Measurement of polarisation amplitudes and triple product asymmetries in the $B_s^0 \to \phi\phi$ decay at LHCb

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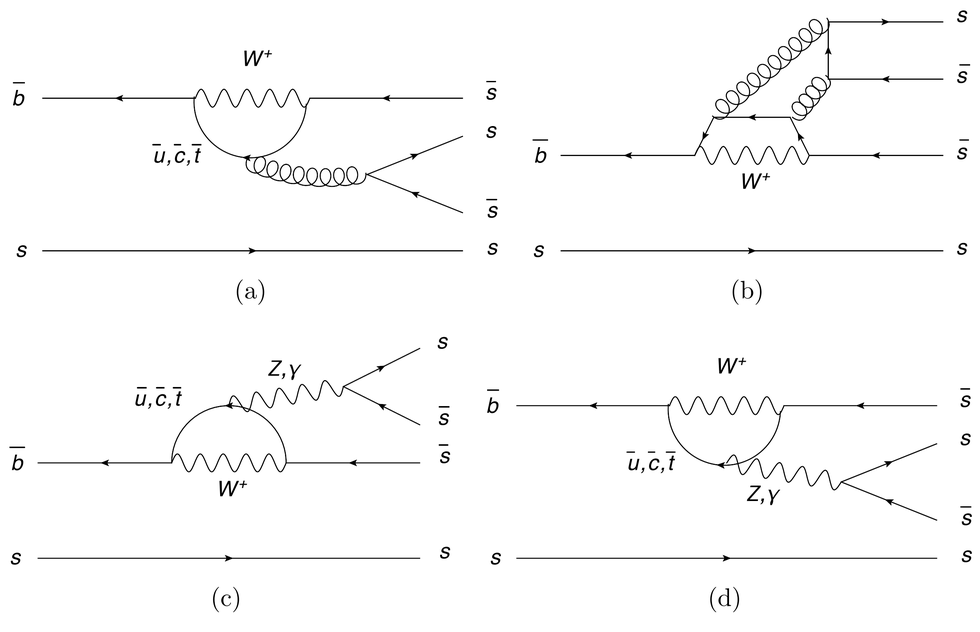
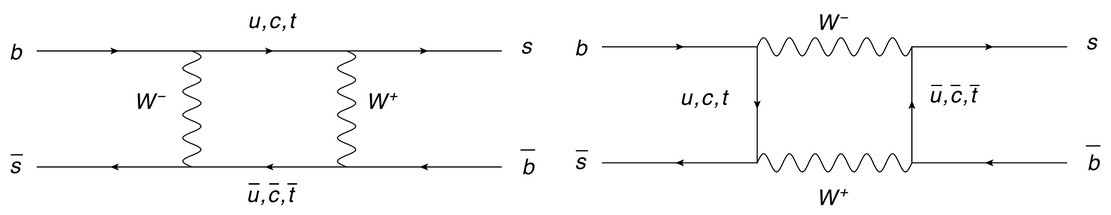
An untagged, time-integrated analysis of the $B_s^0 \to \phi\phi$ decay has been performed with 1 fb^{-1} of pp collision data at centre-of-mass (COM) energy $\sqrt{s} = 7$ TeV taken using the LHCb detector. Optimised selections have yielded 801 $B_s^0 \to \phi\phi$ events at high signal to background ratio. This has allowed for measurements of polarisation amplitudes ($|A_0|^2$, $|A_\perp|^2$, $|A_\parallel|^2$) and strong phase difference (cos$\delta_\parallel$) to be performed. Measurements of T-violating triple product asymmetries have yielded results $A_U = -0.055 \pm 0.036(stat.) \pm 0.018(syst.)$ & $A_V = 0.010 \pm 0.036(stat.) \pm 0.018(syst.)$.

THE $B_s^0 \to \phi\phi$ DECAY

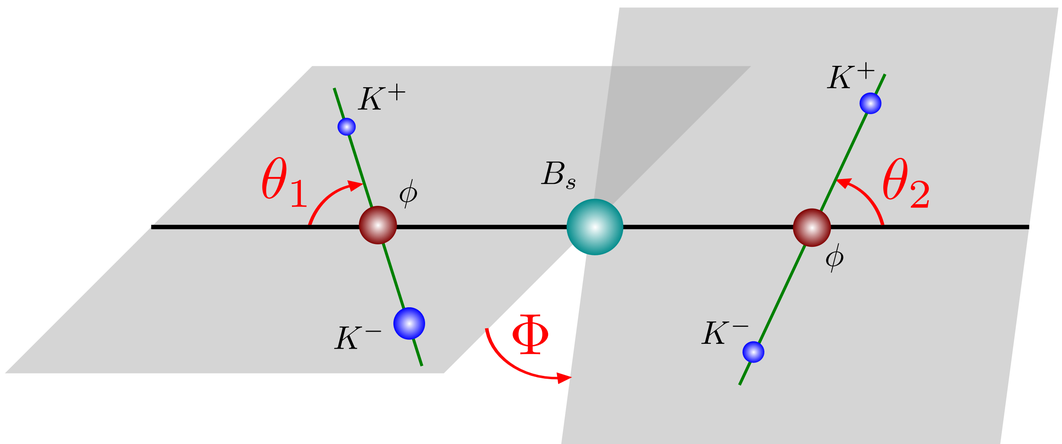
Flavour changing neutral current interactions (FCNC) are forbidden at tree level in the Standard Model (SM). The $B_s^0 \to \phi\phi$ decay is an example of this. Both B_s^0 and the anti-particle $\bar{B}_s^0$ may decay to the same final state $\phi\phi$. This then allows for CP violation to occur in $B_s^0 - \bar{B}_s^0$ mixing, the interference between mixing & decay as well as in the decay itself.



Feynman diagrams that may contribute to the $B_s^0 \to \phi\phi$ decay are shown above and $B_s^0 - \bar{B}_s^0$ mixing shown below. CP violation in the standard model is expected to be small for $B_s^0 \to \phi\phi$ due to the same CKM structure being present in both mixing and decay, therefore allowing for cancellation in the CP violating weak phases [1].



TIME-INTEGRATED ANALYSIS METHOD



The diagram above shows the definition of the helicity angles for the case of the $B_s^0 \to \phi\phi$ decay. Two fits are performed. The time-integrated angular fit for the polarisation amplitudes and strong phase difference assumes zero CP-violation and no production asymmetry. The fitted signal differential decay rate used is

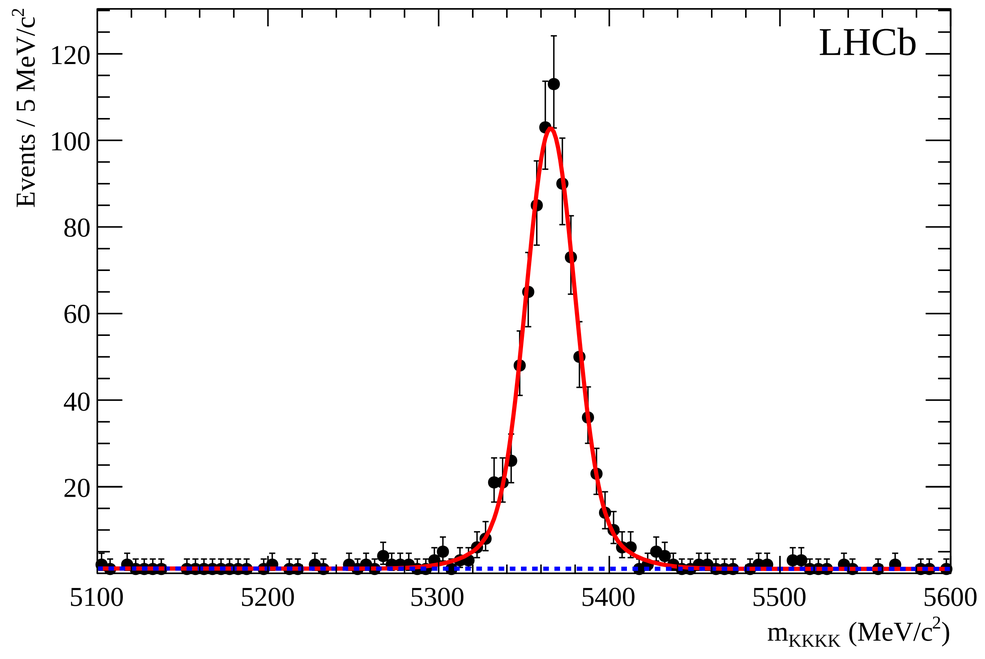
$$\begin{aligned}\frac{d\Gamma}{d\omega} &= 4|A_0|^2\tau_{\rm L}\cos^2\theta_1\cos^2\theta_2 + |A_\parallel|^2\tau_{\rm L}\sin^2\theta_1\sin^2\theta_2(1+\cos 2\Phi) \\ &+ |A_\perp|^2\tau_{\rm H}\sin^2\theta_1\sin^2\theta_2(1-\cos 2\Phi) \\ &+ \sqrt{2}|A_0||A_\parallel|\cos(\delta_\parallel)\tau_{\rm L}\sin 2\theta_1\sin 2\theta_2\cos\Phi\end{aligned}$$

where $\tau_{\rm L}$ and $\tau_{\rm H}$ are the lifetimes of the light and heavy B_s^0 mass eigenstates respectively. The fit for triple product asymmetries is performed through mass counting of datasets according to the sign of triple product observables. We can define observables (U & V) along with their corresponding asymmetries (A_U & A_V) through:

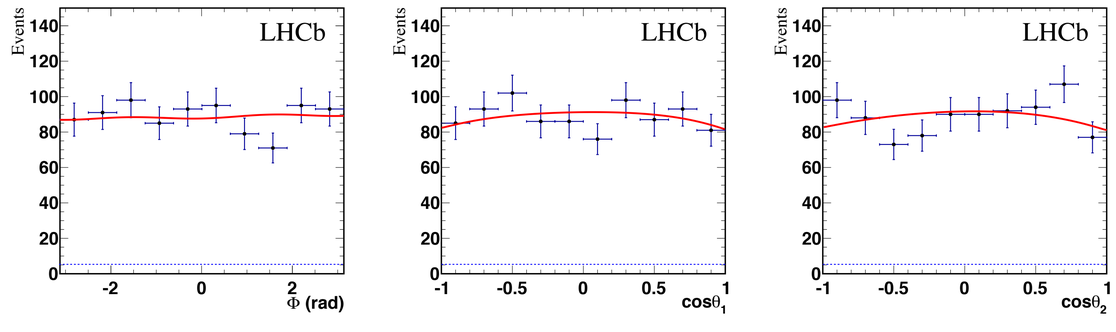
$$\begin{array}{c|c} U = \sin\Phi\cos\Phi & A_U = \frac{\Gamma(U>0)-\Gamma(U<0)}{\Gamma(U>0)+\Gamma(U<0)} \\ V = \sin\Phi \ if \ \cos\theta_1\cos\theta_2 > 0 & \\ \text{else} \quad V = \sin(-\Phi) & A_V = \frac{\Gamma(V>0)-\Gamma(V<0)}{\Gamma(V>0)+\Gamma(V<0)} \end{array}$$

RESULTS

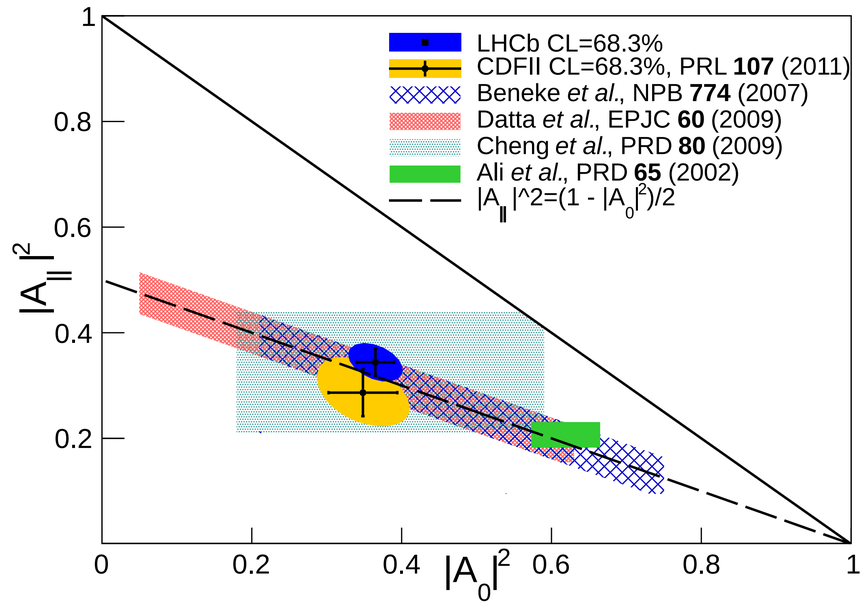
1fb^{-1} of data taken from the LHCb detector and collected during 2011 comprises this analysis. The LHCb detector takes advantage of the fact that at high COM energies (7TeV in this case), $b - \bar{b}$ pairs are produced in the same cone. Shown below is the mass fit to the dataset. 801 ± 29 signal events are observed.



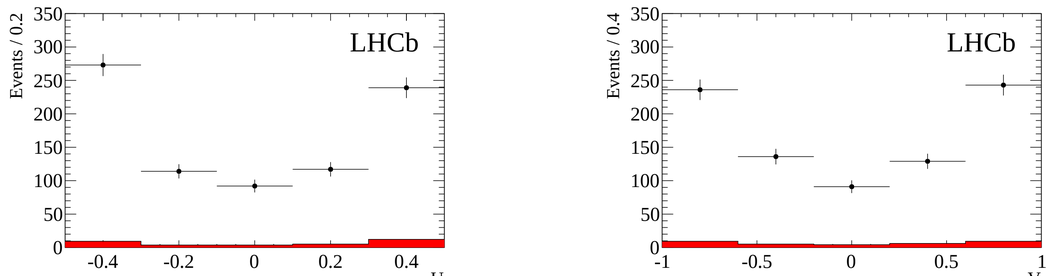
Shown below are projections obtained from the angular fit to the polarisation amplitudes.



The results of the polarisation amplitude fit are shown in a plot below where theory and CDF reported values have also been added.



Shown below are the U and V distributions from LHCb data. In order to calculate asymmetries, the dataset was split in to four portions according to the sign of the U & V observables. These datasets were then fitted to the B_s^0 mass.



Yields from the mass fits were then used to calculate the A_U & A_V asymmetries.

	This Analysis	CDF
A_U	$-0.055 \pm 0.036 \pm 0.018$	$-0.007 \pm 0.064 \pm 0.018$
A_V	$+0.010 \pm 0.036 \pm 0.018$	$-0.120 \pm 0.064 \pm 0.016$

The results are shown in the table above compared to the values reported by the CDF collaboration [3]. Systematic effects are mainly due to acceptance effects and selection effects on U & V observables. MC studies have concluded that reflections from $B_d^0 \to \phi K^*$ & $B_s^0 \to K^*K^*$ are negligible with current selections.

BIBLIOGRAPHY

[1] N. Styles *et al.*, 2009, LHCb-PUB-2009-025
[2] M. Gronau & J. L. Rosner, 2011, arXiv:1107.1232
[3] The CDF Collaboration, 2011, arXiv:1107.4999