Charmed Beauty Decays at LHCb

LHCb_Collaboration::Mike_Williams

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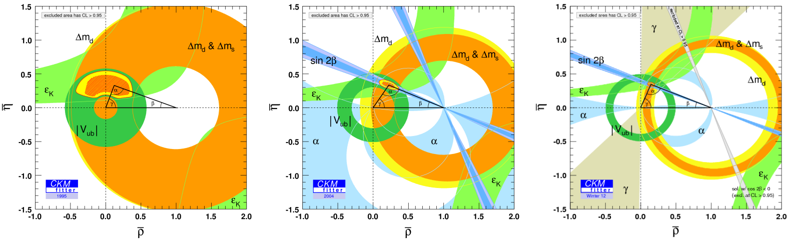
Introduction/Motivation

The CKM matrix describes all quark flavor-changing processes in the SM.

Amazing progress in the past 17 years . . . but still more to learn.

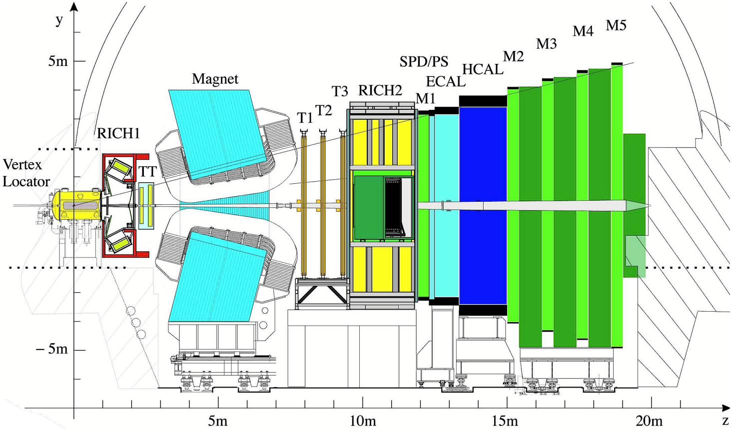
1995 2004 2012



This talk focusses on first observations/evidence for a number of beauty decays to open charm final states.

The LHCb Detector

LHCb: FWD spectrometer ($2 < \eta < 5$) built to study heavy-quark physics.



LHCb has excellent vertex and momentum resolution, PID, μ-ID, *etc.*

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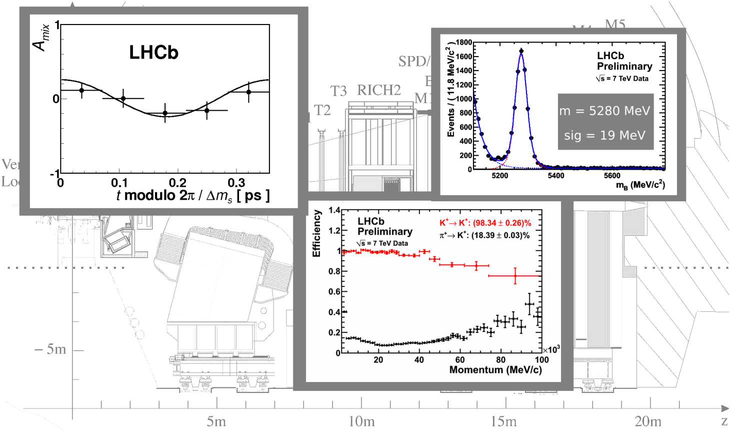
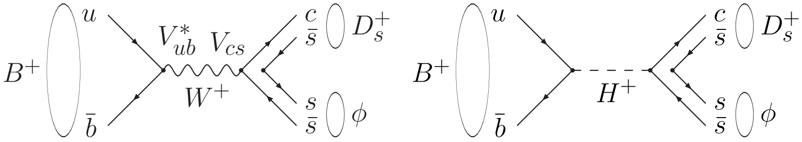


LHCb has excellent vertex and momentum resolution, PID, μ-ID, *etc.*

$B^{\pm} \to D_s^{\pm}\phi$

No hadronic annihilation-type decays of the $B^{\pm}$ have been observed to-date. $\mathcal{B}_{\rm SM}(B^{\pm} \to D_s^{\pm}\phi) = (1-7) \times 10^{-7}$ (large hadronic uncertainty).



BSM physics, *e.g.*, $H^{\pm}$ exchange, could greatly enhance the branching fraction and/or generate a large CP asymmetry ($\mathcal{A}_{CP}$).

$\mathcal{B}(B^{\pm} \to D_s^{\pm}\phi) < 1.9 \times 10^{-6}$ (BABAR, PRD73 011103, hep-ex/0506073)
Existing limit already places strong constraints on 2HD models.

$B^\pm \to D_s^\pm \phi$ [LHCb-PAPER-2012-025] (New!)

Analysis strategy:

- reconstruct $D_s^\pm \to K^+ K^- \pi^\pm$ and $\phi \to K^+ K^-$;
- multivariate (BDT) selections for the $D_s^\pm$ and ϕ trained using huge $\overline{B}_s^0 \to D_s^\pm \pi^\mp$ and $B_s^0 \to J/\psi\phi$ data samples;
- all PID info contained within the BDTs, efficiencies obtained from $\overline{B}_s^0 \to D_s^\pm \pi^\mp$ and $B_s^0 \to J/\psi\phi$ data samples not used in the training;
- topology *sanity* cuts made on $B^\pm \to D_s^\pm \phi$;
- charmless backgrounds suppressed by requiring $D_s^\pm$ significantly downstream of the $B^\pm$ vertex.

Branching fraction normalized to $\mathcal{B}(B^+ \to D_s^+ \overline{D}^0)$.

$B^{\pm} \to D_s^{\pm}\phi$ [LHCb-PAPER-2012-025] (New!)

$|m_{KK} - m_{\phi}| < 20$ MeV   20 MeV/c $< |m_{KK} - m_{\phi}| < 40$ MeV

$|\cos\theta_K^*| > 0.4$

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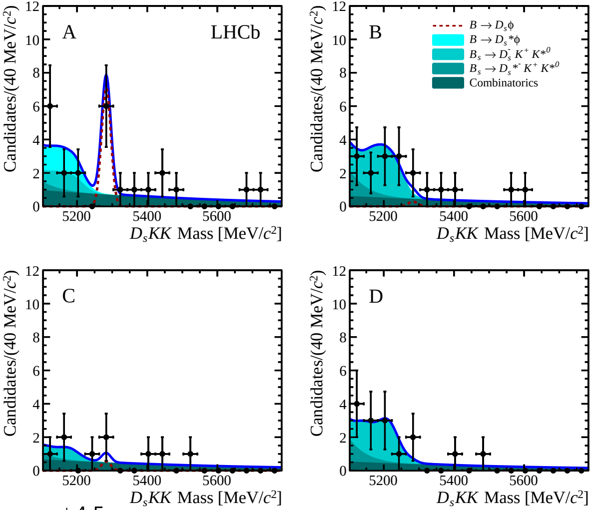


Observe $6.7^{+4.5}_{-2.6}$ signal events with greater than 3σ significance.

$B^\pm \to D_s^\pm \phi$ [LHCb-PAPER-2012-025] (New!)

$$\mathcal{B}(B^\pm \to D_s^\pm \phi) = \left(1.87\,^{+1.25}_{-0.73}\,(\text{stat}) \pm 0.19\,(\text{syst}) \pm 0.32\,(\text{norm})\right) \times 10^{-6}$$

$$\mathcal{A}_{CP}(B^\pm \to D_s^\pm \phi) = -0.01 \pm 0.41\,(\text{stat}) \pm 0.03\,(\text{syst})$$

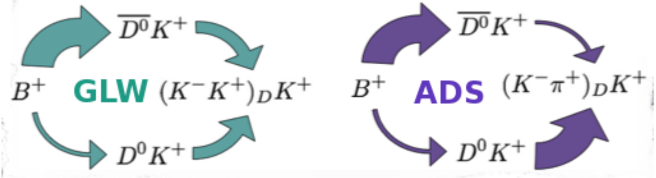
Related Decay Modes

Decay	UL at 90% CL	Decay	$\frac{f_c}{f_u} \times$ UL at 90% CL
$B^+ \to D^+ K^{*0}$	1.8×10^{-6}	$B_c^+ \to D^+ K^{*0}$	0.5×10^{-6}
$B^+ \to D^+ \overline{K}^{*0}$	1.4×10^{-6}	$B_c^+ \to D^+ \overline{K}^{*0}$	0.4×10^{-6}
$B^+ \to D_s^+ K^{*0}$	3.5×10^{-6}	$B_c^+ \to D_s^+ K^{*0}$	0.7×10^{-6}
$B^+ \to D_s^+ \overline{K}^{*0}$	4.4×10^{-6}	$B_c^+ \to D_s^+ \overline{K}^{*0}$	1.1×10^{-6}
		$B_c^+ \to D_s^+ \phi$	0.8×10^{-6}

Small excess in $B^+ \to D^+ K^{*0}$: posterior PDF excludes zero signal at the 89% CL and gives $\mathcal{B}(B^+ \to D^+ K^{*0}) = (0.8\,^{+0.6}_{-0.5}) \times 10^{-6}$.

CKM γ via GLW/ADS

Use interference b/t $\mathcal{A}_{b\to u}^{\bar{b}\to\bar{u}} = \mathcal{A}_{bu} e^{\pm i\gamma}$ and $\mathcal{A}_{b\to c}^{\bar{b}\to\bar{c}} = \mathcal{A}_{bc}$ to extract γ.



[nb, this equation is slightly oversimplified as it ignores the D-decay amplitudes]

$$\begin{aligned}\mathcal{N}_\pm &= |\mathcal{A}_{B^\pm\to D^0K^\pm} + \mathcal{A}_{B^\pm\to\bar{D}^0K^\pm}|^2 \\ &= |\mathcal{A}_{D^0}|^2 + |\mathcal{A}_{\bar{D}^0}|^2 + 2|\mathcal{A}_{D^0}||\mathcal{A}_{\bar{D}^0}|\cos(\Delta\theta_{\rm strong} \pm \gamma)\end{aligned}$$

Classic modes discussed in other LHCb talks (Malde, John). Here I'll show some other players in this game.

$B^0_{(s)} \to \overline{D}^0 K^+ K^-$ [LHCb-PAPER-2012-018]

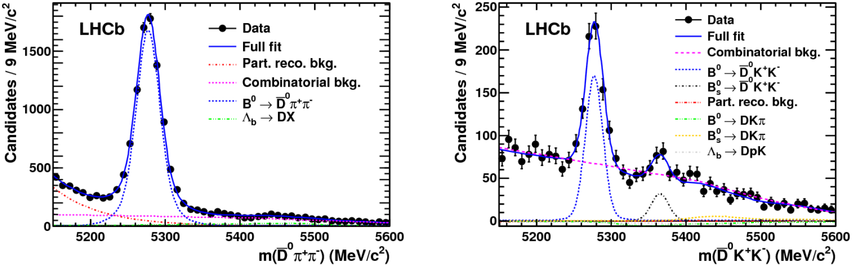
The CKM angle γ can be measured using the decays $B^0_s \to D\phi$ (via GLW/ADS) and $B^0_s \to DK^+K^-$ (via Dalitz-plot analysis).

Step 1: observe $B^0_s \to DK^+K^-$.

LHCb Analysis (uses 0.62 fb^{-1} of 2011 data)

- Reconstruct $\overline{D}^0 \to K^+\pi^-$.
- PID cuts using RICH info; efficiencies obtained from $D^* \to D^0\pi$ data.
- ANN trained on $B^0 \to \overline{D}^0\pi^+\pi^-$ data; efficiency determined in MC.
- $D^* \to D\pi$ veto (including $\pi \to K$ mis ID) applied.

$B^0_{(s)} \to \overline{D}^0 K^+ K^-$ [LHCb-PAPER-2012-018]



$$\frac{\mathcal{B}(B^0 \to \overline{D}^0 K^+ K^-)}{\mathcal{B}(B^0 \to \overline{D}^0 \pi^+ \pi^-)} = 0.056 \pm 0.011 \pm 0.007 \text{ @ } 5.8\sigma \text{ (first observation!)}$$

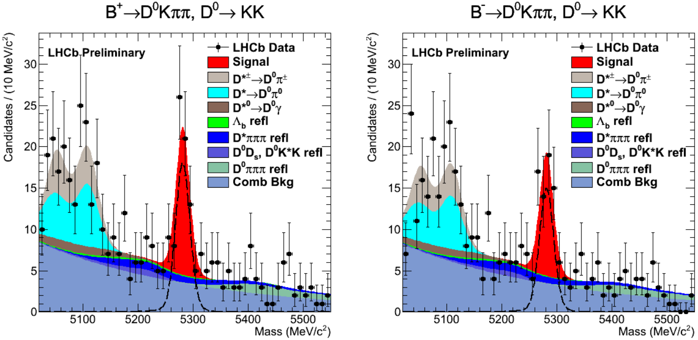
$$\frac{\mathcal{B}(B^0_s \to \overline{D}^0 K^+ K^-)}{\mathcal{B}(B^0 \to \overline{D}^0 K^+ K^-)} = 0.90 \pm 0.27 \pm 0.20 \text{ @ } 3.8\sigma \text{ (first evidence!)}$$

More data needed to go after γ but should have enough using $2011 + 2012$ to measure some relevant quantities here.

$B^- \to D^0 K^- \pi^+ \pi^-$ [LHCb-CONF-2012-021]

The decays $B^- \to D^0 K^- \pi^+ \pi^-$ can be used in the GLW/ADS technique in a similar way as $B^- \to D^0 K^-$ (extra *coherence factor* needed).

First Observations!



Also first observations of the $D^0 \to \pi^+\pi^-$ modes.

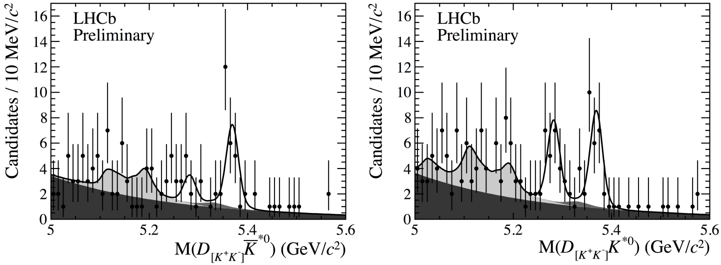
$B^- \to D^0 K^- \pi^+ \pi^-$ [LHCb-CONF-2012-021]

A number of GLW quantities are measured for the $B^- \to D^0 K^- \pi^+ \pi^-$ and $B^- \to D^0 \pi^- \pi^+ \pi^-$ decay modes:

$$R_{CP+} = 0.95 \pm 0.11\ (\text{stat}) \pm 0.02\ (\text{syst})$$
$$\boxed{A_{CP+}^{K\pi\pi} = -0.14 \pm 0.10\ (\text{stat}) \pm 0.01\ (\text{syst})}$$
$$A_{K\pi}^{K\pi\pi} = -0.009 \pm 0.028(\text{stat}) \pm 0.013(\text{syst})$$
$$A_{CP+}^{\pi\pi\pi} = -0.018 \pm 0.018(\text{stat}) \pm 0.007(\text{syst})$$
$$A_{K\pi}^{\pi\pi\pi} = -0.006 \pm 0.006(\text{stat}) \pm 0.010(\text{syst})$$

The largest sensitivity to γ of these observables is $A_{CP+}^{K\pi\pi}$. The ADS and GGSZ modes will be looked for using the 2011 + 2012 data set.

$B^0_{(s)} \to D^0 K^*$ [LHCb-CONF-2012-024]



$$R_{KK} = 1.42^{+0.41}_{-0.35}(\text{stat}) \pm 0.07(\text{syst})$$

$$A^d_{KK} = -0.47^{+0.24}_{-0.25}(\text{stat}) \pm 0.02(\text{syst})$$

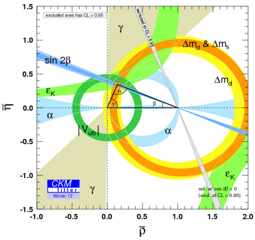
$$A^d_{K\pi} = -0.08 \pm 0.08(\text{stat}) \pm 0.01(\text{syst})$$

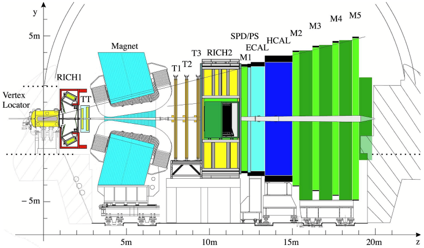
$$A^s_{KK} = 0.04 \pm 0.17(\text{stat}) \pm 0.01(\text{syst})$$

More data will permit the measurement of additional observables in these channels leading to strong constraints on γ.

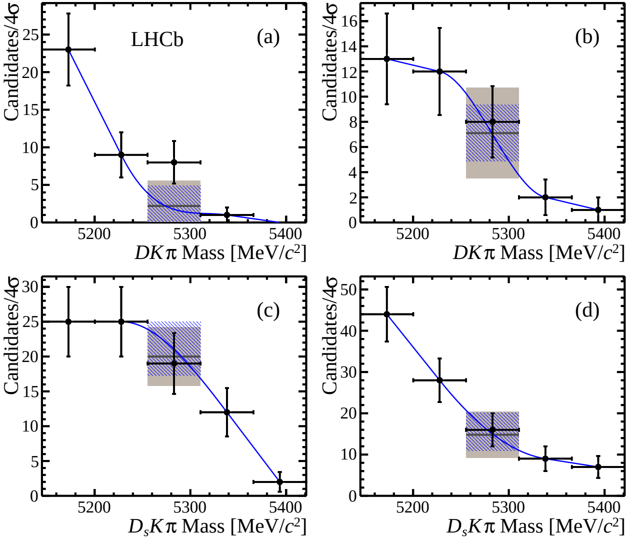
Summary

- LHCb performed great in 2011 and collected just over 1 fb^{-1} of data.
- LHCb has collected about 1.4 fb^{-1} of data already in 2012. The $b\bar{b}$ cross section is also higher in 2012 so the total 2011-2012 data set will have about 3X as many b-hadrons as in 2011 alone.
- Look forward to many more great results from LHCb using this vast data set. Stay tuned!

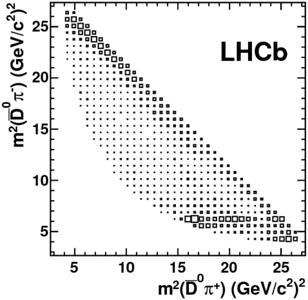


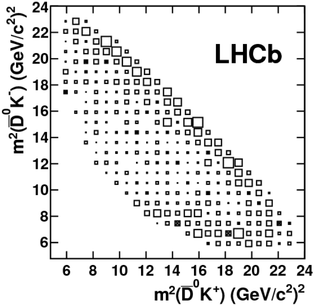


$B^{\pm} \to D^{\pm}_{(s)} K^{*}$ [LHCb-PAPER-2012-025] (New!)

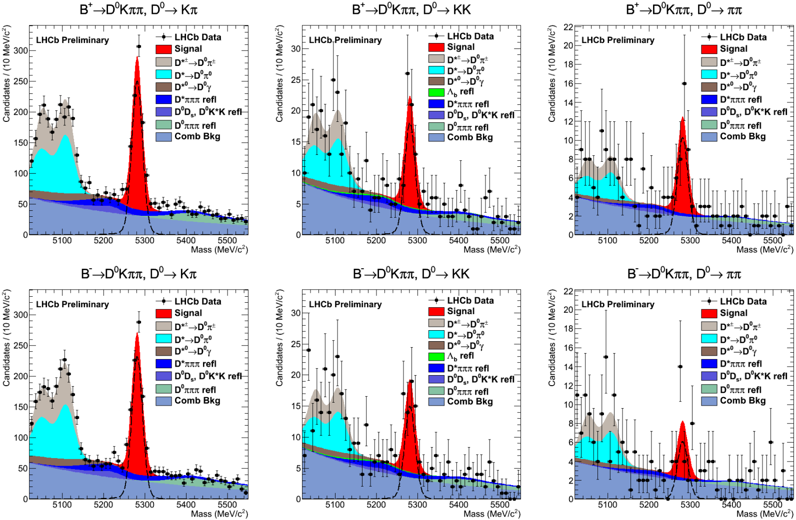


$B^0_{(s)} \to \overline{D}^0 K^+ K^-$ [LHCb-PAPER-2012-018]





$B^- \to D^0 K^- \pi^+ \pi^-$ [LHCb-CONF-2012-021]



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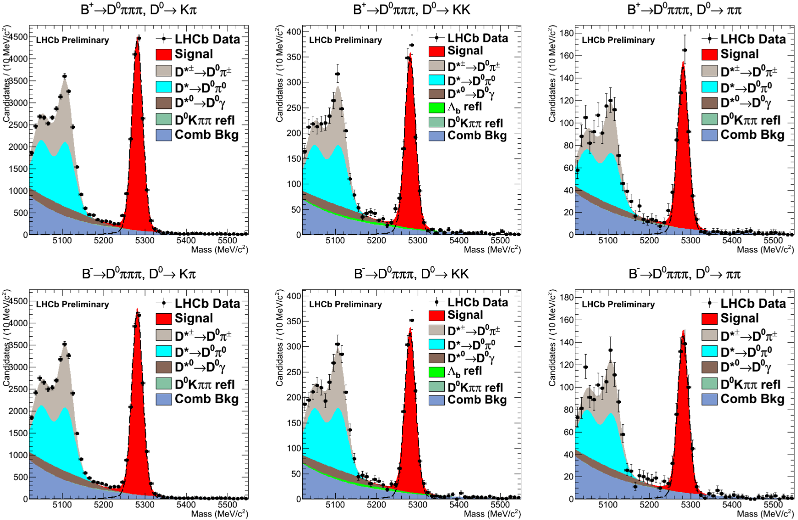

$B^0_{(s)} \to D^0 K^*$ [LHCb-CONF-2012-024]