Studies of multibody charmless B decays at LHCb

Fernando Rodrigues on behalf of the LHCb Collaboration
(Centro Brasileiro de Pesquisas Físicas, Brazil)

International Conference on High Energy Physics 2012
4th - 11th July, 2012 | Melbourne, Australia
Integrated luminosity: 37 pb$^{-1}$ (2010), 1 fb$^{-1}$ (2011), 0.6 fb$^{-1}$ (until ICHEP)
Multibody charmless B decays at LHCb

Integrated luminosity of 1 fb$^{-1}$
2011 Data

$B^\pm$ decays

$B_{d,s}^0$ decays

LHCb-CONF-2012-018 NEW!
$A_{CP} (B^\pm \rightarrow K^{\pm} \pi^+ \pi^-)$
$A_{CP} (B^\pm \rightarrow K^{\pm} K^+ K^-)$

LHCb-CONF-2012-023 NEW!
$B_{d,s}^0 \rightarrow K_S hh$ branching fractions

LHCb-PAPER-2012-004
$B_s^0 \rightarrow \phi \phi$ amplitude analysis
$B^\pm \rightarrow K^\pm \pi^+ \pi^-$ charge asymmetry

$$A_{CP} = A_{CP}^{RAW} - (A_{CP}^{Det.} + A_{CP}^{Prod.})$$

$A_{CP}^{Det.}$ and $A_{CP}^{Prod.}$ are determined from the control channel $B^\pm \rightarrow J/\psi (\mu^+ \mu^-)K^\pm$

Preliminary $1 fb^{-1}$: $18168 \pm 170$ $B^-$ candidates, $17540 \pm 169$ $B^+$ candidates

Preliminary $A_{CP}(K\pi\pi) = +0.034 \pm 0.009_{\text{(stat)}} \pm 0.004_{\text{(syst)}} \pm 0.007_{(J/\psi \, K)}$

Preliminary Significance of 2.8$\sigma$.  

F. Rodrigues, CBPF, Brazil

Multibody charmless $B$ decays at LHCb,
$B^\pm \to K^\pm K^+ K^-$ charge asymmetry

\[ A_{CP}(KKK) = -0.046 \pm 0.009_{(\text{stat})} \pm 0.005_{(\text{syst})} \pm 0.007_{(J/\psi K)} \]

- First evidence of inclusive CP asymmetry in charmless three-body $B^\pm$ decays.
- Significance of $3.7\sigma$.
- $1 fb^{-1}: 10289 \pm 110 B^-$ candidates, $11606 \pm 117 B^+$ candidates.
\( B^\pm \to K^\pm \pi^+\pi^- \) and \( B^\pm \to K^\pm K^+K^- \) phase space

- Phase space without B mass constraint.
- Phase space not background-subtracted.
- \( B^\pm \to \bar{D}^0(D^0)h^\pm, \bar{D}^0(D^0) \to h^+h^- \) contributions removed.
- \( B^\pm \to J/\psi(\mu^+\mu^-)K^\pm \) contributions removed.

\[ m^2_{K^\pm} < m^2_{K^\mp} \]

- \( K^*(890) \) and \( K^*(1430) \)
- \( \rho^0(770) \) and \( f_0(980) \)
- \( f'_2(1525) \)
- \( \phi(1020) \)

LHCb-CONF-2012-018
**CP asymmetry in phase space: $B^\pm \rightarrow K^\pm \pi^+ \pi^-$**

---

**Illustrative view 1**

- Bins with equal number of entries.
- No background subtraction.

CP asymmetry consistent with Belle and BaBar results.
BaBar: PRD78,012004(2008)

---

**Illustrative view 2**

Simplified binned fit in each bin

First bin: the region of $\rho(770)$ and $f_0(980)$.

---

F. Rodrigues, CBPF, Brazil

Multibody charmless $B$ decays at LHCb,
**CP asymmetry in phase space: $B^\pm \rightarrow K^\pm K^+ K^-$**

**Illustrative view 1**

Bins with equal number of entries.

No background subtraction.

**Illustrative view 2**

Simplified binned fit in each bin

$A_{CP}^{RAW}$ located between the $\phi(1020)$ and $f_2(1525)$. 

---

F. Rodrigues, CBPF, Brazil

Multibody charmless B decays at LHCb,

LHCb-CONF-2012-018
Search for the three unobserved modes
$B_s^0 \rightarrow K_S\pi\pi, B_s^0 \rightarrow K_SK\pi$ and $B_s^0 \rightarrow K_SKK$

Measurement of the branching fractions (BF) relative to the well-established BF of $B_d^0 \rightarrow K_S\pi\pi$ from B-factories.

**PDG 2010**

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th>Branching Fraction (10^{-6})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BaBar</td>
</tr>
<tr>
<td>$B_d^0 \rightarrow K^0\pi^+\pi^-$</td>
<td>$50.2 \pm 2.3$</td>
</tr>
<tr>
<td>$B_d^0 \rightarrow K^0K^{\pm}\pi^{\mp}$</td>
<td>$6.4 \pm 1.2$</td>
</tr>
<tr>
<td>$B_d^0 \rightarrow K^0K^+K^-$</td>
<td>$23.8 \pm 2.6$</td>
</tr>
</tbody>
</table>

New $B_d^0 \rightarrow K_SKK$ from BaBar not yet in the average
$(25.4 \pm 1.2) \times 10^{-6}$

arXiv:1201.5897
Simultaneous fit $B_{d,s}^0 \rightarrow K_S \pi \pi$

B candidates in which the $K_S$ decays...

...outside the vertex detector.

Preliminary $\rightarrow$ $689 \pm 35 B_d^0$ candidates.

$47 \pm 18 B_s^0$ candidates.

...inside the vertex detector.

Preliminary $\rightarrow$ $355 \pm 21 B_d^0$ candidates.

$24 \pm 8 B_s^0$ candidates.

Statistical significance $B_s^0 \rightarrow K_S \pi \pi = 4.3\sigma$.

First evidence of the decay $B_s^0 \rightarrow K_S \pi \pi$. 
Simultaneous fit $B_{d,s}^0 \rightarrow K_SKK$

B candidates in which the $K_S$ decays...

...outside the vertex detector.

Preliminary $\rightarrow$ 230 $\pm$ 17 $B_d^0$ candidates.
13.1 $\pm$ 7.1 $B_s^0$ candidates.

...inside the vertex detector.

Preliminary $\rightarrow$ 189 $\pm$ 14 $B_d^0$ candidates.
8.8 $\pm$ 4.3 $B_s^0$ candidates.

Hint of the $B_s^0 \rightarrow K_SKK$. 
Simultaneous fit $B_{d,s}^0 \rightarrow K_SK_\pi$

B candidates in which the $K_S$ decays...

...outside the vertex detector.

Preliminary $\rightarrow 85 \pm 19 B_d^0$ candidates.
265 $\pm 23 B_s^0$ candidates.

...inside the vertex detector.

Preliminary $\rightarrow 50 \pm 11 B_d^0$ candidates.
170 $\pm 16 B_s^0$ candidates.

Statistical significance $B_d^0 \rightarrow K_SK_\pi = 7.6\sigma$.

First observation of the decay $B_s^0 \rightarrow K_SK_\pi$. 
**$B^0_{d,s} \rightarrow K_S h h$ branching fractions results**

**Preliminary →**

\[
\frac{\mathcal{B}(B^0_d \rightarrow K_S K\pi)}{\mathcal{B}(B^0_d \rightarrow K_S \pi\pi)} = 0.117 \pm 0.018 \text{ (stat.)} \pm 0.018 \text{ (syst.)}
\]

\[
\frac{\mathcal{B}(B^0_d \rightarrow K_S KK)}{\mathcal{B}(B^0_d \rightarrow K_S \pi\pi)} = 0.53 \pm 0.04 \text{ (stat.)} \pm 0.04 \text{ (syst.)}
\]

\[
\frac{\mathcal{B}(B^0_s \rightarrow K_S \pi\pi)}{\mathcal{B}(B^0_d \rightarrow K_S \pi\pi)} = 0.24 \pm 0.06 \text{ (stat.)} \pm 0.04 \text{ (syst.)}
\]

\[
\frac{\mathcal{B}(B^0_s \rightarrow K_S K\pi)}{\mathcal{B}(B^0_d \rightarrow K_S \pi\pi)} = 1.96 \pm 0.15 \text{ (stat.)} \pm 0.20 \text{ (syst.)}
\]

\[
\frac{\mathcal{B}(B^0_s \rightarrow K_S KK)}{\mathcal{B}(B^0_d \rightarrow K_S \pi\pi)} = 0.084 \pm 0.031 \text{ (stat.)} \pm 0.019 \text{ (syst.)}
\]

- The observation of $B^0_d \rightarrow K_S K\pi$ by BaBar is confirmed
  \[
  \frac{\mathcal{B}(B^0_d \rightarrow K_S K\pi)}{\mathcal{B}(B^0_d \rightarrow K_S \pi\pi)} = 0.131 \pm 0.025 \text{ (BaBar, arXiv:1003.0640).}
  \]

- The $B^0_d \rightarrow K_S KK$ result is compatible with the B-factory
  \[
  \frac{\mathcal{B}(B^0_d \rightarrow K_S KK)}{\mathcal{B}(B^0_d \rightarrow K_S \pi\pi)} = 0.506 \pm 0.057 \text{ (PDG).}
  \]
$B^0_s \rightarrow \phi\phi$ measurement

Triple products: $U = \sin(2\Phi)/2$ and $V = \pm \sin(\Phi)$
where the positive sign is taken if $\cos \theta_1 \cos \theta_2 \geq 0$
and negative sign otherwise, where

$\sin \Phi = (\vec{n}_1 \times \vec{n}_2) \cdot \vec{p}_1$
$\sin(2\Phi)/2 = (\vec{n}_1 \cdot \vec{n}_2)(\vec{n}_1 \times \vec{n}_2) \cdot \vec{p}_1$

Asymmetries:

$A_U = \frac{N(U>0)-N(U<0)}{N(U>0)+N(U<0)}$ and $A_V = \frac{N(V>0)-N(V<0)}{N(V>0)+N(V<0)}$

Signal yield of $801 \pm 29$ events.
$B_s^0 \rightarrow \phi \phi$ measurement

The triple product asymmetries:

$A_U = -0.055 \pm 0.036^{\text{stat}} \pm 0.018^{\text{syst}}$

$A_V = 0.010 \pm 0.036^{\text{stat}} \pm 0.018^{\text{syst}}$

The polarization amplitudes and strong phase difference in the $B_s^0 \rightarrow \phi \phi$:

$|A_0|^2 = 0.365 \pm 0.022^{\text{stat}} \pm 0.012^{\text{syst}}$

$|A_\perp|^2 = 0.291 \pm 0.024^{\text{stat}} \pm 0.010^{\text{syst}}$

$|A_\parallel|^2 = 0.344 \pm 0.024^{\text{stat}} \pm 0.014^{\text{syst}}$

$\cos(\delta_\parallel) = -0.844 \pm 0.068^{\text{stat}} \pm 0.029^{\text{syst}}$

Improved with respect to the previous CDF measurement.
Conclusions

Many new results and improved measurements:

- $B^\pm \rightarrow K^\pm K^+K^-$: First evidence of inclusive $A_{CP}$ in charmless three-body $B^\pm$ decays. ← Preliminary
- $B^\pm \rightarrow K^\pm \pi^+\pi^-$: Indicative of CP asymmetry. ← Preliminary
- $B^\pm \rightarrow K^\pm K^+K^- \text{ and } B^\pm \rightarrow K^\pm \pi^+\pi^-$: CP asymmetry appears to be concentrated in regions of Dalitz plot. ← Preliminary
- $B^0_s \rightarrow K_S K\pi$: First observation. ← Preliminary
- $B^0_d \rightarrow K_S K\pi$: Confirm the recent observation by the BaBar experiment. ← Preliminary
- $B^0_s \rightarrow \phi\phi$: World leading measurement of polarization and Triple-product asymmetries in this channel.

- More results are expected to come with the 1 fb$^{-1}$ collected last year.
- Expecting $\sim 1.5$ fb$^{-1}$ of LHCb data at 8 TeV centre-of-mass energy in 2012.