Supplementary material for LHCb-PAPER-2016-030

This appendix contains supplementary material that will be posted on the public CDS record but will not appear in the paper.

The asymmetry measurements, $a_{P}^{T-odd}$ and $a_{CP}^{T-odd}$, are shown in Fig. 5 in bins of $|\Phi|$ of the control sample $\Lambda_{b}^{0} \rightarrow \Lambda_{c}^{+} \pi^{-}$. At the bottom of each plot, the numerical result of a $\chi^2$ test calculated with respect to the null hypothesis is shown. The large $\chi^2$/ndf value for the $a_{P}^{T-odd}$ measurements, corresponding to a $p$-value of $1.4 \times 10^{-18}$, indicates significant PV in the control channel. The $p$-value for $CP$ symmetry is 0.14. The uncertainties are statistical only.

![Figure 5](image-url)

Figure 5: The distribution of the triple-product asymmetries (a) $a_{P}^{T-odd}$ and (b) $a_{CP}^{T-odd}$ with respect to the angle $\Phi$ defined by the decay plane of the $pK^{-}$ and $\pi^{+}\pi^{-}$ pairs of the $\Lambda_{b}^{0} \rightarrow \Lambda_{c}^{+} \pi^{-}$ control sample.

The distributions for some relevant mass and $|\Phi|$ projections of $\Lambda_{b}^{0} \rightarrow p\pi^{-}\pi^{+}\pi^{-}$ and $\Lambda_{b}^{0} \rightarrow p\pi^{-}K^{+}K^{-}$ are shown in Figs. 6, 7 and 8, respectively. These plots are background-subtracted using the sPlot method and are not corrected for efficiency. Therefore they should be used for illustrative purposes only.

The results of the simultaneous fit of the integrated distributions of $\Lambda_{b}^{0} \rightarrow p\pi^{-}\pi^{+}\pi^{-}$ and $\Lambda_{b}^{0} \rightarrow p\pi^{-}K^{+}K^{-}$ in the subsamples defined by $\Lambda_{b}^{0}$ flavour and $C_{b}$ $(C_{\bar{b}})$ sign are shown in Fig. 9 and Fig. 10, respectively.

The results of the simultaneous fit of the events in each bin of scheme A are shown in Figs. 11-22.

The results of the simultaneous fit of the events in each bin of scheme B, in the regions $(i - 1)\pi/10 < |\Phi| < (i)\pi/10$, with $i = 1, 2, \ldots, 10$, are shown in Figs. 23-32.

The results of the simultaneous fit to the $\Lambda_{b}^{0} \rightarrow p\pi^{-}K^{+}K^{-}$ events in bin 1 are shown in Fig. 33, while those from bin 2 are in Fig. 34.
Figure 6: The projections of the signal events in the invariant mass of various combinations of particles in the final state for $A_0^0 \rightarrow p\pi^-\pi^+\pi^-$ decays. For each plot, the ratio of events with positive to negative $C_T$ (or $-C_T$ for $A_0^0$) is shown.

The fit to the invariant mass distribution of the $A_0^0 \rightarrow \Lambda^+_c(\rightarrow pK^-\pi^+)\pi^-$ control sample is shown in Fig. 35. The $\chi^2$ distribution of pseudoexperiments with $CP$ symmetry in schemes A and B for $A_0^0 \rightarrow p\pi^-\pi^+\pi^-$ and the distribution of the $\log_{10}$ of the product of the $p$-values of schemes A and B are shown in Figure 36.
Figure 7: The projections of the signal events in the invariant mass of various combinations of particles in the final state and in $|\Phi|$ for $A^0_b \rightarrow p\pi^-\pi^+$ decays. For each plot, the ratio of events with positive to negative $C_\Phi$ (or $-C_\Phi$ for $\bar{A}^0_b$) is shown.
Figure 8: The projections of the signal events in the invariant mass of various combinations of particles in the final state and in $|\Phi|$ for $\Lambda^0_b \rightarrow p\pi^- K^+ K^-$ decays. For each plot, the ratio of events with positive to negative $C_T$ (or $-C_T$ for $\Lambda^0_b$) is shown.
Figure 9: Projections of the unbinned maximum likelihood fit to the $\Lambda_b^0 \rightarrow p\pi^-\pi^+\pi^-$ decays in the four subsamples defined by $\Lambda_b^0$ flavour and $C_T$ ($\bar{C}_T$) sign. The data correspond to the entire phase space.
Figure 10: Projections of the unbinned maximum likelihood fit to the $\Lambda_b^0 \rightarrow p \pi^- K^+ K^-$ decays in the four subsamples defined by $\Lambda_b^0$ flavour and $\mathcal{C}_T (\mathcal{C}_T)$ sign. The data correspond to the entire phase space.
Figure 11: Projections of the unbinned maximum likelihood fit to the $A_0^0 \to p\pi^-\pi^+\pi^-$ decays in bin 1 in scheme A.
Figure 12: Projections of the unbinned maximum likelihood fit to the $\Lambda^0_b \to p\pi^+\pi^-\pi^-$ decays in bin 2 in scheme A.
Figure 13: Projections of the unbinned maximum likelihood fit to the $\Lambda_b^0 \rightarrow p\pi^+\pi^-$ decays in bin 3 in scheme A.
Figure 14: Projections of the unbinned maximum likelihood fit of the $\Lambda^0_b \to p\pi^\pm\pi^\mp$ decays in bin 4 in scheme A.
Figure 15: Projections of the unbinned maximum likelihood fit to the $\Lambda_{c}^{0}(C_{T}>0)$ decays in bin 5 in scheme A.
Figure 16: Projections the unbinned maximum likelihood fit to the $A^0_{b} \to p\pi^+\pi^-\pi^-$ decays in bin 6 in scheme A.
Figure 17: Projections of the unbinned maximum likelihood fit to the $A_0^0 \rightarrow p \pi^- \pi^+ \pi^-$ decays in bin 7 in scheme A.
Figure 18: Projections of the unbinned maximum likelihood fit to the $A_0^0 \rightarrow p\pi^-\pi^+\pi^-$ decays in bin 8 in scheme A.
Figure 19: Projections of the unbinned maximum likelihood fit to the $\Lambda_b^0 \to p\pi^-\pi^+\pi^-$ decays in bin 9 in scheme A.
Figure 20: Projections of the unbinned maximum likelihood fit to the $\Lambda_b^0 \rightarrow p\pi^+\pi^-\pi^-$ decays in bin 10 in scheme A.
Figure 21: Projections of the unbinned maximum likelihood fit to the $\Lambda_b^0 \rightarrow p\pi^-\pi^+\pi^-$ decays in bin 11 in scheme A.
Figure 22: Projections of the unbinned maximum likelihood fit to the $\Lambda_b^0 \rightarrow p\pi^-\pi^+\pi^-$ decays in bin 12 in scheme A.
Figure 23: Projections of the unbinned maximum likelihood fit to the $\Lambda^0_b \to p\pi^-\pi^+\pi^-$ decays in the region $0 < |\Phi| < \pi/10$, corresponding to bin 1 in scheme B.
Figure 24: Projections of the unbinned maximum likelihood fit to the $\Lambda_{b}^{0}(C_{T}>0)$ decays in the region $\pi/10 < |\Phi| < 2\pi/10$, corresponding to bin 2 in scheme B.
Figure 25: Projections of the unbinned maximum likelihood fit to the $\Lambda_c^0 \rightarrow p\pi^-\pi^+\pi^-$ decays in the region $2\pi/10 < |\Phi| < 3\pi/10$, corresponding to bin 3 in scheme B.
Figure 26: Projections of the unbinned maximum likelihood fit to the $\Lambda_c^0 \rightarrow p \pi^- \pi^+ \pi^-$ decays in the region $3\pi/10 < |\Phi| < 4\pi/10$, corresponding to bin 4 in scheme B.
Figure 27: Projections of the unbinned maximum likelihood fit to the $\Lambda_b^0 \rightarrow p \pi^- \pi^+ \pi^-$ decays in the region $4\pi/10 < |\Phi| < 5\pi/10$, corresponding to bin 5 in scheme B.
Figure 28: Projections of the unbinned maximum likelihood fit to the $\Lambda_b^0 \rightarrow p\pi^-\pi^+\pi^-$ decays in the region $5\pi/10 < |\Phi| < 6\pi/10$, corresponding to bin 6 in scheme B.
Figure 29: Projections of the unbinned maximum likelihood fit to the $\Lambda^0_b \rightarrow p\pi^-\pi^+\pi^-$ decays in the region $6\pi/10 < |\Phi| < 7\pi/10$, corresponding to bin 7 in scheme B.
Figure 30: Projections of the unbinned maximum likelihood fit to the $\Lambda_c^0 \to p\pi^-\pi^+\pi^-$ decays in the region $7\pi/10 < |\Phi| < 8\pi/10$, corresponding to bin 8 in scheme B.
Figure 31: Projections of the unbinned maximum likelihood fit to the $\Lambda_c^0 \to p\pi^-\pi^+\pi^-$ decays in the region $8\pi/10 < |\Phi| < 9\pi/10$, corresponding to bin 9 in scheme B.
Figure 32: Projections of the unbinned maximum likelihood fit to the $\Lambda_c^0 \rightarrow p\pi^+\pi^-$ decays in the region $9\pi/10 < |\Phi| < \pi$, corresponding to bin 10 in scheme B.
Figure 33: Projections of the unbinned maximum likelihood fit to the $A_0^0 \to p\pi^- K^+ K^-$ decays in bin 1.
Figure 34: Projections of the unbinned maximum likelihood fit to the $\Lambda_b^0 \rightarrow p\pi^-K^+K^-$ decays in bin 2.
Figure 35: The invariant mass distribution of the $\Lambda_b^0 \rightarrow \Lambda_c^+ (\rightarrow pK^-\pi^+)\pi^-$ candidates, which constitutes a control sample for this analysis. A binned maximum likelihood fit is overlaid on the data points as a blue curve. The contribution of each component is represented by a line as shown in the legend.
Figure 36: The $\chi^2$ distributions obtained using 40,000 pseudoexperiments with $CP$ symmetry for (a) scheme A, and (b) scheme B; and (c) the distribution of the $\log_{10}$ of the product of the $p$-values of schemes A and B.