Supplementary material for LHCb-PAPER-2012-041

1 Supplementary cross-check measurements

Three cross-check analyses are performed in parallel with the principal measurements presented in this paper. In two of these, the D^0 and D^+ production cross-sections are measured with the alternative decay modes $D^0 \to K^-\pi^+\pi^-\pi^+$ and $D^+ \to \phi(K^-K^+)\pi^+$ using the same methodology as that for the primary measurements. In the last, a third determination of the D^0 production cross-sections is made with an alternative selection of $D^0 \to K^-\pi^+$ decays and an alternative yield determination method. We now give a brief description of these additional studies and summaries of their results.

1.1 $D^0 \to K^-\pi^+\pi^-\pi^+$ and $D^+ \to \phi(K^-K^+)\pi^+$ analyses

The excellent tracking and particle identification performance of the LHCb detector enables clean samples of prompt multi-body decays to be reconstructed. We exploit these properties to measure the D^0 differential cross-sections with a sample of $D^0 \to K^-\pi^+\pi^-\pi^+$ decays. The analysis methodology is the same as that for the principal result from $D^0 \to K^-\pi^+$ of LHCb-PAPER-2012-041. Using $\mathcal{B}(D^0 \to K^-\pi^+\pi^-\pi^+) = (8.07^{+0.21}_{-0.19})\%$ [1] in Eq. 2 of LHCb-PAPER-2012-041, we measure the differential D^0 meson production cross-sections recorded in Table 1. The results are in agreement with the primary results presented in Table 7 of LHCb-PAPER-2012-041.

Validation of the D^+ cross-sections with the $D^+ \to \phi(K^-K^+)\pi^+$ decay mode follows naturally from the $D_s^+ \to \phi(K^-K^+)\pi^+$ measurement. Using the same selection and analysis procedure for $D^+ \to \phi(K^-K^+)\pi^+$ as for $D_s^+ \to \phi(K^-K^+)\pi^+$ we obtain the differential D^+ cross-sections in Table 2. These are in agreement with the primary results in Table 8 of LHCb-PAPER-2012-041.

No branching fraction is readily available for $D^+ \to K^-K^+\pi^+$ with a K^-K^+ invariant mass in a $\pm 20\,\mathrm{MeV}/c$ window around the $\phi(1020)$ mass. We use a sample of $D^+ \to K^-K^+\pi^+$ to estimate an efficiency-corrected relative fraction of $0.23 \pm 0.02(\mathrm{stat})$ $D^+ \to K^-K^+\pi^+$ decays in the $\phi(1020)$ mass window. When multiplied by the world-average $D^+ \to K^-K^+\pi^+$ branching fraction of $(9.54 \pm 0.26) \times 10^{-3}$ [1], we get a $D^+ \to \phi(K^-K^+)\pi^+$ branching fraction of $(2.18 \pm 0.06) \times 10^{-3}$. We do not perform a detailed treatment of the systematic uncertainty of this determination, but we do adopt the difference between it and the resonant $D^+ \to \phi(K^-K^+)\pi^+$ world-average branching fraction of $(2.65^{+0.08}_{-0.09}) \times 10^{-3}$ [1] as an estimate of the size of the systematic uncertainty. Thus the branching fraction for the $D^+ \to \phi(K^-K^+)\pi^+$ analysis is $\mathcal{B}(D^+ \to \phi(K^-K^+)\pi^+) = (2.18 \pm 0.47) \times 10^{-3}$.

It should be noted that we do not combine the measurements from these cross-check studies with those of the primary analyses in order to minimise problems due to unknown correlations between different measurements in the analysis.

1.2 $D^0 \to K^-\pi^+$ cross-check without particle identification

A sample of $D^0 \to K^-\pi^+$ selected solely with a small number of geometric and kinematic variables is used to validate aspects of the main analysis method. This selection is a further development in the spirit of the $K^0_S \to \pi^+\pi^-$ and $\Lambda \to p\pi^-$ selections of Refs. [2, 3]. Because it uses no particle identification information, this selection allows us to verify our method for determining the PID efficiencies in the primary analyses. In addition, this analysis uses a two-step method for yield determinations developed to check the results of our multidimensional fits. First, a cubic sideband subtraction in the invariant mass distribution is performed to determine the sum of the yields from signal and secondary background. Next, a binned χ^2 fit to the sideband subtracted $\log_{10}(\text{IP}\,\chi^2)$ distribution is used to determine the prompt signal fraction.

Unlike for the modes in Section 1.1, the results from this analysis and the primary analysis are not statistically independent. Even under the extreme assumption that the two samples are statistically fully correlated, we see good agreement between the differential cross-sections from this alternate measurement in Table 3 and those for the primary result in Table 7 of LHCb-PAPER-2012-041. We do not provide an average including these results.

2 HepData tables

The CERN Document Server preprint of this paper is accompanied by flat text files containing the information in Tables 6–10 of LHCb-PAPER-2012-041. These are intended for inclusion in the Reactions Database of the Durham HepData Project.

References

[1] Particle Data Group, J. Beringer *et al.*, *Review of particle physics*, Phys. Rev. **D86** (2012) 010001.

[2] LHCb collaboration, R. Aaij *et al.*, *Prompt K^0_S production in pp collisions at $\sqrt{s} = 0.9$ TeV*, Phys. Lett. **B693** (2010) 69, arXiv:1008.3105.

[3] LHCb collaboration, R. Aaij *et al.*, *Measurement of V^0 production ratios in pp collisions at $\sqrt{s} = 0.9$ and 7 TeV*, JHEP **08** (2011) 034, arXiv:1107.0882.

Table 1: The cross-check decay mode $D^0 \to K^-\pi^+\pi^-\pi^+$ is used to measure the differential production cross-sections, $d\sigma/dp_T$, in μb/(GeV/c) for prompt D^0 + c.c. mesons in bins of (p_T, y). The first uncertainty is statistical, and the second is the total systematic.

p_T (GeV/c)	y (2.0, 2.5)	(2.5, 3.0)	(3.0, 3.5)	(3.5, 4.0)	(4.0, 4.5)
(0, 1)			240.34 ± 63.55 ± 58.88		
(1, 2)		192.27 ± 54.33 ± 52.70	119.19 ± 18.77 ± 22.52	147.17 ± 24.93 ± 29.99	
(2, 3)	145.20 ± 32.11 ± 32.32	70.23 ± 6.92 ± 13.58	68.73 ± 5.27 ± 14.02	47.42 ± 5.21 ± 10.25	68.64 ± 13.60 ± 23.07
(3, 4)	38.07 ± 6.60 ± 8.19	37.86 ± 2.66 ± 7.09	30.15 ± 1.84 ± 5.66	24.88 ± 2.00 ± 5.02	8.66 ± 2.02 ± 2.39
(4, 5)	17.64 ± 2.32 ± 4.52	17.87 ± 1.18 ± 3.54	13.23 ± 0.88 ± 2.57	10.20 ± 0.84 ± 1.85	5.11 ± 1.09 ± 1.06
(5, 6)	9.53 ± 1.59 ± 2.08	9.52 ± 0.70 ± 1.83	6.26 ± 0.50 ± 1.25	3.80 ± 0.44 ± 0.69	2.16 ± 0.61 ± 0.71
(6, 7)	3.83 ± 0.64 ± 0.78	3.86 ± 0.38 ± 0.83	2.92 ± 0.30 ± 0.56	2.00 ± 0.30 ± 0.38	1.68 ± 0.47 ± 0.58
(7, 8)	2.79 ± 0.46 ± 0.55	2.36 ± 0.28 ± 0.43	1.76 ± 0.21 ± 0.41	0.97 ± 0.18 ± 0.20	

Table 2: The cross-check decay mode $D^+ \to \phi(K^-K^+)\pi^+$ is used to measure the differential production cross-sections, $d\sigma/dp_T$, in μb/(GeV/c) for prompt D^+ + c.c. mesons in bins of (p_T, y). The first uncertainty is statistical, and the second is the total systematic.

p_T (GeV/c)	y (2.0, 2.5)	(2.5, 3.0)	(3.0, 3.5)	(3.5, 4.0)	(4.0, 4.5)
(0, 1)					
(1, 2)		54.36 ± 11.16 ± 16.61	51.26 ± 10.16 ± 15.10		
(2, 3)	39.98 ± 11.27 ± 13.16	14.59 ± 4.37 ± 5.59	25.68 ± 4.67 ± 7.01	22.65 ± 5.19 ± 7.59	
(3, 4)	20.18 ± 5.51 ± 6.31	15.00 ± 2.90 ± 4.02	16.86 ± 2.95 ± 4.42	12.52 ± 3.10 ± 3.72	
(4, 5)		7.92 ± 1.88 ± 2.12	4.04 ± 1.32 ± 1.12		
(5, 6)		3.45 ± 1.17 ± 0.93			
(6, 7)		3.04 ± 1.03 ± 0.83			

Table 3: The cross-check selection of $D^0 \to K^-\pi^+$ without particle identification is used to measure the differential production cross-sections, $\mathrm{d}\sigma/\mathrm{d}p_\mathrm{T}$, in μb/(GeV/$c$) for prompt D^0 + c.c. mesons in bins of (p_T, y). The first uncertainty is statistical, and the second is the total systematic.

p_T	y				
(GeV/c)	$(2.0, 2.5)$	$(2.5, 3.0)$	$(3.0, 3.5)$	$(3.5, 4.0)$	$(4.0, 4.5)$
$(0, 1)$		$123.93 \pm 40.78 \pm 20.97$	$137.42 \pm 43.96 \pm 25.91$		
$(1, 2)$	$120.82 \pm 12.04 \pm 17.61$	$127.49 \pm 9.56 \pm 18.40$	$100.72 \pm 10.43 \pm 14.59$	$70.88 \pm 11.38 \pm 10.51$	$52.80 \pm 18.13 \pm 11.99$
$(2, 3)$	$78.24 \pm 4.63 \pm 7.54$	$78.44 \pm 3.28 \pm 7.49$	$64.84 \pm 3.34 \pm 6.19$	$53.63 \pm 4.28 \pm 5.24$	$28.32 \pm 5.52 \pm 5.77$
$(3, 4)$	$45.28 \pm 2.50 \pm 3.77$	$37.72 \pm 1.75 \pm 3.10$	$32.95 \pm 1.80 \pm 2.72$	$20.71 \pm 2.03 \pm 1.73$	$14.89 \pm 2.43 \pm 1.78$
$(4, 5)$	$19.76 \pm 1.28 \pm 1.61$	$16.18 \pm 1.00 \pm 1.30$	$13.74 \pm 1.01 \pm 1.11$	$9.79 \pm 1.10 \pm 0.83$	$6.05 \pm 1.18 \pm 0.57$
$(5, 6)$	$9.05 \pm 0.85 \pm 0.74$	$9.07 \pm 0.68 \pm 0.73$	$5.76 \pm 0.65 \pm 0.47$	$3.89 \pm 0.71 \pm 0.35$	$3.08 \pm 0.69 \pm 0.41$
$(6, 7)$	$4.99 \pm 0.55 \pm 0.44$	$4.60 \pm 0.44 \pm 0.40$	$3.14 \pm 0.44 \pm 0.29$	$2.01 \pm 0.42 \pm 0.19$	$1.03 \pm 0.44 \pm 0.20$
$(7, 8)$	$2.59 \pm 0.39 \pm 0.22$	$2.33 \pm 0.34 \pm 0.20$	$0.90 \pm 0.33 \pm 0.10$	$0.95 \pm 0.33 \pm 0.11$	