Measurements of branching fractions and angular observables in $B$ decays to $VV$ final states

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(On behalf of the LHCb collaboration)

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Measurements of branching fractions and angular observables in $B$ decays to $VV$ final states

Álvaro Dosil Suárez

Outline

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   - Amplitude analysis

2. $B_S^0 \rightarrow J/\psi K^*0$
   - Angular parameters
   - Branching fraction

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Measurements of branching fractions and angular observables in B decays to VV final states

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Introduction

$B_s^0 \rightarrow J/\psi K^+ K^-$ decays have been used to study mixing-induced $CP$ violation. In order to best exploit these decays a better understanding of the $hh$ composition is necessary.

A large $\phi(1020)$ component is well known$^1$, and the $f'_2(1525)$ has recently been observed$^2$ and confirmed$^3$, but the source of S–wave contributions has not been identified.

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$B^0_s \to J/\psi K^+ K^-$ Data selection

- Analysis of 1.0 $\text{fb}^{-1}$ of LHCb data collected in 2011
- A set of selection cuts was applied, relying on the main strengths of LHCb (Vertex resolution, momentum, PID...)
- We also parametrized the misidentified $\bar{B}^0 \to J/\psi K^- \pi^+$

Amplitude analysis

$B^0_s \to J/\psi K^+ K^-$

Angular parameters

Branching fraction

Summary

We found $(M(\bar{B}^0_s) \pm 20 \text{ MeV})$:

- $N_{B^0_s \to J/\psi K^+ K^-} = 19195 \pm 150$
- $N_{Bkg} = 894 \pm 24$

arXiv:1302.1213 (accepted in PRD)
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$B^0_s \rightarrow J/\psi K^+ K^-$ Amplitude analysis

$B^0_s \rightarrow J/\psi K^+ K^-$ Angular parameters

Branching fraction

Summary

- Dalitz plot generated with $B^0_s$ candidates within $(M(B^0_s) \pm 20 \text{ MeV})$
- Two clear horizontal bars from the $\phi(1020)$ and $f'_2(1525)$ resonances

<table>
<thead>
<tr>
<th>Resonances</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_0(980)$</td>
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<tr>
<td>$\phi(1020)$</td>
</tr>
<tr>
<td>$f_0(1370)$</td>
</tr>
<tr>
<td>$f'_2(1525)$</td>
</tr>
<tr>
<td>$f_2(1640)$</td>
</tr>
<tr>
<td>$\phi(1680)$</td>
</tr>
<tr>
<td>$f_2(1750)$</td>
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<tr>
<td>$f_2(1950)$</td>
</tr>
</tbody>
</table>

arXiv:1302.1213 (accepted in PRD)
**Results**

**S–wave**

We observe an S–wave \((1.1 \pm 0.1^{+0.2}_{-0.1})\%\) of the yield in \((M(\phi(1020))\pm 12\text{ MeV})\)

**Branching fractions**

\[
\mathcal{B}(\bar{B}_s^0 \rightarrow J/\psi X) = \frac{N_{\bar{B}_s^0}}{N_{B^-}} \times \mathcal{B}(B^- \rightarrow J/\psi K^-) \times \frac{1}{f_s/f_d}
\]

\[
\mathcal{B}(\bar{B}_s^0 \rightarrow J/\psi K^+ K^-) = (7.70 \pm 0.08(stat) \pm 0.39(syst) \pm 0.60 \left(\frac{f_s}{f_d}\right)) \times 10^{-4}
\]

\[
\mathcal{B}(\bar{B}_s^0 \rightarrow J/\psi \phi(1020)) = (10.50 \pm 0.13(stat) \pm 0.64(syst) \pm 0.82 \left(\frac{f_s}{f_d}\right)) \times 10^{-4}
\]

\[
\mathcal{B}(\bar{B}_s^0 \rightarrow J/\psi f_2'(1525)) = (2.61 \pm 0.20(stat)^{+0.52}_{-0.46}(syst) \pm 0.20 \left(\frac{f_s}{f_d}\right)) \times 10^{-4}
\]

**Summary**

arXiv:1302.1213(accepted in PRD)

\[\mathcal{B}(B^- \rightarrow J/\psi K^-) = (10.18 \pm 0.42) \times 10^{-4}\]. Belle (arXiv:hep-ex/0211047) and BaBar (arXiv:hep-ex/0412062) average

\[\frac{f_s}{f_d} = 0.256 \pm 0.020\] The LHCb collaboration, R. Aaij et al., Measurement of the fragmentation fraction ratio \(f_s/f_d\) and its dependence on \(B\) meson kinematics, arXiv:1301.5286; The LHCb collaboration, R. Aaij et al., Measurement of \(b\)-hadron production fractions in 7 TeV pp collisions, Phys. Rev. D 85 032008 (2012), arXiv:1111.2357
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**B_s^0 \rightarrow J/\psi K^{*0}**

***Introduction***

Important to control the penguin effects in $B_s^0 \rightarrow J/\psi \phi$ and their impact on $\phi_s$ determination $^a$


\[ B(B_s^0 \rightarrow J/\psi K^{*0}) = (8.3 \pm 3.8) \times 10^{-5} \]

- Was first observed by CDF (Phys. Rev. D 83, 052012 (2011))

- LHCb reported a measurement of BR using $\sim 37$ pb$^{-1}$ (LHCb–CONF–2011–025)

\[ B(B_s^0 \rightarrow J/\psi K^{*0}) = (3.5^{+1.1}_{-1.0} \text{ (stat)} \pm 0.9 \text{ (syst)}) \times 10^{-5} \]

Under the assumption that the light quark (d,s) is an spectator of the decay of the b quark, the $B(B_s^0 \rightarrow J/\psi K^{*0})$ can be calculated as:

\[ B(B_s^0 \rightarrow J/\psi K^{*0}) \sim \frac{|V_{cd}|^2}{|V_{cs}|^2} \times B(B_d^0 \rightarrow J/\psi K^{*0}) = (6.5 \pm 1.0) \times 10^{-5} \]
The results presented here are based only on the analysis of 0.37 fb$^{-1}$ from the 2011 dataset.

Data selection relies basically on:

- Vertex resolution, momentum and particle identification
- A geometrical likelihood (GL) built from:
  - Impact Parameters of the $B_s^0$ candidate and its daughter tracks wrt PV
  - Decay time of the $B_s^0$ candidate
  - Distance of closest approach of the $J/\psi$ and $K^{*0}$ and trained with background from sidebands and signal from simulation

4 The number of $B_s^0$ and $B^0$ candidates found are:

- $N_{B^0} = 13,365 \pm 116$
- $N_{B_s^0} = 114 \pm 11$

Taking into account the $K\pi$ S–wave component and assuming no direct $CP$ violation and insignificant $B^0_{(s)} - \bar{B}^0_{(s)}$ production asymmetry:

$$\frac{d^3\Gamma}{d\Omega} \propto 2|A_0|^2 \cos^2 \psi (1 - \sin^2 \theta \cos^2 \varphi) + |A_\parallel|^2 \sin^2 \psi (1 - \sin^2 \theta \sin^2 \varphi) + |A_\perp|^2 \sin^2 \psi \sin^2 \theta + \frac{1}{\sqrt{2}} |A_0||A_\parallel| \cos(\delta_\parallel - \delta_0) \sin 2\psi + 2 |A_S|^2 \left[ 1 - \sin^2 \theta \cos^2 \varphi \right] + \frac{4\sqrt{3}}{3} |A_0||A_S| \cos(\delta_S - \delta_0) \cos \psi \left[ 1 - \sin^2 \theta \cos^2 \varphi \right] + \frac{\sqrt{6}}{3} |A_\parallel||A_S| \cos(\delta_\parallel - \delta_S) \sin \psi \sin^2 \theta \sin 2\varphi$$

$$f_{L,\parallel,\perp} = \frac{|A_0,\parallel,\perp|^2}{|A_0|^2 + |A_\parallel|^2 + |A_\perp|^2}$$
\( B_s^0 \to J/\psi \bar{K}^*0 \) angular parameters measured for the first time

| \( B_s^0 \to J/\psi \bar{K}^*0 \) parameters | \( |A_S|^2 \) | \( f_L \) | \( f_\parallel \) |
|---------------------------------------------|--------|--------|--------|
| Value and statistical uncertainty          | 0.07^{+0.15}_{-0.07} | 0.50 ± 0.08 | 0.19^{+0.10}_{-0.08} |
| Systematic uncertainties                   |        |        |        |
| Angular acceptance                         | 0.044  | 0.011  | 0.016  |
| Background angular model                   | 0.038  | 0.017  | 0.013  |
| Assumption \( \delta_S(M_{K\pi}) = \text{constant} \) | 0.026  | 0.005  | 0.002  |
| \( B^0 \) contamination                    | 0.036  | 0.004  | 0.007  |
| Fit bias                                   |        |        | 0.005  |
| Total systematic uncertainty               | 0.073  | 0.021  | 0.022  |

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\(^5\)The LHCb collaboration, R. Aaij et al., Measurement of the \( B \to J/\psi K^* \) branching fraction and angular amplitudes, Phys. Rev. D 86 071102(R) (2012), arXiv:1208.0738
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$B_s^0 \rightarrow J/\psi K^{*0}$ Branching fraction

\[
\frac{\mathcal{B}(B_s^0 \rightarrow J/\psi K^{*0})}{\mathcal{B}(B_d^0 \rightarrow J/\psi K^{*0})} = \frac{f_d/f_s}{f_s} \frac{\varepsilon_{B_d}^{\text{tot}}}{\varepsilon_{B_s}^{\text{tot}}} \frac{\lambda_{B_d}}{\lambda_{B_s}} \frac{f_{K^{*0}}^{(d)}}{f_{K^{*0}}^{(s)}} \frac{N_{B_d^0}}{N_{B_s^0}}
\]

### Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hadronization fractions</td>
<td>$f_d/f_s$</td>
<td>$3.75 \pm 0.29$</td>
</tr>
<tr>
<td>Efficiency ratio</td>
<td>$\varepsilon_{B_d}^{\text{tot}}/\varepsilon_{B_s}^{\text{tot}}$</td>
<td>$0.97 \pm 0.01$</td>
</tr>
<tr>
<td>Angular corrections</td>
<td>$\lambda_{B_d}/\lambda_{B_s}$</td>
<td>$1.01 \pm 0.04$</td>
</tr>
<tr>
<td>Ratio of $K^{*0}$ fractions</td>
<td>$f_{K^{*0}}^{(s)}/f_{K^{*0}}^{(d)}$</td>
<td>$1.09 \pm 0.08$</td>
</tr>
<tr>
<td>$B$ signal yields</td>
<td>$N_{B_d^0}/N_{B_s^0}$</td>
<td>$(8.5^{+0.9}_{-0.8} \pm 0.8) \times 10^{-3}$</td>
</tr>
</tbody>
</table>

### Details


Summary

LHCb

In the first data taking period LHCb performed extremely well.

\[ \overline{B}_s^0 \rightarrow J/\psi K^+K^- \quad (1.0 \text{ fb}^{-1} \text{ at } \sqrt{s} = 7 \text{ TeV}) \]

- The S–wave measured is \((1.1 \pm 0.1^{+0.2}_{-0.1})\% \) of the yield in \((M(\phi(1020)) \pm 12 \text{ MeV})\)
- we also measured the absolute branching fractions of:
  \[
  \mathcal{B}(\overline{B}_s^0 \rightarrow J/\psi K^+K^-) = (7.70 \pm 0.08 \pm 0.39 \pm 0.60) \times 10^{-4}
  \]
  \[
  \mathcal{B}(\overline{B}_s^0 \rightarrow J/\psi \phi(1020)) = (10.50 \pm 0.13 \pm 0.64 \pm 0.82) \times 10^{-4}
  \]
  \[
  \mathcal{B}(\overline{B}_s^0 \rightarrow J/\psi f_2'(1525)) = (2.61 \pm 0.20^{+0.52}_{-0.46} \pm 0.20) \times 10^{-4}
  \]

\[ \overline{B}_s^0 \rightarrow J/\psi K^*^0 \quad (0.37 \text{ fb}^{-1} \text{ at } \sqrt{s} = 7 \text{ TeV}) \]

- We have measured \(\mathcal{B}(\overline{B}_s^0 \rightarrow J/\psi K^*^0) = (4.4^{+0.5}_{-0.4} \pm 0.8) \times 10^{-5}\). Compatible with the previous CDF measurement and theoretical expectations.
- The first measurement of polarization fractions in this decay was also performed.
  \[
  f_L = 0.50 \pm 0.08 \pm 0.02
  \]
  \[
  f_\parallel = 0.19^{+0.10}_{-0.08} \pm 0.02
  \]
  \[
  |A_S|^2 = 0.07^{+0.15}_{-0.07}
  \]
BACKUP SLIDES
The reflection background arises from the decay $\bar{B}^0 \rightarrow J/\psi K^- \pi^+$, where the $\pi^+$ is misidentified as a $K^+$.

From the events calculated in the fit, we estimate the number of events in the $\bar{B}^0_s$ signal region, based on a simulation of the shape of the reflected distribution.

Invariant mass distribution for $J/\psi K^+ K^-$ candidates 25 – 200 MeV above the $\bar{B}^0_s$ mass, reinterpreted as $\bar{B}^0 \rightarrow J/\psi K^\mp \pi^\pm$ events. The fit is to a signal Gaussian whose mass and width are allowed to vary as well as the polynomial background.