

Studies of multibody charmless B decays at LHCb

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Contents

- 1 CP Violation in $B^\pm \rightarrow K^\pm h^+ h^-$ decays
- 2 CP asymmetries and dynamics in $B^\pm \rightarrow p\bar{p}h^\pm$
- 3 Branching fraction measurements of $B_{(s)}^0 \rightarrow K_s^0 h^\pm h^\mp$
- 4 Search for $\Lambda_b^0 \rightarrow \Lambda \eta'$

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CPV in $B^\pm \rightarrow K^\pm h^+ h^-$

arXiv:1306.1246

NEW!

- Motivated by large CP violation (CPV) observed in $B_{(S)}^0 \rightarrow K^{\pm(\mp)}\pi^{\pm(\pm)}$
 - Source of strong phase difference unknown
 - Final state hadron rescattering ($\pi^+\pi^- \rightarrow K^+K^-$)
- Measure CP asymmetries in $B^\pm \rightarrow K^\pm\pi^+\pi^-$ and $B^\pm \rightarrow K^\pm K^+K^-$
- Using 1 fb^{-1} 2011 data recorded by LHCb ($\approx 33\%$ total data)

$$A_{CP}(B^\pm \rightarrow f^\pm) = \frac{\Gamma(B^- \rightarrow f^-) - \Gamma(B^+ \rightarrow f^+)}{\Gamma(B^- \rightarrow f^-) + \Gamma(B^+ \rightarrow f^+)}$$

Actually measure:

$$\begin{aligned} A_{\text{raw}} &= A_{CP} + A_\Delta \\ A_\Delta &= A_D(K^\pm) + A_P(B^\pm) \end{aligned}$$

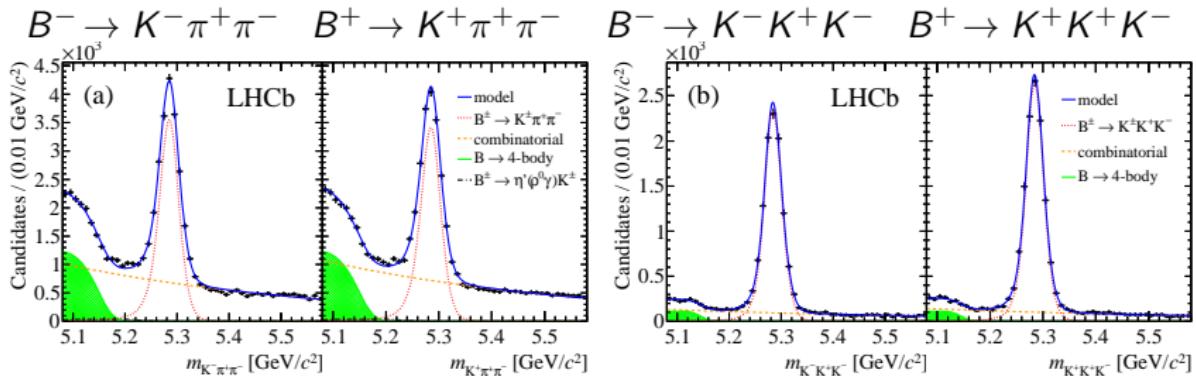
- A_Δ measured using a sample of $B^\pm \rightarrow J/\psi(\mu^+\mu^-)K^\pm$

- $A_{CP}(J/\psi K) = (0.1 \pm 0.7)\%$ Phys. Rev. D86 (2012) 010001

Inclusive Measurements

arXiv:1306.1246

NEW!



$$A_{CP}(B^\pm \rightarrow K^\pm \pi^+ \pi^-) = 0.032 \pm 0.008 \text{ (stat)} \pm 0.004 \text{ (syst)} \pm 0.007 (A_{CP}(J/\psi K))$$

$$A_{CP}(B^\pm \rightarrow K^\pm K^+ K^-) = -0.043 \pm 0.009 \text{ (stat)} \pm 0.003 \text{ (syst)} \pm 0.007 (A_{CP}(J/\psi K))$$

- Significance of asymmetry:

$$A_{CP}(K^\pm \pi^+ \pi^-) : 2.8\sigma$$

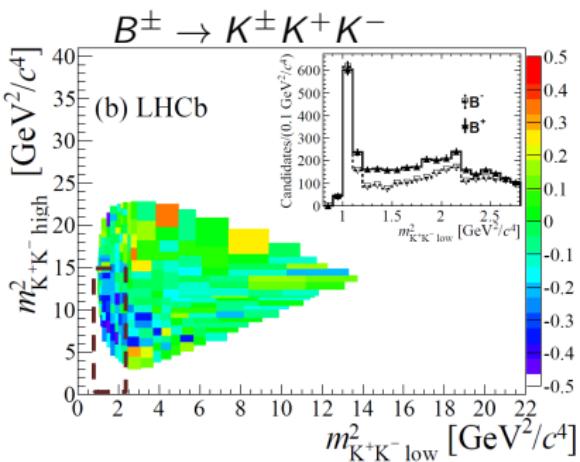
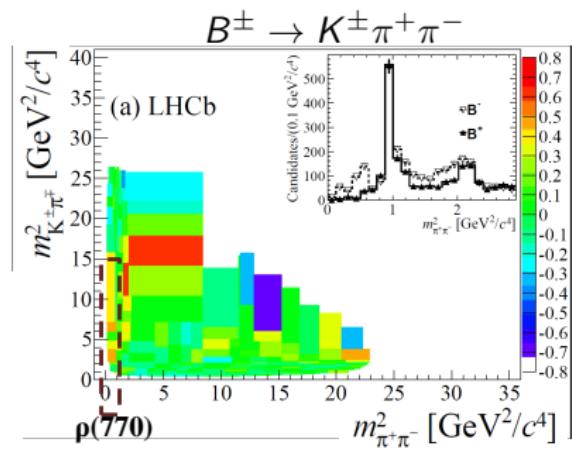
$$A_{CP}(K^\pm K^+ K^-) : 3.7\sigma$$

Study of phase space

arXiv:1306.1246

NEW!

- Study A_{CP}^N in Dalitz plane, where $A_{CP}^N = \Phi[N(B^+), N(B^-)]$



$$A_{CP}^{\text{reg}}(B^\pm \rightarrow K^\pm \pi^+ \pi^-) = 0.678 \pm 0.078 \text{ (stat)} \pm 0.032 \text{ (syst)} \pm 0.007 (A_{CP}(J/\psi K))$$

$$A_{CP}^{\text{reg}}(B^\pm \rightarrow K^\pm K^+ K^-) = -0.226 \pm 0.020 \text{ (stat)} \pm 0.004 \text{ (syst)} \pm 0.007 (A_{CP}(J/\psi K))$$

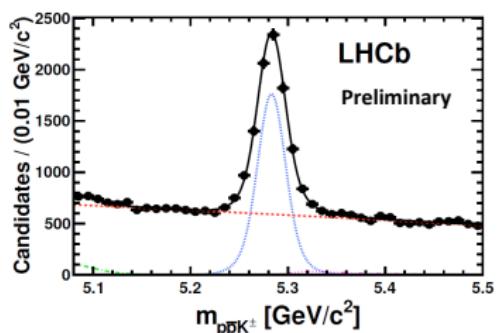
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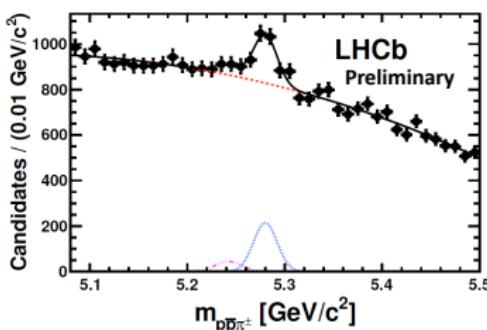
Study of $B^\pm \rightarrow K^\pm p\bar{p}$ and $B^\pm \rightarrow \pi^\pm p\bar{p}$

LHCb-PAPER-2013-031

- Very similar to $B^\pm \rightarrow K^\pm h^+ h^-$
- Hadron rescattering ($hh \rightarrow p\bar{p}$) not expected to play a large role
 - Test of this model
 - A_{CP} should be small
- Uses same dataset and similar selection to previous analysis



$$N(p\bar{p}K^\pm) = 7029 \pm 139$$



$$N(p\bar{p}\pi^\pm) = 656 \pm 70$$

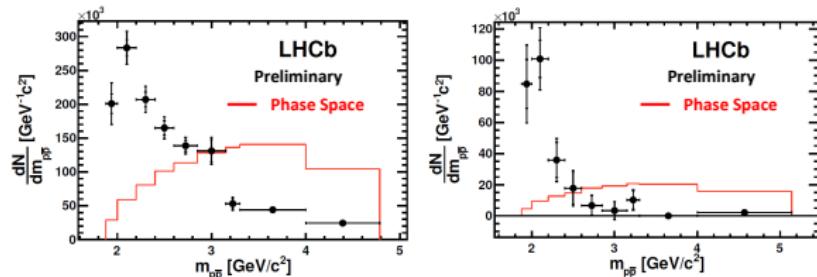
- Measuring the dynamics and \mathcal{CP} asymmetry of the decay

Differential production spectra

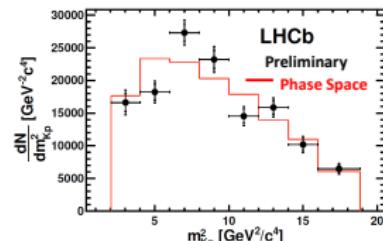
LHCb-PAPER-2013-031

NEW!

- Differential production spectra as a function of $m_{p\bar{p}}$
 - Charmonium contribution removed:
 - $B^\pm \rightarrow K^\pm J/\psi$, $B^\pm \rightarrow K^\pm \eta_c$, $B^\pm \rightarrow K^\pm \psi(2S)$ and $B^\pm \rightarrow \pi^\pm J/\psi$



- Differential production spectra as a function of $m_{(ph)^0}^2$ for $B^\pm \rightarrow p\bar{p}K^\pm$

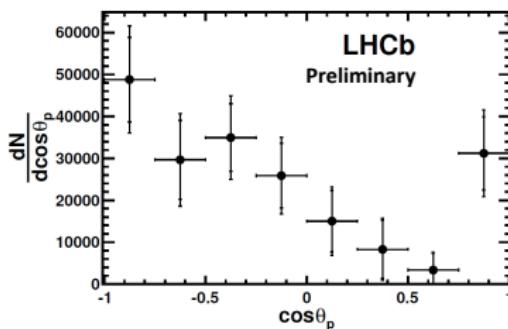
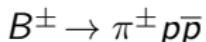
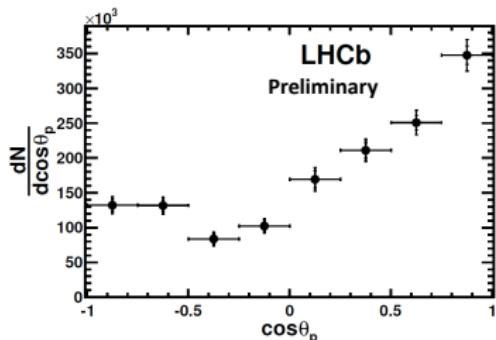
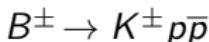


Differential production spectra

LHCb-PAPER-2013-031

NEW!

- Differential signal yields as a function of $\cos\theta_p$



- Measure Forward-Backward asymmetry, A_{FB}

$$A_{FB} = \frac{N_{\text{pos}}^{\text{RAW}} - f \times N_{\text{neg}}^{\text{RAW}}}{N_{\text{pos}}^{\text{RAW}} + f \times N_{\text{neg}}^{\text{RAW}}} , \quad f = \frac{\epsilon_{\text{pos}}}{\epsilon_{\text{neg}}}$$

$$A_{FB}(p\bar{p}K^\pm) = 0.370 \pm 0.018 \text{ (stat)} \pm 0.016 \text{ (syst)}$$

$$A_{FB}(p\bar{p}\pi^\pm) = -0.392 \pm 0.117 \text{ (stat)} \pm 0.015 \text{ (syst)}$$

\mathcal{CP} asymmetries.

LHCb-PAPER-2013-031

Preliminary, NEW!

- Measure \mathcal{CP} asymmetries in $B^\pm \rightarrow p\bar{p}K^\pm$
- Perform simultaneous fit to B^+ and B^- samples to extract B^\pm yields
- Extract A_{CP} again using $B^\pm \rightarrow J/\psi K^\pm$
- A_{CP} measured in different regions:
 - Full $p\bar{p}K^\pm$ spectrum
 - $m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$
 - Charmonia resonances

$$A_{CP}(p\bar{p}K^\pm) = -0.022 \pm 0.031 \text{ (stat)} \pm 0.007 \text{ (syst)}$$
 Full spectrum

$$A_{CP}(p\bar{p}K^\pm) = -0.047 \pm 0.036 \text{ (stat)} \pm 0.007 \text{ (syst)}$$
 Low $m_{p\bar{p}}$

$$A_{CP}(\eta_c K^\pm) = 0.046 \pm 0.057 \text{ (stat)} \pm 0.007 \text{ (syst)}$$

$$A_{CP}(\psi(2S)K^\pm) = -0.002 \pm 0.123 \text{ (stat)} \pm 0.007 \text{ (syst)}$$

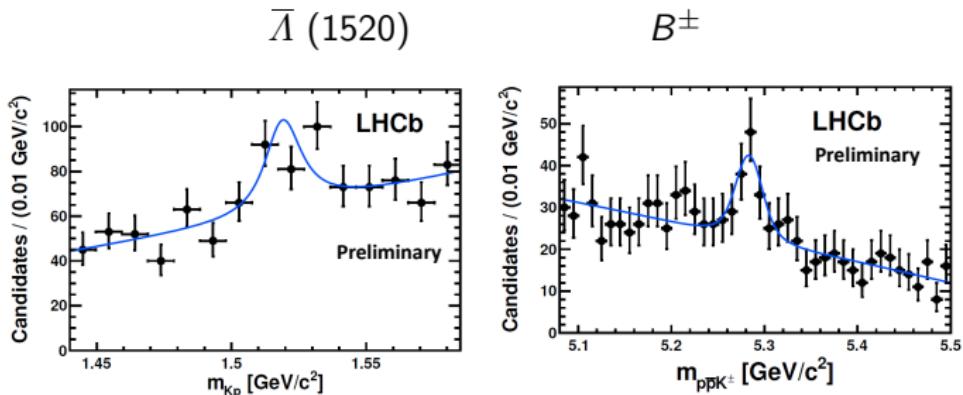
- No significant \mathcal{CP} asymmetries found in any region!

Observation of $B^+ \rightarrow \bar{\Lambda}(1520)p$

LHCb-PAPER-2013-031

NEW!

- Resonance observed in the $m_{(Kp)}^2$ spectrum, corresponding to $\bar{\Lambda}(1520)$ mass.
- Investigate signal in the region $1.44 < m_{pK} < 1.585 \text{ GeV}/c^2$
- 2D fit to $m_B - m_{Kp}$, projected below

5.1 σ

$$\frac{\mathcal{B}(B^+ \rightarrow \bar{\Lambda}(1520)p)}{\mathcal{B}(B^+ \rightarrow J/\psi K^+)} = 0.041^{+0.011}_{-0.010} (\text{stat}) \pm 0.001 (\text{syst})$$

$$\mathcal{B}(B^+ \rightarrow \bar{\Lambda}(1520)p) = (3.9^{+1.0}_{-0.9} (\text{stat}) \pm 0.1 (\text{syst}) \pm 0.3 (\text{BF})) \times 10^{-7}$$

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Studies of $B_{(s)}^0 \rightarrow K_s^0 h^\pm h^\mp$

LHCb-PAPER-2013-042

NEW!

- Towards a full amplitude analysis of 3-body decays
- Today present update of branching fraction measurements

Decay	Observed?	Favoured?
$B^0 \rightarrow K_s^0 K^+ K^-$	✓	✓
$B^0 \rightarrow K_s^0 K^\pm \pi^\mp$	✓	✗
$B^0 \rightarrow K_s^0 \pi^+ \pi^-$	✓	✓
$B_s^0 \rightarrow K_s^0 K^+ K^-$	✗	✗
$B_s^0 \rightarrow K_s^0 K^+ K^-$	✗	✓
$B_s^0 \rightarrow K_s^0 K^+ K^-$	✗	✗

- Boosted Decision Tree (BDT) used to separate signal and background.
- Selection separated depending where K_s^0 decays:
 - Upstream of the VELO: Long-Long (LL)
 - Downstream of the VELO: Downstream-Downstream (DD)
- Optimisation of BDT performed differently for favoured modes:

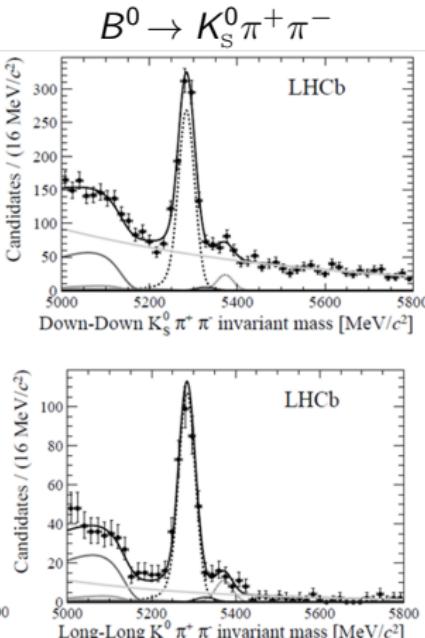
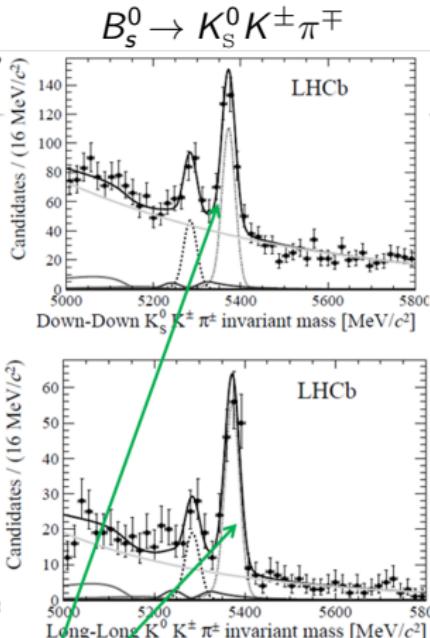
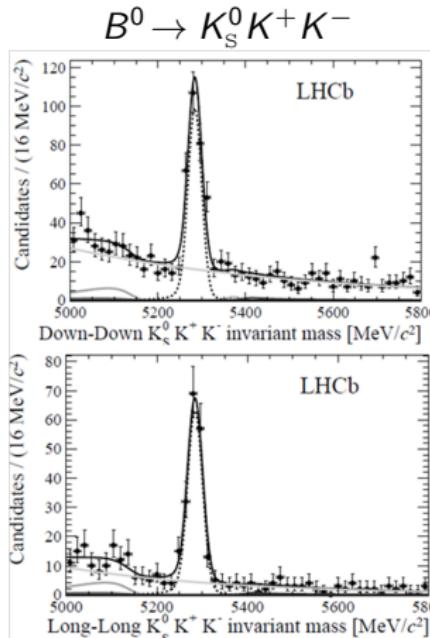
Loose BDT Selection.

LHCb-PAPER-2013-042

NEW!

- Loose BDT cut for favoured modes

Preliminary.



Clear first observation of
 $B_s^0 \rightarrow K_S^0 K^\pm \pi^\mp$

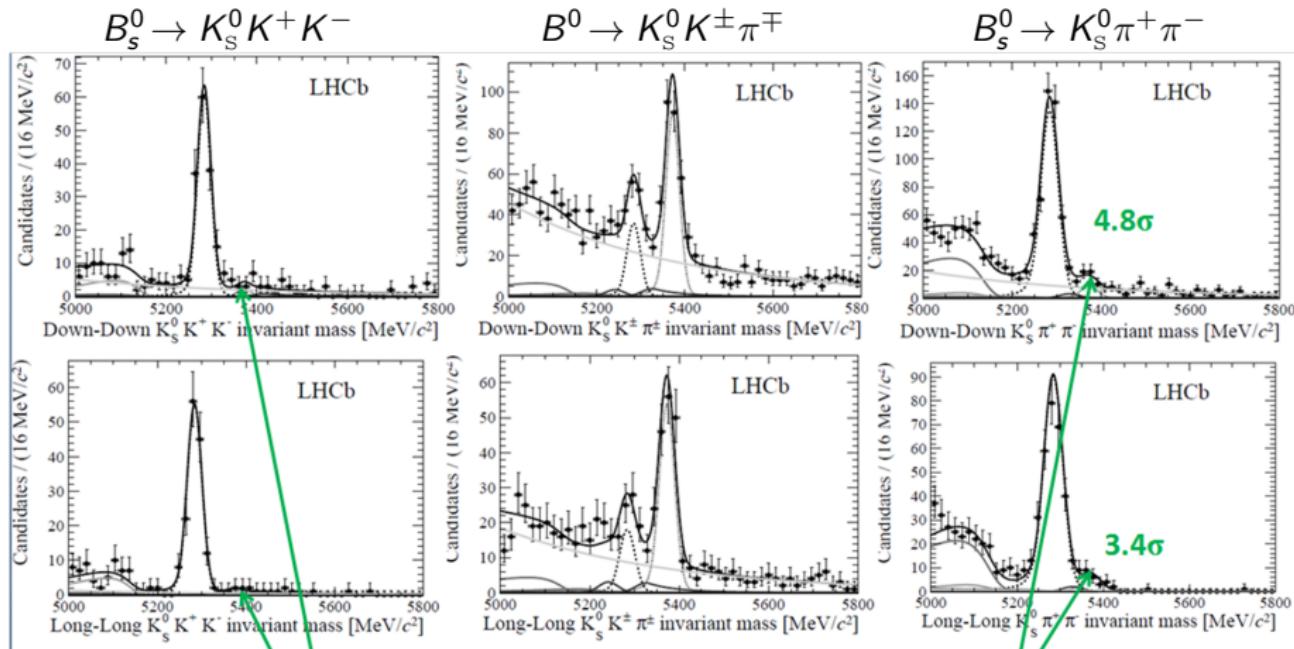
Tight BDT Selection.

LHCb-PAPER-2013-042

NEW!

- Tight BDT cut for suppressed modes.

Preliminary.

No evidence of $B_s^0 \rightarrow K_S^0 K^+ K^-$ Observation of $B_s^0 \rightarrow K_S^0 \pi^+ \pi^-$ at 5.9σ

Branching Fraction Measurements

LHCb-PAPER-2013-042

NEW!

- Branching fractions measured relative to $B^0 \rightarrow K_s^0 \pi^+ \pi^-$.
- 90% Confidence belt obtained for $B_s^0 \rightarrow K_s^0 K^+ K^-$ using Feldman Cousins (FC) method. **Phys. Rev. D57 (1998) 3873**

Preliminary.

$$\frac{\mathcal{B}(B_s^0 \rightarrow K_s^0 K^\pm \pi^\mp)}{\mathcal{B}(B^0 \rightarrow K_s^0 \pi^+ \pi^-)} = 1.48 \pm 0.11 \text{ (stat.)} \pm 0.08 \text{ (syst.)} \pm 0.11 \text{ } (f_s/f_d),$$

$$\frac{\mathcal{B}(B^0 \rightarrow K_s^0 K^+ K^-)}{\mathcal{B}(B^0 \rightarrow K_s^0 \pi^+ \pi^-)} = 0.385 \pm 0.030 \text{ (stat.)} \pm 0.026 \text{ (syst.)},$$

$$\frac{\mathcal{B}(B_s^0 \rightarrow K_s^0 \pi^+ \pi^-)}{\mathcal{B}(B^0 \rightarrow K_s^0 \pi^+ \pi^-)} = 0.29 \pm 0.06 \text{ (stat.)} \pm 0.03 \text{ (syst.)} \pm 0.02 \text{ } (f_s/f_d),$$

$$\frac{\mathcal{B}(B^0 \rightarrow K_s^0 K^\pm \pi^\mp)}{\mathcal{B}(B^0 \rightarrow K_s^0 \pi^+ \pi^-)} = 0.130 \pm 0.017 \text{ (stat.)} \pm 0.012 \text{ (syst.)},$$

$$\frac{\mathcal{B}(B_s^0 \rightarrow K_s^0 K^+ K^-)}{\mathcal{B}(B^0 \rightarrow K_s^0 \pi^+ \pi^-)} \in [0.004; 0.068] \text{ at 90\% C.L. .}$$

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Search for $\Lambda_b^0 \rightarrow \Lambda\eta'$ NEW!

- New search for baryonic decays to η and η'
 - Investigating $\eta-\eta'$ mixing
 - No baryonic decays observed in this channel
 - Theoretical predictions: $\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda\eta') \approx (1.8 - 19) \times 10^{-6}$

Ahmady *et al.*

Phys. Lett. B598 (2004) 203

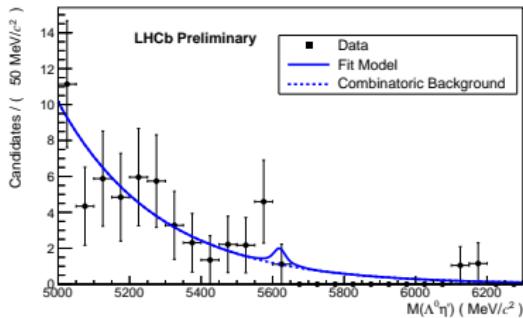
- Dataset recorded in 2012, corresponding to 2.0 fb^{-1}

Results

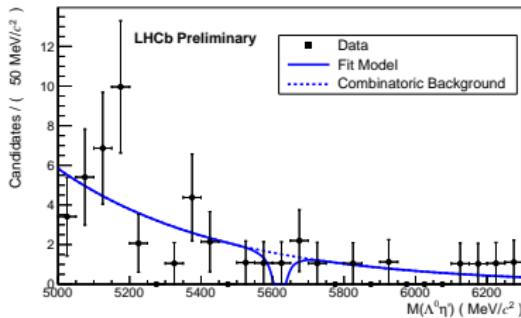
LHCb-CONF-2013-010

Preliminary, NEW!

LL



DD



- No significant signal observed
- Use FC method to place a limit on branching fractions relative to $B^0 \rightarrow K_S^0\eta'$:

$$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda\eta')}{\mathcal{B}(B^0 \rightarrow K_S^0\eta')} < 9.6 \times 10^{-2} \text{ at 90% CL}$$

Using $\mathcal{B}(B^0 \rightarrow K^0\eta') = (66 \pm 4) \times 10^{-6}$

$$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda\eta') < 6.3 \times 10^{-6} \text{ at 90% CL.}$$

Summary

- First evidence for CP violation in inclusive $B^\pm \rightarrow K^\pm K^+ K^-$ decay
- Studies of $B^\pm \rightarrow p\bar{p}h^\pm$
 - No CP asymmetries observed: no hadron rescattering expected
 - First observation of $B^+ \rightarrow \bar{\Lambda}(1520)p$
- First observation of $B_s^0 \rightarrow K_s^0 K^\pm \pi^\mp$ and $B_s^0 \rightarrow K_s^0 \pi^+ \pi^-$
 - No evidence for $B_s^0 \rightarrow K_s^0 \pi^+ \pi^-$ in 1 fb^{-1} 2011 data
- Search for the decay $\Lambda_b^0 \rightarrow \Lambda\eta'$
 - No evidence for signal in 2 fb^{-1} 2012 data.
- All analyses will benefit from full 3 fb^{-1} dataset (2011+2012)