First observation of $B_S^0 \rightarrow D^0 K^0$ and measurement of the ratio $\frac{B(S^0 \rightarrow D^0 K^0)}{B(S^0 \rightarrow D^0 \rho^0)}$ with LHCb at $\sqrt{s} = 7$ TeV

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Abstract

In 36 pb\(^{-1}\) of pp collisions at a centre-of-mass energy $\sqrt{s} = 7$ TeV, we observe for the first time the decay $B_S^0 \rightarrow D^0 K^0$. The $B_S^0 \rightarrow D^0 K^0$ decay mode is a potentially dangerous background for the Cabibbo suppressed decay $B^0 \rightarrow D^0 K^0$, used in the measurement of the CKM angle $\gamma$. A clear signal of 34.5 ± 9.0 events is obtained with a statistical significance over 9 standard deviations and we measure its branching ratio relative to the $B^0 \rightarrow D^0 K^0$ branching ratio $\frac{B(B_S^0 \rightarrow D^0 K^0)}{B(B^0 \rightarrow D^0 K^0)} = 1.39 \pm 0.31$ (stat) ± 0.17 (sys) ± 0.13 $(\epsilon/K)$. The $B_S^0 \rightarrow D^0 K^0$ branching fraction is then $B(B_S^0 \rightarrow D^0 K^0) = (4.44 \pm 1.00 \text{ (stat)} \pm 0.55 \text{ (sys)} \pm 0.56 \epsilon/K) \times 10^{-4}$.

Introduction: context and motivation

Long term plan [2011-201X]

- $B^0 \rightarrow D^0 K^0$ interference between diagrams involving $b \rightarrow c$ and $b \rightarrow c$ transitions.
- CKM unitarity triangle angle $\gamma$; theoretically clean extraction [1,2]; Standard Model benchmark.

Short term plan [2010-2011]

Understanding background for suppressed $B^0 \rightarrow D^0 K^0$ decays: favoured $B_S^0 \rightarrow D^0 K^0$ in the same final state.

Additional motivations

- $B_S^0 \rightarrow D^0 K^0$ not yet measured.
- Comparing $B_S^0 \rightarrow D^0 K^0$ and $B^0 \rightarrow D^0 K^0$ is a probe of $SU(3)$ breaking in colour suppressed $B^0 \rightarrow D^0 V$ decays.

The LHCb detector [3]

- LO hardware trigger (in 2010, $E_T > 3.6$ GeV/c) and HLT $B$ inclusive software trigger.

Analysis Strategy

<table>
<thead>
<tr>
<th>channel</th>
<th>$B$ decay</th>
<th>$R$(in 10(^{-3}))</th>
<th>total $R$(in 10(^{-3}))</th>
<th>Events produced in LHCb</th>
<th>gen. acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^0 \rightarrow D^0 \rho^0$</td>
<td>32 ± 5</td>
<td>12 ± 2</td>
<td>30000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B^0 \rightarrow D^0 K^0$</td>
<td>4.2 ± 0.5</td>
<td>1.1 ± 0.2</td>
<td>1800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B_S^0 \rightarrow D^0 K^0$</td>
<td>10 ± 3</td>
<td>8 to 23</td>
<td>3000 to 9000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Systematics

Source of the uncertainty $\sigma_{\%}$
- $\frac{B(S^0 \rightarrow D^0 K^0)}{B(S^0 \rightarrow D^0 \rho^0)}$ | MC statistics | $0.055 \pm 0.004$ | 6.4 \% |
- MC statistics | $1.0 \%$ |
- Change in the central value of the vector mass window $\chi_0 = 1.02 \pm 0.01$ | $1.0 \%$ |
- Difference in $p_T$ distributions of tracks between data and MC $\chi_0 = 0.802 \pm 0.200$ | $2.5 \%$ |
- Use of the unweighted calibration sample for $R(B)$ | $1.0 \pm 0.05$ | 0.8 \% |
- LO Hadron threshold influence on $\tau_{\text{cut}}$ | $1.20 \pm 0.08$ | 3.0 \% |
- $B_S^0$ triggering efficiency independent on the mode $\tau_{\text{cut}} = 1.03 \pm 0.03$ | $1.6 \%$ |
- PDF parameterizations | $6.4 \%$ |
- Statistical uncertainty on the non-$p_T$ component | $30 \pm 7 \%$ | $6.8 \%$ |
- Overall relative systematic uncertainty | $12.3 \%$ |
- Higgs average $\sigma_{\%}$ | $3.1 \pm 0.47$ | $12.7 \%$ |

Results

- First observation of $B_S^0 \rightarrow D^0 K^0$ with $N = 34.5 \pm 9.0$ (> 9.0 from change of likelihood with no signal).
- $\frac{B(S^0 \rightarrow D^0 K^0)}{B(S^0 \rightarrow D^0 \rho^0)} = 1.39 \pm 0.31$ (stat) ± 0.17 (sys) ± 0.13 $(\epsilon/K)$.
- $B(B_S^0 \rightarrow D^0 K^0) = (4.44 \pm 1.00 \text{ (stat)} \pm 0.55 \text{ (sys)} \pm 0.56 \epsilon/K) \times 10^{-4}$.
- $B(S^0 \rightarrow D^0 K^0) = (1.20 \pm 0.08)$.
- $B(S^0 \rightarrow D^0 K^0) < 3.4 \%$ (90\% C.L).

Selections

| [2] The LHCb Collaboration, Roadmap for selected key measurements of LHCb, [epj-e1012.1719]. |
| [9] R.-H. Li, C.-D. Li and H. Zuo, $B(D_{s}^0) \rightarrow D_{s}^0 \rho, D_{s}^0 V, D_{s}^0 \rho D_{s}^{*0} V$ decays in the perturbative QCD approach, Phys. Rev. D 78 (2008) 014018. |