Measurement of CP violation and mixing in $B_s \rightarrow J/\psi \phi$ in ATLAS

Tomas Jakoubek

Institute of Physics of the Academy of Sciences of the Czech Republic
E-mail: tomas.jakoubek@cern.ch

Flavour tagged time dependent angular analysis of the $B_s \rightarrow J/\psi \phi$ decay is reported, using 14.3 fb$^{-1}$ of integrated luminosity collected by the ATLAS detector from 8 TeV LHC proton-proton collisions recorded in 2012. CP-violation in this channel is described by a weak phase $\phi_s$, which is sensitive to new physics contributions. Measured parameters are statistically combined with those from 4.9 fb$^{-1}$ of 7 TeV data, leading to the final results from ATLAS in Run1: $\phi_s = -0.098 \pm 0.084$ (stat.) $\pm 0.040$ (syst.) rad, which is in good agreement with Standard Model expectations. Also other measured parameters are consistent with the world average.

16th International Conference on B-Physics at Frontier Machines
2-6 May 2016
Marseille, France

Speaker.
†On behalf of the ATLAS collaboration.
1. Introduction

The $B_s^0 \to J/\psi \phi$ decay channel is expected to be sensitive to new physics contributions. In this channel, CP violation occurs due to interference between direct decays and decays occurring through $B_s^0 - \bar{B}_{s}^0$ mixing. The frequency of this mixing is characterized by the mass difference $\Delta M_s$ between light ($B_L$) and heavy ($B_H$) mass eigenstates. Difference between decay widths can be described using a CP-violating phase $\phi_s$. In the Standard Model (SM) this phase can be related to the Cabibbo-Kobayashi-Maskawa (CKM) quark mixing matrix elements via the relation

$$\phi_s \simeq -2 \arg \left( \frac{-V_{ts}V_{tb}^* V_{cs}V_{cb}^*}{V_{ts}^*V_{tb}} \right).$$  

(1.1)

Assuming no physics beyond the SM contributions to the $B_s^0$ mixing and decays, a value of $\phi_s = -0.0363^{+0.0016}_{-0.0015}$ rad is predicted by combining beauty and kaon physics observables [1]. Other physical quantity involved in $B_s^0 - \bar{B}_{s}^0$ mixing are the decay width $\Gamma_s = \Gamma_s^L + \Gamma_s^H$ and the the decay width difference $\Delta \Gamma_s = \Gamma_s^L - \Gamma_s^H$, where $\Gamma_s^L$ and $\Gamma_s^H$ are the decay widths of the different eigenstates. Many new physics models predict larger $\phi_s$ values whilst satisfying all existing constraints, including the precisely measured value of $\Delta M_s$.

Our analysis is based on 4.9 fb$^{-1}$ of $\sqrt{s} = 7$ TeV data from proton-proton collisions collected with the ATLAS detector [2] in the year 2011 [3], combined with 14.3 fb$^{-1}$ of $\sqrt{s} = 8$ TeV data from the year 2012 into the complete Run1 results presented here [4].

2. Methodology

To be selected, events must contain at least one reconstructed primary vertex, formed from at least four Inner Detector (ID) tracks, and at least one pair of oppositely charged muons reconstructed using information from the Muon Spectrometer (MS) and the ID. Pairs of oppositely charged muon tracks are refitted to a common vertex and the pair is accepted if $\chi^2/\text{ndf} < 10$. To account for varying mass resolution in different parts of the detector, the $|\eta(\mu)|$ dependent $J/\psi$ mass cuts are applied. Decays $\phi \to K^+K^-$ are reconstructed from all pairs of oppositely charged particles with $p_T > 1$ GeV and $|\eta| < 2.5$ that are not identified as muons. Candidates for $B_s$ are selected by fitting the four tracks to a common vertex with $J/\psi$ mass constrain [5]. Candidate is accepted if the vertex fit has $\chi^2/\text{ndf} < 3$ and $|m(K^+K^-) - m_{\phi}| < 11$ MeV, where the $\phi$ mass value, $m_{\phi}$, is taken from [5]. If there is more than one accepted $B_s$ candidate in the event, the one with the lowest $\chi^2/\text{ndf}$ is selected.

For each $B_s$ candidate the proper decay time $t$ is calculated:

$$t = \frac{L_{xy} m(B_s)}{p_T(B_s)},$$  

(2.1)

where $p_T(B_s)$ is the transverse momentum of the $B_s$ meson and $m(B_s)$ is the mass of the $B_s$ meson, taken from [5]. The transverse decay length $L_{xy}$ is the displacement in the transverse plane of the $B_s$ meson decay vertex with respect to the primary vertex, projected onto the direction of the $B_s$ transverse momentum.
Flavour tagging has been used to improve this CP violation measurement. Initial flavour of (neutral) \( B_s \) can be inferred using the other \( B \)-meson, produced in the event (so-called “Opposite-Side Tagging”). Muon, electron, and jet-charge tagging methods have been used. Calibration of these methods have been done using decays of “self-calibrated” channel \( B^\pm \to J/\psi K^\pm \) (flavour of the \( B \)-meson at production is provided by the kaon charge).

Detector effects have been studied using Monte Carlo (MC) - “acceptance maps” (relying on three angles and \( p_T \)) have been created and applied to the data. Also an observed time dependence of the muon trigger has been corrected by weighting function (derived using real data and MC).

3. Results

Time-angular unbinned maximum likelihood fit has then been performed on \( B^0_s \) candidates within a mass range of \( 5.15 \text{ GeV} < m(B^0_s) < 5.65 \text{ GeV} \) to extract the parameters characterising the decay. Below the important physical parameters are summarized: mean \( B^0_s \) lifetime, the decay width difference \( \Delta \Gamma_s \), and the CP-violating week phase \( \phi_s \). All results (2011, 2012, and the full Run1 statistical combination) are consistent with the world average values. Mass and lifetime fit projections are shown in Figure 1. Comparison with other experiments is shown in Figure 2.

<table>
<thead>
<tr>
<th>Par</th>
<th>8 TeV data</th>
<th>7 TeV data</th>
<th>Run1 combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Value</td>
<td>Stat</td>
<td>Syst</td>
</tr>
<tr>
<td>( \phi_s ) [rad]</td>
<td>-0.123</td>
<td>0.089</td>
<td>0.041</td>
</tr>
<tr>
<td>( \Delta \Gamma_s ) [ps(^{-1})]</td>
<td>0.096</td>
<td>0.013</td>
<td>0.007</td>
</tr>
<tr>
<td>( \Gamma_s ) [ps(^{-1})]</td>
<td>0.678</td>
<td>0.004</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Table 1: Current results using data from 8 TeV \( pp \) collisions, the previous measurement using 7 TeV data, and the values for the parameters of the two measurements, statistically combined [4].

4. Acknowledgments

I would like to thank for support from grants of the Ministry of Education, Youth and Sports of the Czech Republic under the project LG15052.

References


[3] The ATLAS Collaboration, Flavor tagged time-dependent angular analysis of the \( B_s \to J/\psi \phi \) decay and extraction of \( \Delta \Gamma_s \) and the weak phase \( \phi_s \) in ATLAS, Phys. Rev. D 90 (2014) 5, 052007.

[4] The ATLAS Collaboration, Measurement of the CP-violating phase \( \phi_s \) and the \( B^0_s \) meson decay width difference with \( B^0_s \to J/\psi \phi \) decays in ATLAS, [hep-ex/1601.03297].
Measurement of CP violation and mixing in $B_s \to J/\psi \phi$ in ATLAS

Tomas Jakoubek

Figure 1: (Left) Mass fit projection of the 2012 data. The red line shows the total fit, the dashed green line shows the signal component while the long-dashed blue line shows the contribution from $B_{s0}^0 \to J/\psi K^{0*}$ events. (Right) Proper decay time fit projection of 2012 data. The red line shows the total fit while the green dashed line shows the total signal. The total background is shown as the blue dashed line with the long-dashed grey line showing the prompt $J/\psi$ background [4].

Figure 2: Plot of the 68% confidence-level contours in the $\phi_s - \Delta \Gamma_s$ plane with the individual contours of ATLAS, CMS, CDF, D0, and LHCb experiments, their combined contour (solid line and shaded area), as well as the Standard Model predictions (thin black rectangle) [6].
