Measurement of the Polarization Amplitudes and Triple Product Asymmetries in the $B_s^0 \to \phi\phi$ Decay at LHCb

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The $B_s^0 \to \phi\phi$ decay is an example of a flavour changing neutral current (FCNC) interaction and as such, may only proceed via penguin diagrams in the Standard Model. CP violation in the $B_s^0 \to \phi\phi$ decay may be accessed with a time-integrated untagged method using T-violating triple product asymmetries (further information on this rich subject may be found in [1, 2, 3, 4]). The rest of this document details the study of the triple product asymmetries (A_U and A_V), polarization amplitudes ($|A_0|^2$, $|A_\parallel|^2$ and $|A_\perp|^2$) and strong phase difference in the $B_s^0 \to (\phi \to KK)\ (\phi \to KK)$ decay using 1.0 fb^{-1} of proton-proton collision data collected at centre-of-mass (COM) energy $\sqrt{s} = 7$ TeV with the LHCb detector.

1 Experimental Method and Results

A total of 801 ± 29 signal candidates are observed through a cut based selection optimized with the use of the $_s\mathcal{P}lot$ method [5] to distinguish signal from background.

The measurement of the polarization amplitudes ($|A_0|^2$, $|A_\parallel|^2$, $|A_\perp|^2$) and strong phase difference ($\cos\delta_\parallel$) is performed using a time-integrated, untagged probability density function (PDF) under the assumption that the time acceptance is uniform and that the CP-violating weak phase is zero. A maximum log-likelihood fit is then performed to the three helicity angles (see Reference [6] for more information). The lifetimes of the heavy and light B_s^0 mass eigenstates are constrained to be within the errors of the LHCb measured values [7] taking in to account correlations. S-wave contributions are ignored in the fit. Data-driven methods indicate the S-wave contribution to be $(1 \pm 1)\%$, therefore systematic uncertainties are based on a 2% S-wave contribution. The angular acceptance is determined from simulated events. The limited number of simulated events determines the systematic uncertainty due to the angular acceptance. The time acceptance is understood from Monte Carlo events and simplified simulations are used to assign a systematic uncertainty from the assumption that it is uniform. The polarization amplitudes and strong phase difference are measured to be

$$
\begin{aligned}
|A_0|^2 &= 0.365 \pm 0.022\,(\text{stat}) \pm 0.012\,(\text{syst})\,, \\
|A_\perp|^2 &= 0.291 \pm 0.024\,(\text{stat}) \pm 0.010\,(\text{syst})\,, \\
|A_\parallel|^2 &= 0.344 \pm 0.024\,(\text{stat}) \pm 0.014\,(\text{syst})\,, \\
\cos(\delta_\parallel) &= -0.844 \pm 0.068\,(\text{stat}) \pm 0.029\,(\text{syst})\,.
\end{aligned}
$$

Triple product asymmetries are based on T-odd observables U and V (defined in Reference [6]). Events are separated in to datasets according to whether $U(V) > 0$ and a simutlaneous fit is then performed to the obtain the asymmetries (A_U,A_V) using the $KKKK$ invariant mass as the discriminating observable.

The main systematic uncertainties arise from the choice of signal and background model; the effect of ignoring the time acceptance and the angular acceptance of the $B_s^0 \to \phi\phi$ decay. The systematic uncertainties on the triple product asymmetries due to acceptance effects are estimated using simplified MC studies.

Simultaneous fits to the U(V) datasets yield triple product asymmetries of

$$
\begin{aligned}
A_U &= -0.055 \pm 0.036\,(\text{stat}) \pm 0.018\,(\text{syst})\,, \\
A_V &= 0.010 \pm 0.036\,(\text{stat}) \pm 0.018\,(\text{syst})\,.
\end{aligned}
$$

2 Summary

We provide the most accurate measurements of the physics parameters in the $B_s^0 \to \phi\phi$ penguin decay, which are in agreement with those reported from QCD factorization methods [8, 9]. The most precise measurements of CP violation in the $B_s^0 \to \phi\phi$ decay through triple product asymmetries are reported and are found to be in agreement with SM expectations of CP conservation in the $B_s^0 \to \phi\phi$ decay.

References

[1] G. Valencia. Phys. Rev. D39:3339–3345 (1988).

[2] W. Bensalem, A. Datta, and D. London. Phys. Lett. B538:309–320 (2002).

[3] M. Gronau and J. L. Rosner. Phys. Rev. D84:096013 (2011).

[4] A. Datta, M. Duraisamy, and D. London. arXiv:1207.4495 (2012).

[5] M. Pivk and F. R. Le Diberder. Nucl. Instrum. Meth. A555:356–369 (2005).

[6] LHCb collaboration Phys. Lett. B713:369–377 (2012).

[7] LHCb collaboration Phys. Lett. B713:378–386 (2012).

[8] M. Beneke, J. Rohrer, and D. Yang. Nucl. Phys. B774:64–101 (2007).

[9] H. Cheng and C. Chua. Phys. Rev. D80:114026 (2009).