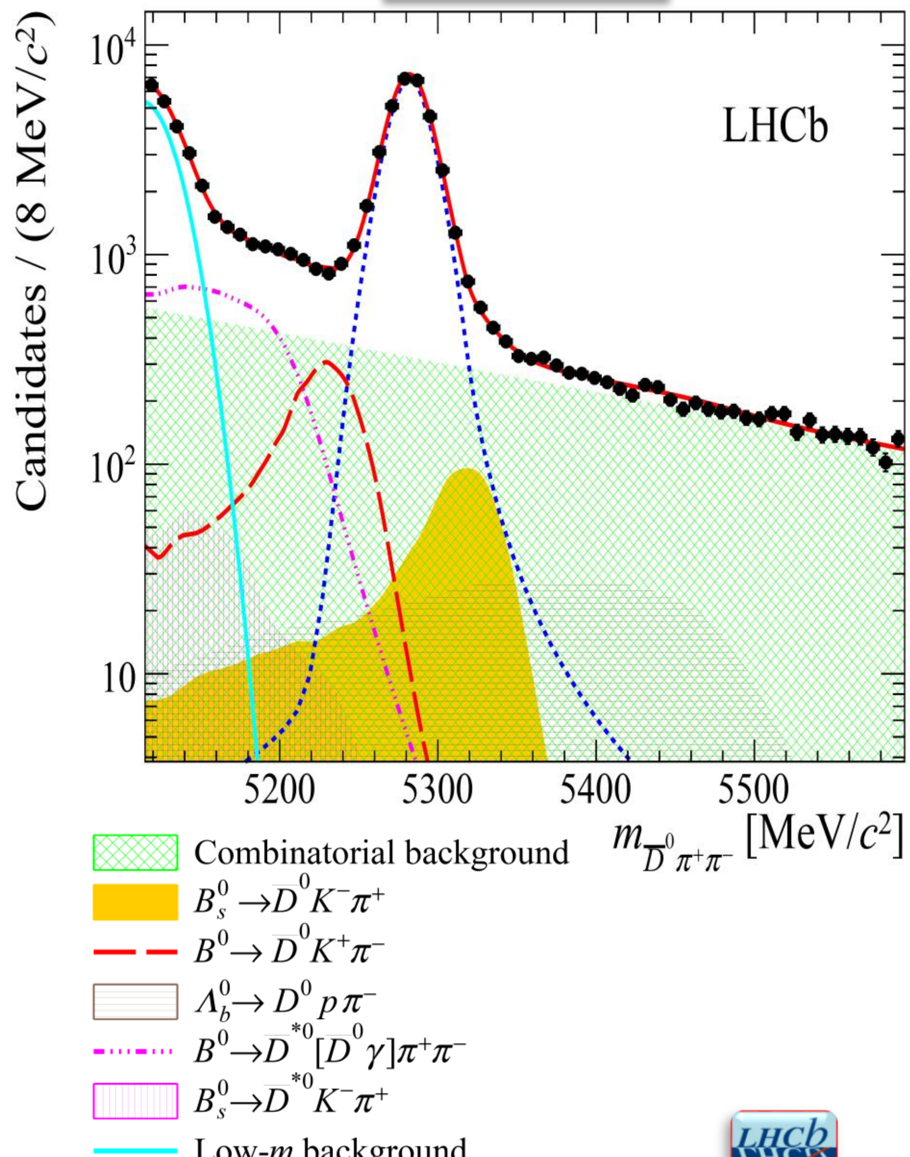
arXiv:1807.01891

invariant mass fit of $B^0_{(s)} \rightarrow \bar{D}^0 h^+ h^-$ decays

Fit output details

Parameter	$B^0 \rightarrow \bar{D}^0 \pi^+ \pi^-$	$B^0_{(s)} \rightarrow \bar{D}^0 K^+ K^-$
m_0 [MeV/c^2]	5282.0 ± 0.1	5282.6 ± 0.3
σ_1 [MeV/c^2]	9.7 ± 1.0	fixed at 9.7
σ_2 [MeV/c^2]	16.2 ± 0.8	fixed at 16.2
f_{CB}	0.3 ± 0.1	0.6 ± 0.1
$a_{\text{comb.}}$ $[10^{-3} \times (\text{MeV}/c^2)^{-1}]$	-3.2 ± 0.1	-1.3 ± 0.4
$N_{B^0 \rightarrow \bar{D}^0 h^+ h^-}$	$29\,943 \pm 243$	1918 ± 74
$N_{B^0_s \rightarrow \bar{D}^0 h^+ h^-}$	–	473 ± 33
$N_{\text{comb.}}$	$20\,266 \pm 463$	1720 ± 231
$N_{B^0_s \rightarrow \bar{D}^0 K^- \pi^+}$	923 ± 191	151 ± 47
$N_{B^0 \rightarrow \bar{D}^0 K^+ \pi^-}$	2450 ± 211	131 ± 65
$N_{\Lambda^0_b \rightarrow D^0 p K^-}$ (constrained)	–	197 ± 44
$N_{\Xi^0_b \rightarrow D^0 p K^-}$ (constrained)	–	57 ± 20
$N_{\Lambda^0_b \rightarrow D^0 p \pi^-}$ (constrained)	1016 ± 136	74 ± 32
$N_{B^0_s \rightarrow \bar{D}^{*0} K^- \pi^+}$	540 (fixed)	833 ± 185
$N_{B^0_s \rightarrow \bar{D}^{*0} K^+ K^-}$	–	775 ± 100
$N_{B^0 \rightarrow \bar{D}^{*0}[\bar{D}^0 \gamma] \pi^+ \pi^-}$	7697 ± 325	–
$N_{\text{Low}-m}$	$14\,914 \pm 222$	1632 ± 68
χ^2/ndf (p-value)	52/46 (25%)	43/46 (60%)

$B^0 \rightarrow \bar{D}^0 \pi^+ \pi^-$

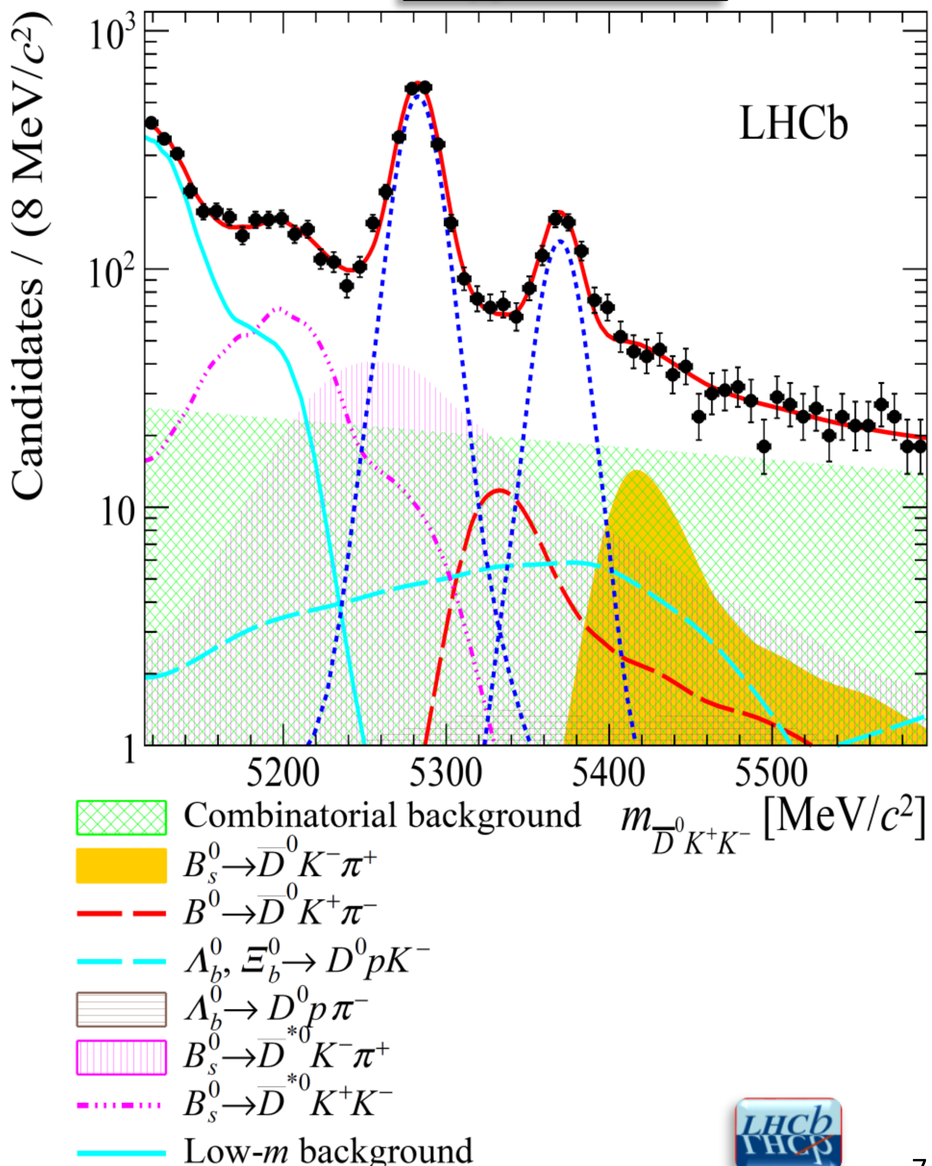


invariant mass fit of $B^0_{(s)} \to \bar{D}^0 h^+ h^-$ decays

Fit output details

Parameter	$B^0 \to \bar{D}^0\pi^+\pi^-$	$B^0_{(s)} \to \bar{D}^0 K^+ K^-$
m_0 [MeV/c^2]	5282.0 ± 0.1	5282.6 ± 0.3
σ_1 [MeV/c^2]	9.7 ± 1.0	fixed at 9.7
σ_2 [MeV/c^2]	16.2 ± 0.8	fixed at 16.2
f_{CB}	0.3 ± 0.1	0.6 ± 0.1
$a_{\mathrm{comb.}}$ $[10^{-3} \times (\mathrm{MeV}/c^2)^{-1}]$	-3.2 ± 0.1	-1.3 ± 0.4
$N_{B^0 \to \bar{D}^0 h^+ h^-}$	$29\,943 \pm 243$	1918 ± 74
$N_{B^0_s \to \bar{D}^0 h^+ h^-}$	–	473 ± 33
$N_{\mathrm{comb.}}$	$20\,266 \pm 463$	1720 ± 231
$N_{B^0_s \to \bar{D}^0 K^- \pi^+}$	923 ± 191	151 ± 47
$N_{B^0 \to \bar{D}^0 K^+ \pi^-}$	2450 ± 211	131 ± 65
$N_{\Lambda^0_b \to D^0 p K^-}$ (constrained)	–	197 ± 44
$N_{\Xi^0_b \to D^0 p K^-}$ (constrained)	–	57 ± 20
$N_{\Lambda^0_b \to D^0 p \pi^-}$ (constrained)	1016 ± 136	74 ± 32
$N_{B^0_s \to \bar{D}^{*0} K^- \pi^+}$	540 (fixed)	833 ± 185
$N_{B^0_s \to \bar{D}^{*0} K^+ K^-}$	–	775 ± 100
$N_{B^0 \to \bar{D}^{*0}[\bar{D}^0\gamma]\pi^+\pi^-}$	7697 ± 325	–
$N_{\mathrm{Low}-m}$	$14\,914 \pm 222$	1632 ± 68
χ^2/ndf (p-value)	52/46 (25%)	43/46 (60%)

$B^0_{(s)} \to \bar{D}^0 K^+ K^-$



arXiv:1807.01891

Ratios of branching fractions & efficiencies

✓ Compute ratios of branching fractions:

$$\frac{\mathcal{B}\left(B^0 \to \overline{D}^0 K^+ K^-\right)}{\mathcal{B}\left(B^0 \to \overline{D}^0 \pi^+ \pi^-\right)} = \frac{N_{B^0 \to \overline{D}^0 K^+ K^-}}{N_{B^0 \to \overline{D}^0 \pi^+ \pi^-}} \times \frac{\varepsilon_{B^0 \to \overline{D}^0 \pi^+ \pi^-}}{\varepsilon_{B^0 \to \overline{D}^0 K^+ K^-}}$$

$$\frac{\mathcal{B}\left(B^0_s \to \overline{D}^0 K^+ K^-\right)}{\mathcal{B}\left(B^0 \to \overline{D}^0 K^+ K^-\right)} = r_{B^0_s / B^0} \times \frac{\varepsilon_{B^0 \to \overline{D}^0 K^+ K^-}}{\varepsilon_{B^0_s \to \overline{D}^0 K^+ K^-}} \times \frac{1}{f_s / f_d}$$

✓ $\mathcal{B}\left(B^0 \to \overline{D}^0 \pi^+ \pi^-\right)$ **from PDG2018** (including Phys. Rev. D 92 (2015) 032002)

✓ f_s / f_d **from LHCb** (JHEP 04 (2003) 001 & LHCb-CONF-2013-011)

✓ Efficiencies account for acceptance/reconstruction, hardware L0 /software HLT1/2 triggering, PID and selections (including Fisher discriminant).

- Mostly computed with simulation, but PID/tracking simulation corrected with data control samples.
- Hardware L0 trigger part determined from calibration data samples.
- Global efficiency corrected for phase-space effects in $B^0_{(s)} \to \overline{D}^0 h^+ h^-$ multi-body decays on event-by-event basis using sPlot technique (i.e. sWeights).

Systematic uncertainties

- ✓ Many sources of systematic uncertainty cancel in the ratios of branching fractions
- ✓ Other non-vanishing sources:
  - Hardware L0 trigger (signal specific part).
  - PID difference in the h^+h^- selection for $B^0_{(s)} \to \bar{D}^0 K^+ K^-$ signal and $B^0 \to \bar{D}^0 \pi^+ \pi^-$ normalisation mode.
  - Signal and background modelling in the invariant mass fit.

Source [%]	$\mathcal{R}_{\overline{D}^0 K^+ K^- / \overline{D}^0 \pi^+ \pi^-}$	$\mathcal{R}_{B^0_s / B^0}$
HW trigger efficiency	2.0	–
PID efficiency	2.0	–
PDF modelling	3.2	4.5
f_s/f_d	–	5.8
Total [%]	4.3	7.3

Where:

$$\mathcal{R}_{\overline{D}^0 K^+ K^- / \overline{D}^0 \pi^+ \pi^-} \equiv \mathcal{B}(B^0 \to \overline{D}^0 K^+ K^-)/\mathcal{B}(B^0 \to \overline{D}^0 \pi^+ \pi^-)$$
$$\mathcal{R}_{B^0_s / B^0} \equiv \mathcal{B}(B^0_s \to \overline{D}^0 K^+ K^-)/\mathcal{B}(B^0 \to \overline{D}^0 K^+ K^-)$$

arXiv:1807.01891

Results 3/fb

$$\frac{\mathcal{B}(B^0 \to \overline{D}^0 K^+ K^-)}{\mathcal{B}(B^0 \to \overline{D}^0 \pi^+ \pi^-)} = (6.9 \pm 0.4 \pm 0.3)\%$$

stat. syst.

$$\mathcal{B}(B^0 \to \overline{D}^0 K^+ K^-) = (6.1 \pm 0.4 \pm 0.3 \pm 0.3) \times 10^{-5}$$

stat. syst. normalis.

(was $(4.7 \pm 0.9 \pm 0.6 \pm 0.5) \times 10^{-5}$ with 0.6/fb *)

$$\frac{\mathcal{B}(B_s^0 \to \overline{D}^0 K^+ K^-)}{\mathcal{B}(B^0 \to \overline{D}^0 K^+ K^-)} = (93.0 \pm 8.9 \pm 6.9)\%$$

stat. syst.

$$\mathcal{B}(B_s^0 \to \overline{D}^0 K^+ K^-) = (5.7 \pm 0.5 \pm 0.4 \pm 0.5) \times 10^{-5}$$

stat. syst. normalis.

Observed !

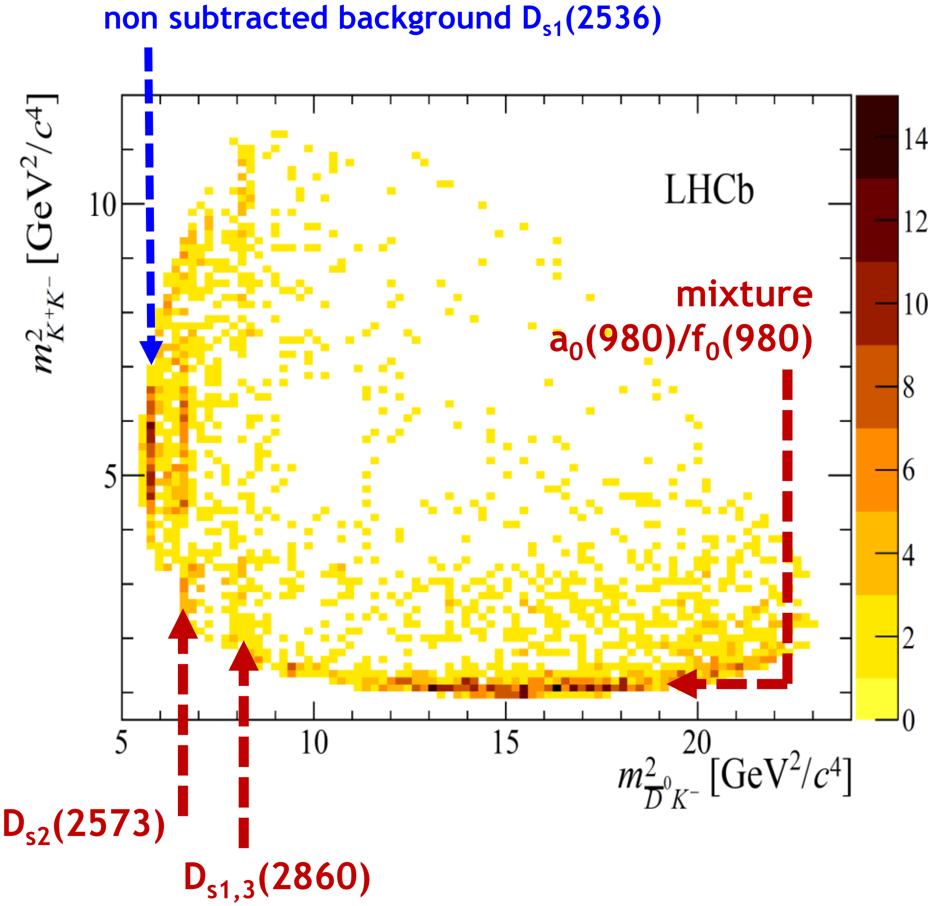
(was $(4.2 \pm 1.3 \pm 0.9 \pm 1.1) \times 10^{-5}$ with 0.6/fb *)

* Phys. Rev. Lett. 109 (2012) 131801

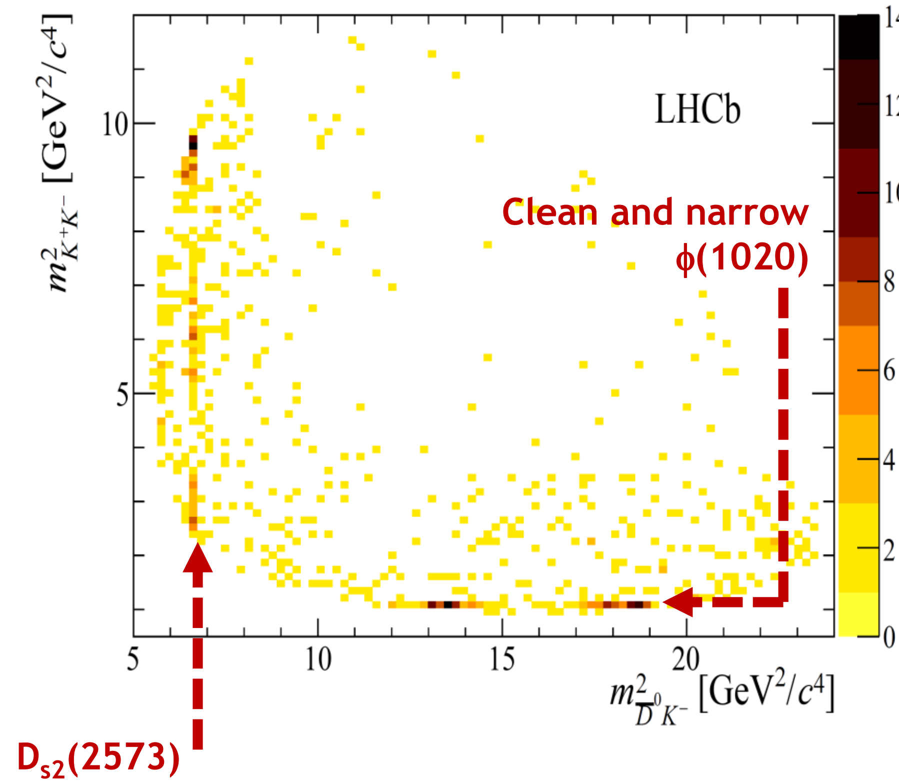
arXiv:1807.01891

Inspection of Dalitz plot

$B^0 \to \bar{D}^0 K^+ K^-$ (in [5240,5320] MeV/c²)



$B^0_s \to \bar{D}^0 K^+ K^-$ (in [5340,5400] MeV/c²)



➔ **Performed only with LHC Run1 : motivates amplitude analysis with additional LHCb data**

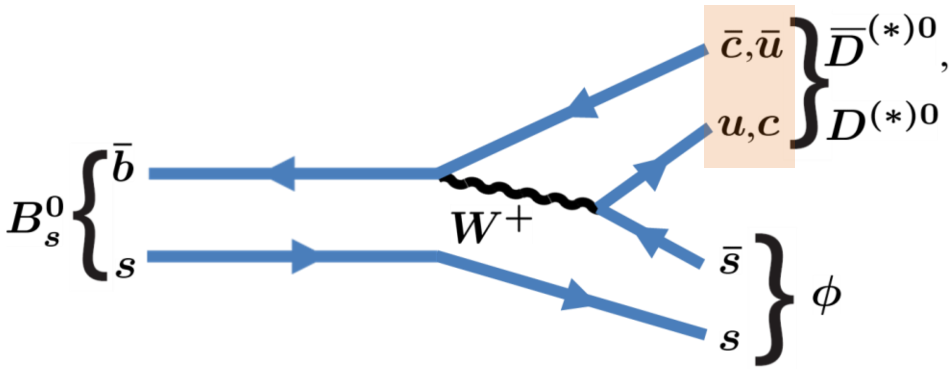
arXiv:1807.01892

Studies of $B^0_{(s)} \rightarrow \bar{D}^{(*)0}\phi$

✓ The $\phi(1020)$ is a narrow resonance and using the selected candidates in $B^0_{(s)} \rightarrow \bar{D}^0 K^+ K^-$ of 1807.01891 permits studies on $B^0_{(s)} \rightarrow \bar{D}^{(*)0}\phi$

✓ Significant sensitivity to the CKM angle γ for $B^0_s \rightarrow \bar{D}^{(*)0}\phi$ decays:
(Phys. Lett. B253 (1991) 483 & LHCb-PUB-2010-005)

- Precision on CKM angle γ still limited (i.e. around 5° ➔ see talk by Alberto Correa dos Reis) to indirectly constraint BSM physics
  ➔ alternate methods welcome
- b → c and b → u interfering transition of about same size: $r_B \approx 30\text{-}50\%$ ($B^0_s \rightarrow D^+_s K^-$ JHEP 03 (2018) 059)
- For the D^{*0} decay (VV) the reconstruction can be partial, if f_L known, to almost double the B^0_s dataset (i.e. omit γ/π^0 (Phys. Lett. B777 (2017) 16))



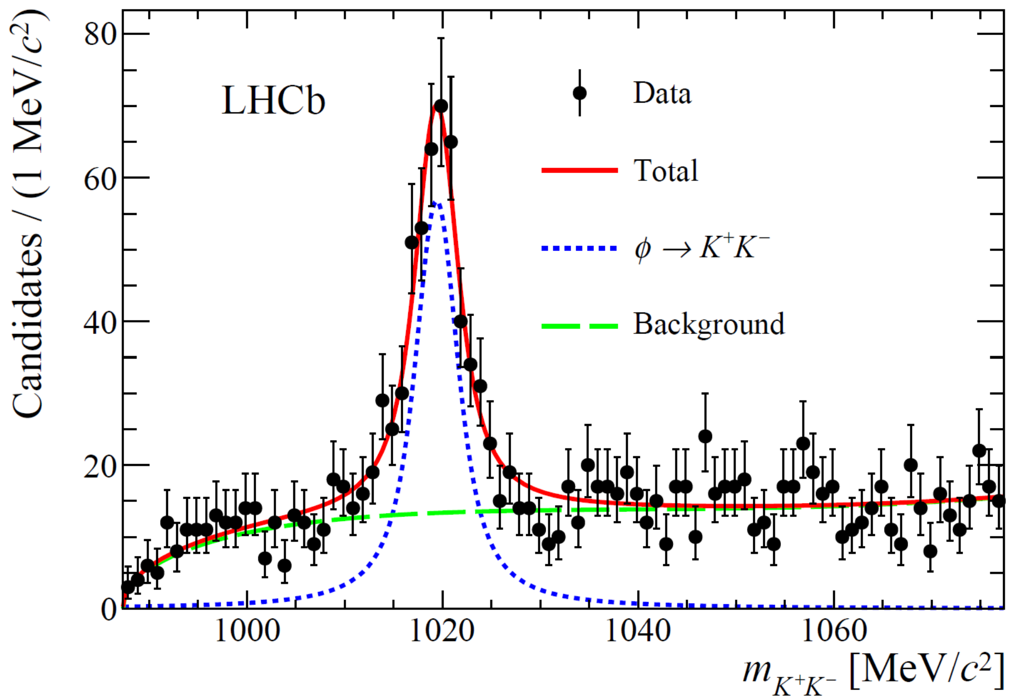
✓ $\mathcal{B}(B^0_s \rightarrow \bar{D}^0\phi)$ is $(3.0 \pm 0.8) \times 10^{-5}$ as measured with LHCb 1/fb with a specific selection normalised to $\mathcal{B}(B^0_s \rightarrow \bar{D}^0 \bar{K}^{*0})$ (Phys. Lett. B727 (2013) 403)

✓ $B^0_s \rightarrow \bar{D}^{*0}\phi$ is still unobserved

arXiv:1807.01892

The $\phi \to K^+K^-$ spectrum of $B^0_{(s)} \to \bar{D}^{(*)0} K^+K^-$

✓ Using selected $B^0_{(s)}$ candidates (see slide on invariant mass fit) in the window $m_{DKK} \in [5000, 6000]$ GeV/c^2 obtain the following m_{KK} spectrum:

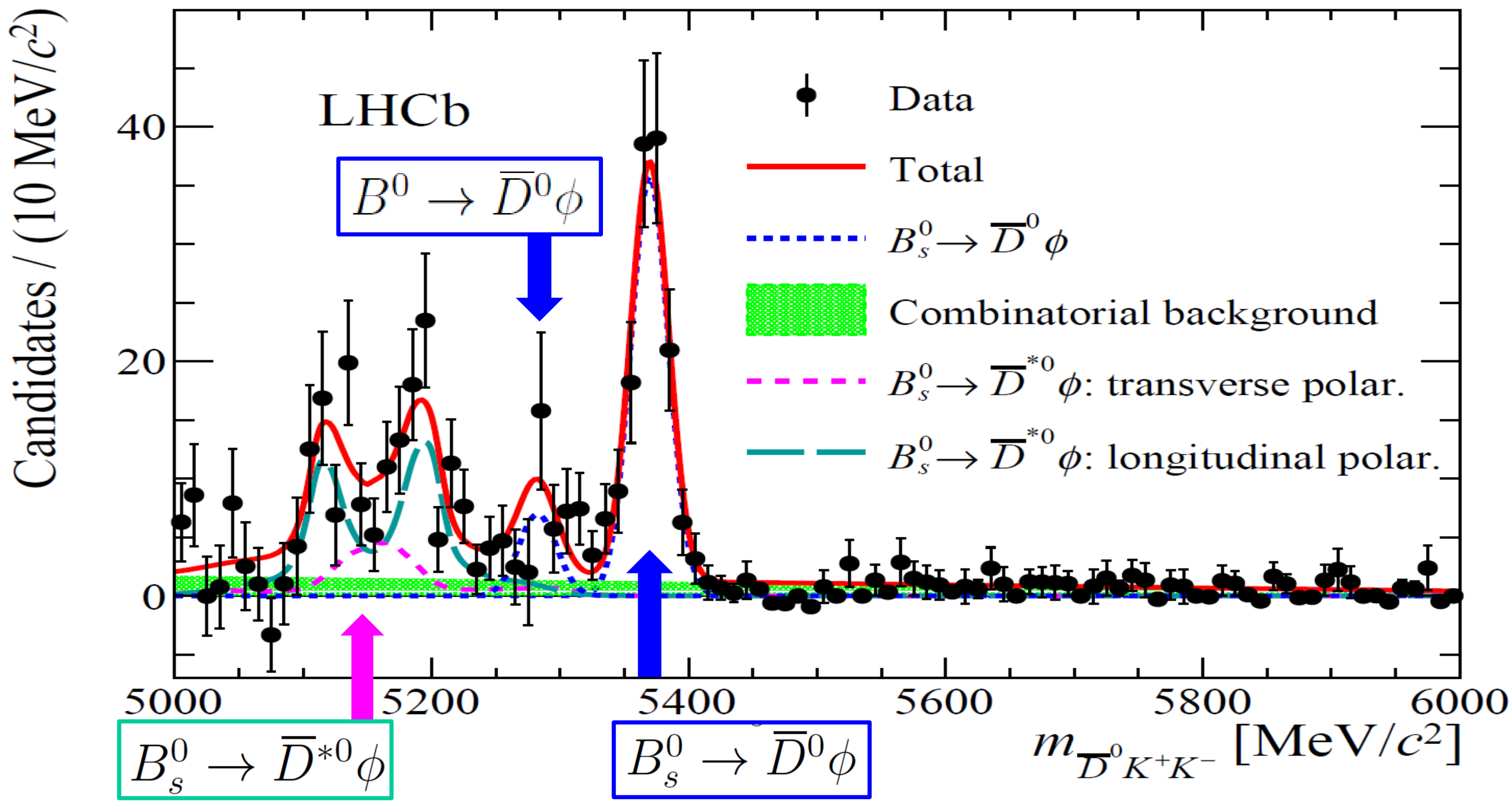


427 ± 30 ϕ signal candidates
1152 ± 41 K^+K^- background

✓ Fit signal with relativistic Breit-Wigner PDF and background with threshold PDF proportional to $(p \times q).(1 + ax + b(2x^2 - 1))$, where p & q are the momentum of the K in the KK rest frame and D in DKK rest frame and $x = 2(m_{K+K-} - 2m_K)/90\ \mathrm{MeV}/c^2 - 1$

✓ Fit used to obtain sPlot-projected mass spectrum $m_{\bar{D}^0 K^+ K^-}$ (correlations with m_{KK} less than 6%)

The projected mass spectrum of $B^0_{(s)} \to \bar{D}^{(*)0}\phi$

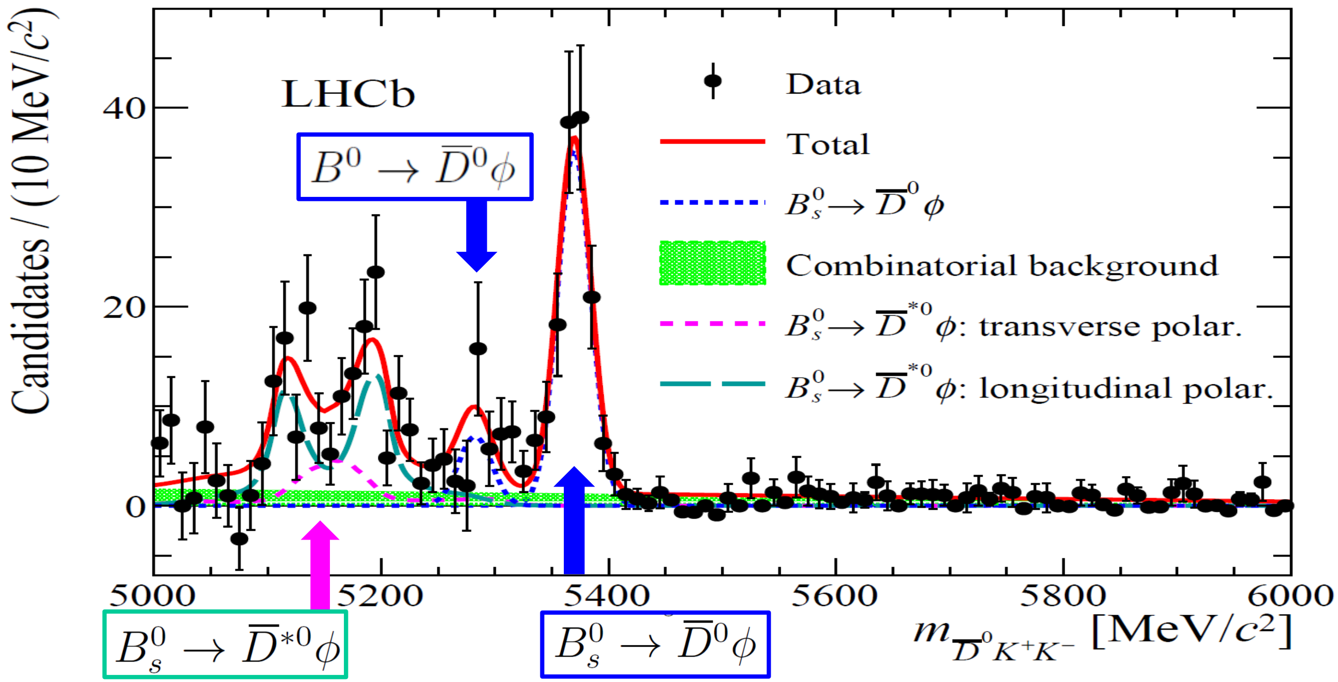


Invariant mass fit:

- ✓ Shape of B^0 and B^0_s decaying to $\bar{D}^0\phi$ modelled by Gaussian functions (mass difference fixed to PDG2018).
- ✓ Shape of B^0_s decaying to $\bar{D}^{*0}\phi$ determined from simulation : sum of 2 PDFs with fully longitudinal/transverse polarisation (f_L=1 or 0) and relative branching fraction D^{*0} to $D^0\gamma/D^0\pi^0$ fixed to PDG2018 value.
- ✓ Remaining combinatorial background modelled by straight line.

arXiv:1807.01892

Fit results for $B^0_{(s)} \to \bar{D}^{(*)0}\phi$



$$N_{B^0_s \to \bar{D}^0\phi} = 132 \pm 13,\ N_{B^0 \to \bar{D}^0\phi} = 26 \pm 11, \text{ and } \boxed{N_{B^0_s \to \bar{D}^{*0}\phi} = 163 \pm 19}, \text{ with } f_L = (73 \pm 15)\%.$$

Observation of $B^0_s \to \bar{D}^{*0}\phi$ with more than 7 standard deviations !

The whole procedure was repeated with various m_{KK} background fit parameters obtained from various regions to evaluate possible biases due to K^+K^- S-Waves under the ϕ resonance.

arXiv:1807.01892

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

$$\frac{\mathcal{B}(B^0_{(s)} \to \overline{D}^{(*)0}\phi)}{\mathcal{B}(B^0 \to \overline{D}^0\pi^+\pi^-)} = \frac{N_{B^0_{(s)}\to\overline{D}^{(*)0}\phi} \times \varepsilon(B^0 \to \overline{D}^0\pi^+\pi^-)}{N_{B^0\to\overline{D}^0\pi^+\pi^-} \times \varepsilon(B^0_{(s)} \to \overline{D}^{(*)0}\phi)} \times \frac{\mathcal{F}}{\mathcal{B}(\phi \to K^+K^-)},$$

where $\mathcal{F}$ is 1 for B^0 decays and f_d/f_s for B^0_s decays.

- ✓ **Efficiencies computed as for 1807.01891.**
- ✓ **Various sources of systematic uncertainties considered [%]:**

Source	$\frac{\mathcal{B}(B^0_s\to\overline{D}^0\phi)}{\mathcal{B}(B^0\to\overline{D}^0\pi^+\pi^-)}$	$\frac{\mathcal{B}(B^0\to\overline{D}^0\phi)}{\mathcal{B}(B^0\to\overline{D}^0\pi^+\pi^-)}$	$\frac{\mathcal{B}(B^0_s\to\overline{D}^{*0}\phi)}{\mathcal{B}(B^0\to\overline{D}^0\pi^+\pi^-)}$	$\frac{\mathcal{B}(B^0_s\to\overline{D}^{*0}\phi)}{\mathcal{B}(B^0_s\to\overline{D}^0\phi)}$	f_L
$N_{B^0_{(s)}\to\overline{D}^{(*)0}\phi}$	1.5	27.0	4.8	4.9	4.1
$N_{B^0\to\overline{D}^0\pi^+\pi^-}$	2.0	2.0	2.0	–	–
$\epsilon_{\rm PID}$	2.0	2.0	2.0	–	–
$\epsilon_{\rm trigger}$	2.0	2.0	2.0	–	–
$\mathcal{B}(\phi \to K^+K^-)$*	1.0	1.0	1.0	–	–
f_s/f_d**	5.8	–	5.8	–	–
Lifetime***	0.8	–	0.8	1.6	1.6
Total	7.0	27.1	8.4	5.2	4.4

* PDG2018 ** JHEP 04 (2003) 001 & LHCb-CONF-2013-011 *** See: Phys. Rev. D 86 (2012) 014027

arXiv:1807.01892

Results for Branching fractions of $B^0_s \to \bar{D}^{(*)0}\phi$

$$\frac{\mathcal{B}(B^0_s \to \bar{D}^0\phi)}{\mathcal{B}(B^0 \to \bar{D}^0\pi^+\pi^-)} = (3.4 \pm \underset{\text{stat.}}{0.4} \pm \underset{\text{syst.}}{0.2})\%$$

$$\mathcal{B}(B^0_s \to \bar{D}^0\phi) = (3.0 \pm \underset{\text{stat.}}{0.3} \pm \underset{\text{syst.}}{0.2} \pm \underset{\text{normalis.}}{0.2}) \times 10^{-5}$$

Compatible and twice as accurate as Phys. Lett. B727 (2013) 403

$$\frac{\mathcal{B}(B^0_s \to \bar{D}^{*0}\phi)}{\mathcal{B}(B^0 \to \bar{D}^0\pi^+\pi^-)} = (4.2 \pm \underset{\text{stat.}}{0.5} \pm \underset{\text{syst.}}{0.4})\%$$

Observation with more than 7 standard deviations !

$$\mathcal{B}(B^0_s \to \bar{D}^{*0}\phi) = (3.7 \pm \underset{\text{stat.}}{0.5} \pm \underset{\text{syst.}}{0.3} \pm \underset{\text{normalis.}}{0.2}) \times 10^{-5}$$

$$\frac{\mathcal{B}(B^0_s \to \bar{D}^{*0}\phi)}{\mathcal{B}(B^0_s \to \bar{D}^0\phi)} = 1.23 \pm \underset{\text{stat.}}{0.20} \pm \underset{\text{syst.}}{0.06}$$

Fraction of longitudinal polarisation:

$$f_{\mathrm{L}} = (73 \pm \underset{\text{stat.}}{15} \pm \underset{\text{syst.}}{3})\%$$

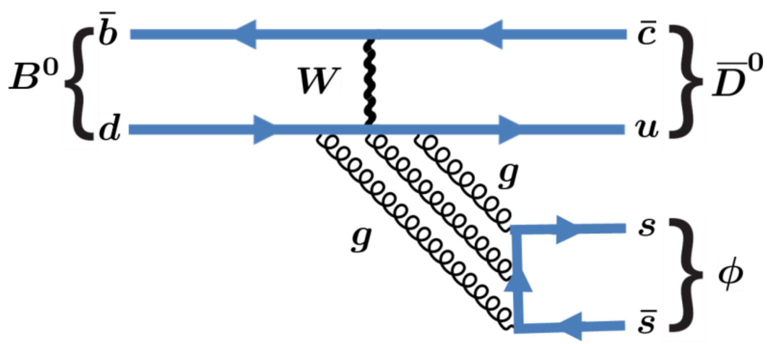
- ✓ $f_L<90\%$, compatible with colour-suppressed VV open charm B^0-decays (e.g. BaBar: Phys. Rev D 84 (2011) 112007 or Belle: Phys. Rev. D 92 (2015) 012013)
- ✓ About the same number of fully longitudinally polarised $B_s \to D^*\phi$ wrt $B_s \to D\phi$: 1.23x0.73=0.9

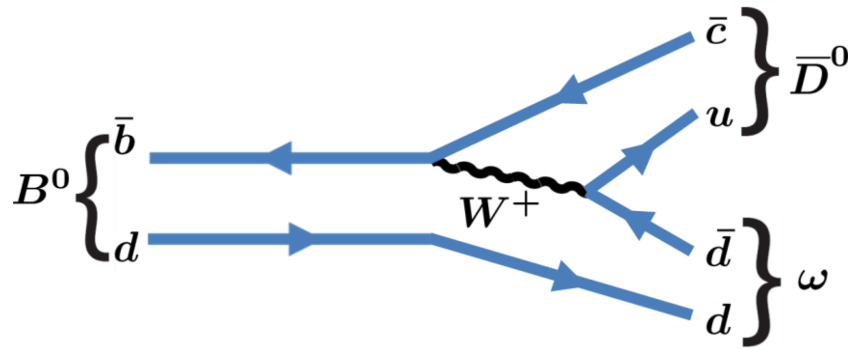
➔ Yet another mode for CKM angle γ !

arXiv:1807.01892

Search for the $B^0 \to \bar{D}^0 \phi$ decay

➔ Occurs through W-exchange diagram + Okubo-Zweig-Iizuka (OZI) suppression or through ω-ϕ mixing





➔ Yet non-significant $B^0 \to \bar{D}^0 \phi$ signal (~2σ), interpreted as:

$$\frac{\mathcal{B}(B^0 \to \bar{D}^0 \phi)}{\mathcal{B}(B^0 \to \bar{D}^0 \pi^+ \pi^-)} = (1.2 \underbrace{\pm 0.7}_{\text{stat.}} \underbrace{\pm 0.3}_{\text{syst.}}) \times 10^{-3}$$

$$\Rightarrow \mathcal{B}(B^0 \to \bar{D}^0 \phi) = (1.1 \underbrace{\pm 0.6}_{\text{stat.}} \underbrace{\pm 0.3}_{\text{syst.}} \underbrace{\pm 0.1}_{\text{normalis.}}) \times 10^{-6}$$

Adapted prediction from Phys. Lett. B 666 (2008) 185 + BaBar Phys. Rev. D 84 (2011) 112007: $(1.6 \pm 0.1) \times 10^{-6}$

➔ Upper limits set on both branching fraction and mixing angle (i.e. ideally mixed states*) assuming that the contribution from ω-ϕ mixing dominates (@ 90% (95%) of CL):

$$\mathcal{B}(B^0 \to \bar{D}^0 \phi) < 2.0 \ (2.2) \times 10^{-6} \quad \Rightarrow \quad |\delta| < 5.2^\circ \ (5.5^\circ)$$

Factor 6 better improvement wrt BaBar (Phys. Rev. D76 (2007) 051103)

* $\omega^I \equiv (u\bar{u} + d\bar{d})/\sqrt{2}$ and $\phi^I \equiv s\bar{s}$ $\quad \begin{pmatrix} \omega \\ \phi \end{pmatrix} = \begin{pmatrix} \cos\delta & \sin\delta \\ -\sin\delta & \cos\delta \end{pmatrix} \begin{pmatrix} \omega^I \\ \phi^I \end{pmatrix}$

arXiv:1807.01891
arXiv:1807.01892

Conclusions and perspectives on $B^0_{(s)} \to \bar{D}^{(*)0} K^+ K^-$ decays

With 3/fb collected at LHC Run1, LHCb:

- ✓ Observes the B^0 and $B^0_s \to \bar{D}^0 K^+ K^-$ decays

  ➔ an amplitude analysis is within reach with Run2 LHCb data

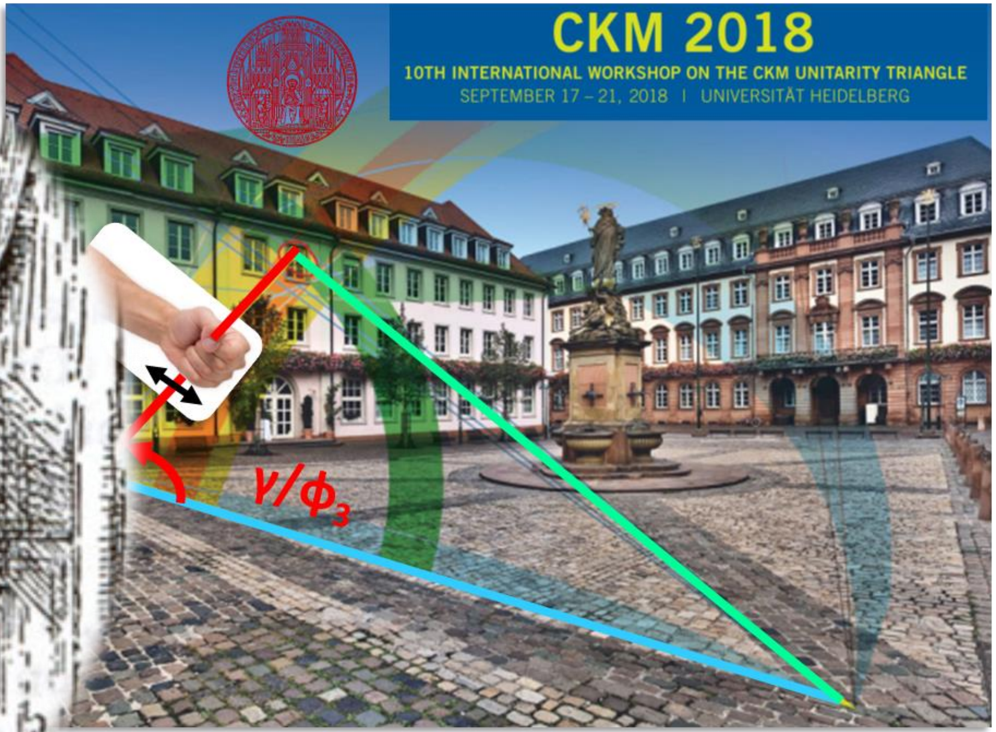
- ✓ Observes the $B^0_s \to \bar{D}^{*0} \phi$ decay and measures its f_L
- ✓ Confirms and measures better the $B^0_s \to \bar{D}^0 \phi$ decay

  ➔ both can be used to measure the CKM angle γ with Run2 LHCb data

- ✓ Improves the limit on $B^0 \to \bar{D}^0 \phi$ and constraints the ω-ϕ mixing angle

  ➔ observation within reach with Run2 LHCb data

BACKUP Slides



Efficiencies & branching ratios

	$B^0 \to \overline{D}{}^0\pi^+\pi^-$	$B^0 \to \overline{D}{}^0K^+K^-$	$B^0_s \to \overline{D}{}^0K^+K^-$
$\varepsilon^{\rm geom}$ [%]	15.8 ± 0.1	17.0 ± 0.1	16.9 ± 0.1
$\varepsilon^{\rm sel \mid geom}$ [%]	1.2 ± 0.1	1.1 ± 0.1	1.1 ± 0.1
$\varepsilon^{\rm PID \mid sel\ \&\ geom}$ [%]	95.5 ± 1.2	75.7 ± 1.4	76.3 ± 2.0
$\varepsilon^{\rm TIS}$ [%]	42.2 ± 0.7	42.2 ± 0.7	42.2 ± 0.7
$\varepsilon^{\rm TOS}$ [%]	40.6 ± 0.6	40.3 ± 0.8	40.6 ± 1.2
$\bar{\varepsilon}^{\rm DP}_{\rm corr.}$ [%]	85.5 ± 2.9	95.7 ± 4.1	$101.0^{+3.2}_{-7.1}$
$\varepsilon^{\rm TIS}_{B^0_{(s)}\to\overline{D}{}^0h^+h^-}$ $[10^{-4}]$	6.4 ± 0.2	5.9 ± 0.3	$6.0^{+0.3}_{-0.5}$
$\varepsilon^{\rm TOS}_{B^0_{(s)}\to\overline{D}{}^0h^+h^-}$ $[10^{-4}]$	6.1 ± 0.2	5.7 ± 0.3	$5.8^{+0.3}_{-0.5}$
$\varepsilon_{B^0_{(s)}\to\overline{D}{}^0h^+h^-}$ $[10^{-4}]$	10.6 ± 0.3	9.8 ± 0.4	$10.1^{+0.4}_{-0.6}$

$$\boxed{\varepsilon_{B^0_{(s)}\to\overline{D}{}^0h^+h^-} = \varepsilon^{\rm geom} \times \varepsilon^{\rm sel|geom} \times \varepsilon^{\rm PID|sel\ \&\ geom} \times \varepsilon^{\rm HW\ Trig|PID\ \&\ sel\ \&\ geom}}$$

$$\varepsilon^{\rm HW\ Trig|PID\ \&\ sel\ \&\ geom} = \frac{N_{\rm TIS} + N_{\rm TOS\&!TIS}}{N_{\rm ref}} = \varepsilon^{\rm TIS} + f \times \varepsilon^{\rm TOS}$$

$$\bar{\varepsilon}^{\rm DP}_{\rm corr.} = \frac{\sum_i \omega_i}{\sum_i \omega_i/\varepsilon(m^2_{i,\overline{D}{}^0h^+}, m^2_{i,\overline{D}{}^0h^-})}$$

$$\varepsilon_{B^0_{(s)}\to\overline{D}{}^0h^+h^-} = \varepsilon^{\rm TIS}_{B^0_{(s)}\to\overline{D}{}^0h^+h^-} + f \times \varepsilon^{\rm TOS}_{B^0_{(s)}\to\overline{D}{}^0h^+h^-}$$

arXiv:1807.01891

Systematic uncertainties

- ✓ Many sources of systematic uncertainty cancel in the ratios of branching fractions
- ✓ Other sources:
  - Hardware trigger
  - PID difference in the h^+h^- selection for $B^0_{(s)} \to \bar{D}^0 K^+ K^-$ signal and $B^0 \to \bar{D}^0 \pi^+\pi^-$ norm. mode
  - Signal and background modelling

Source [%]	$N_{B^0\to\overline{D}^0\pi^+\pi^-}$	$N_{B^0\to\overline{D}^0K^+K^-}$	$r_{B^0_s/B^0}$
$B^0_{(s)} \to \overline{D}^0 h^+ h^-$ signal PDF	1.0	2.1	4.2
$B^0 \to \overline{D}^{*0}[\overline{D}^0\gamma]\pi^+\pi^-$	1.6	–	–
$B^0 \to \overline{D}^0 K^+\pi^-$	0.3	–	–
$B^0_s \to \overline{D}^{*0} K^-\pi^+$	0.4	1.4	0.4
$B^0_s \to \overline{D}^{*0} K^+K^-$	–	0.5	1.3
Smearing & shifting	0.5	0.1	0.9
Total	2.0	2.6	4.5
Total on $N_{\rm sig}/N_{\rm normal}$	3.2		4.5