

# Supplementary material for LHCb-PAPER-2020-010

The number of VELO hits in like-sign events is compared with that in opposite-sign in Fig. S1. The average is about 13% higher in like-sign events.

Ratios of total cross-section between two pairs in the same category (LS or OS) and different by only one charm hadron, for the reduced rapidity and  $p_T$  range, compared to the ratios of single charm prompt production in  $pp$  collisions [1], are shown in Table S1 and Fig. S2. Good agreement are found up to a factor relevant for the number of charm-quark hadronization paths into charm pairs. The results suggest that charm hadronization is not strongly modified in  $p$ -Pb data with respect to  $pp$  collisions.

In Figs. S3 and S4, the  $D^0D^0$  and  $D^0\bar{D}^0$  pair  $p_T$  distributions and the distributions of two charm-hadron rapidity difference are shown, without the  $p_T(D^0) > 2 \text{ GeV}/c$  requirement. The distribution is similar between  $D^0D^0$  and  $D^0\bar{D}^0$  pairs and is compatible with PYTHIA8 simulation. In Fig. S5, the  $m_{DD}$  and  $\Delta\phi$  distributions of  $J/\psi D^0$  pairs are presented.

The effective cross-section  $\sigma_{\text{eff}, p\text{Pb}}$  in bins of rapidity measured using  $J/\psi D^0$  and  $D^0D^0$  pair production cross-section is shown in Fig. S6, and is compared with prediction from Ref. [2].

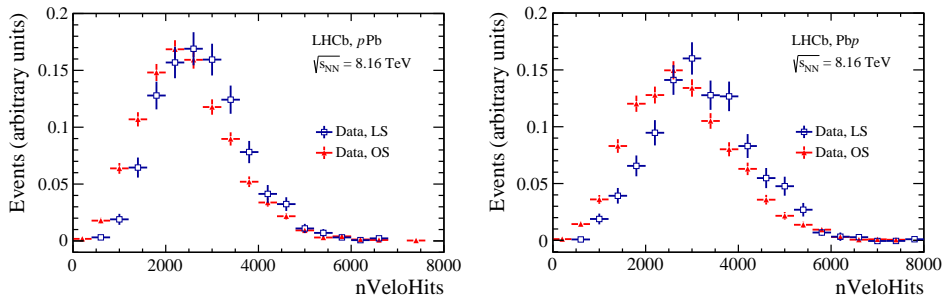


Figure S1: Background subtracted distribution of VELO hits in (open square) like-sign (LS) and (filled triangle) opposite-sign (OS) charm-pair data, for  $p\text{Pb}$  (left) and  $\text{Pbp}$  (right) data.

Table S1: Ratios of total cross-sections (including charge-conjugate final states) in the range  $p_T(D^0, D^+, D_s^+) > 2 \text{ GeV}/c$  for  $p\text{Pb}$  and  $\text{Pbp}$  data, compared to measurements of  $\sigma(D^+)/\sigma(D^0)$  and  $\sigma(D_s^+)/\sigma(D^+)$  in  $pp$  collisions [1]. The first uncertainty is statistical and the second systematic for  $p$ -Pb data. The scale factor is either 1/2, 1, or 2, depending on the numbers of possible hadronization paths in the denominator and numerator.

Pairs	$1.7 < y < 3.7$	$-4.7 < y < -2.7$	Scale $\times$ (inclusive ratio)
$D^0D^+/D^0D^0$	$0.78 \pm 0.07 \pm 0.04$	$0.86 \pm 0.08 \pm 0.12$	$2 \times (0.435 \pm 0.043)$
$D^+D^+/D^0D^+$	$0.25 \pm 0.03 \pm 0.02$	$0.27 \pm 0.04 \pm 0.05$	$1/2 \times (0.435 \pm 0.043)$
$D^0D^-/D^0\bar{D}^0$	$0.85 \pm 0.04 \pm 0.04$	$0.84 \pm 0.04 \pm 0.08$	$2 \times (0.435 \pm 0.043)$
$D^+D_s^-/D^0D_s^-$	$0.47 \pm 0.09 \pm 0.04$	$0.55 \pm 0.11 \pm 0.08$	$1 \times (0.435 \pm 0.043)$
$D^+D_s^+/D^0D_s^+$	$0.38 \pm 0.17 \pm 0.02$	$0.55 \pm 0.26 \pm 0.15$	$1 \times (0.435 \pm 0.043)$
$D^0D_s^+/D^0D^+$	$0.46 \pm 0.11 \pm 0.02$	$0.74 \pm 0.26 \pm 0.06$	$1 \times (0.325 \pm 0.074)$
$D^0D_s^-/D^0D^-$	$0.48 \pm 0.06 \pm 0.03$	$0.47 \pm 0.06 \pm 0.01$	$1 \times (0.325 \pm 0.074)$
$J/\psi D^+/J/\psi D^0$	$0.41 \pm 0.07 \pm 0.02$	$0.47 \pm 0.07 \pm 0.06$	$1 \times (0.435 \pm 0.043)$

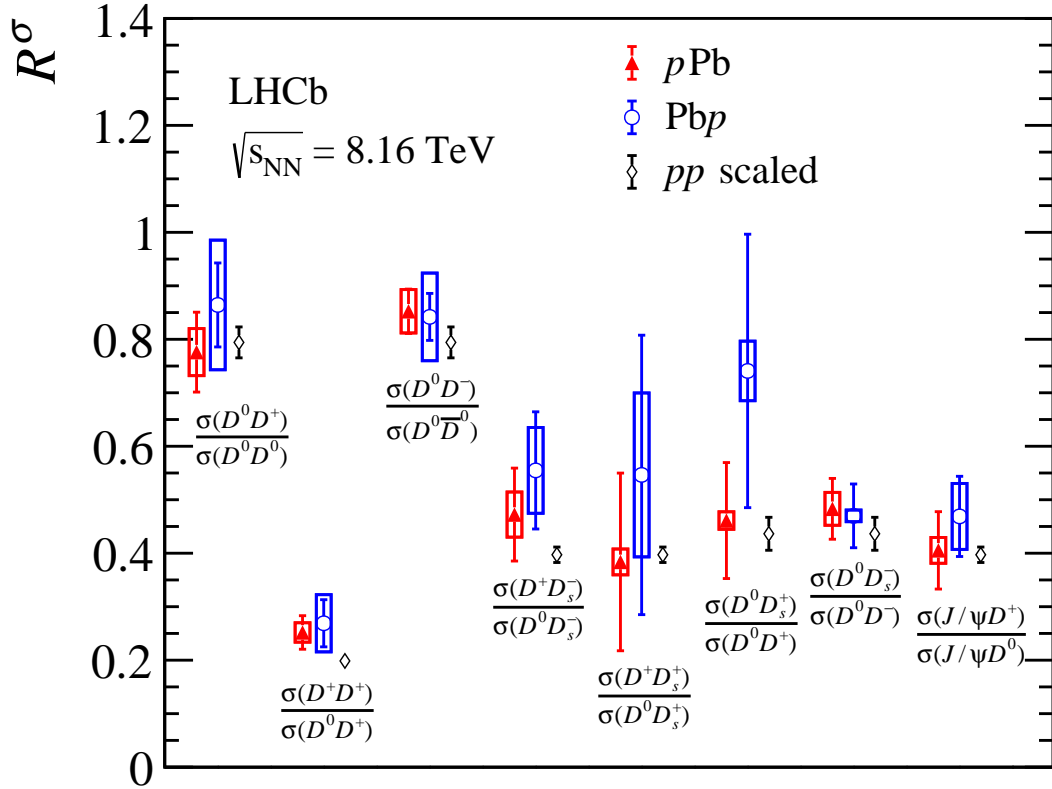


Figure S2: Ratios of total cross-sections (including charge-conjugate final states) in the range  $p_T(D^0, D^+, D_s^+) > 2 \text{ GeV}/c$  for (red triangle)  $p\text{Pb}$  and (blue circle)  $\text{Pb}p$  data, compared to measurements in (black diamond)  $pp$  collisions [1], showing (error bars) statistical and (boxes) systematic uncertainties and (black) scaled measurements of inclusive production ratio in  $pp$  collisions [1]. The scale factor for  $pp$  data is either 1/2, 1, or 2 depending on the number of possible hadronization paths for the pairs in the denominator and numerator of the ratio.

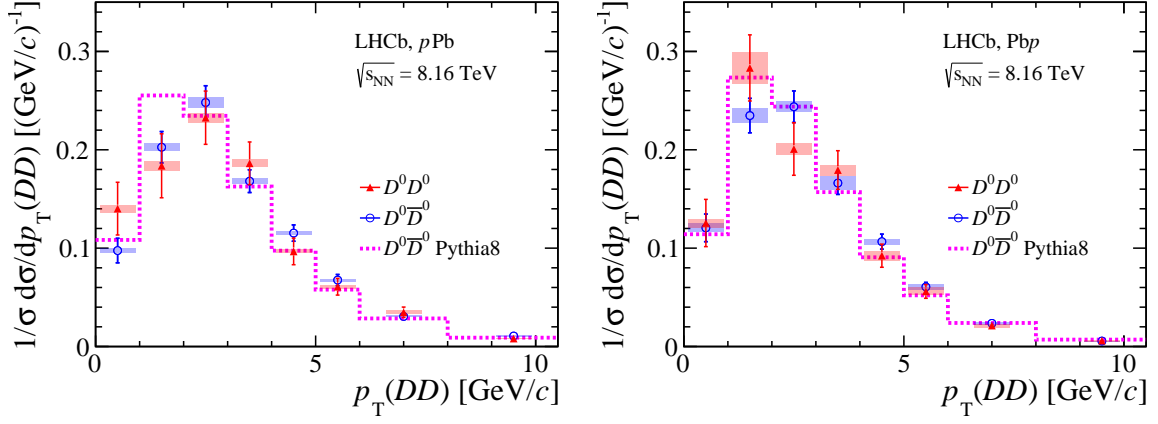


Figure S3: Distributions of the pair transverse momentum for (red)  $D^0 D^0$  and (blue)  $D^0 \bar{D}^0$  pairs in (left)  $p\text{Pb}$ , (right)  $\text{Pbp}$  data and (magenta band) PYTHIA8 simulation. Vertical bars (shaded area) are statistical (systematic) uncertainties.

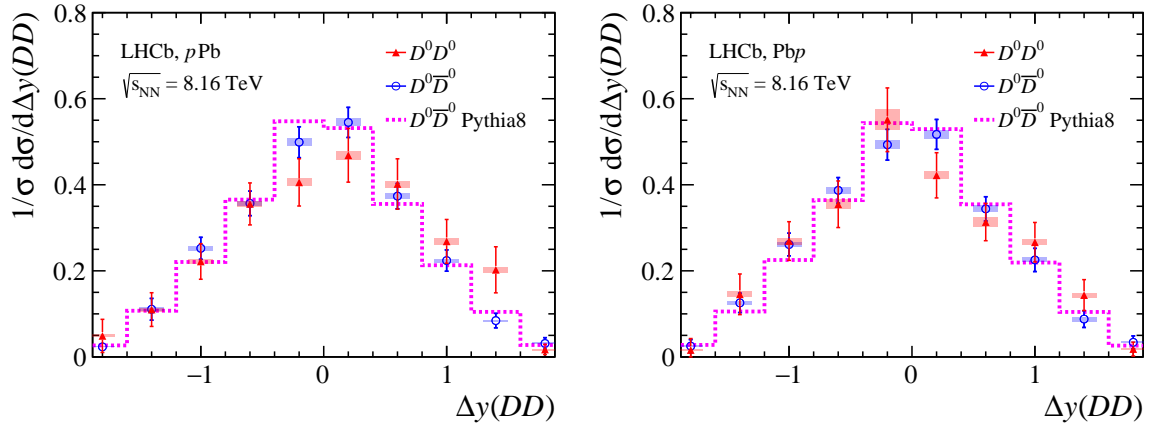


Figure S4: Distributions of the rapidity difference between the two charm hadrons in (red)  $D^0 D^0$  and (blue)  $D^0 \bar{D}^0$  pairs in (left)  $p\text{Pb}$  and (right)  $\text{Pbp}$  data and the (magenta band) PYTHIA8 simulation. Vertical bars (shaded area) are statistical (systematic) uncertainties.

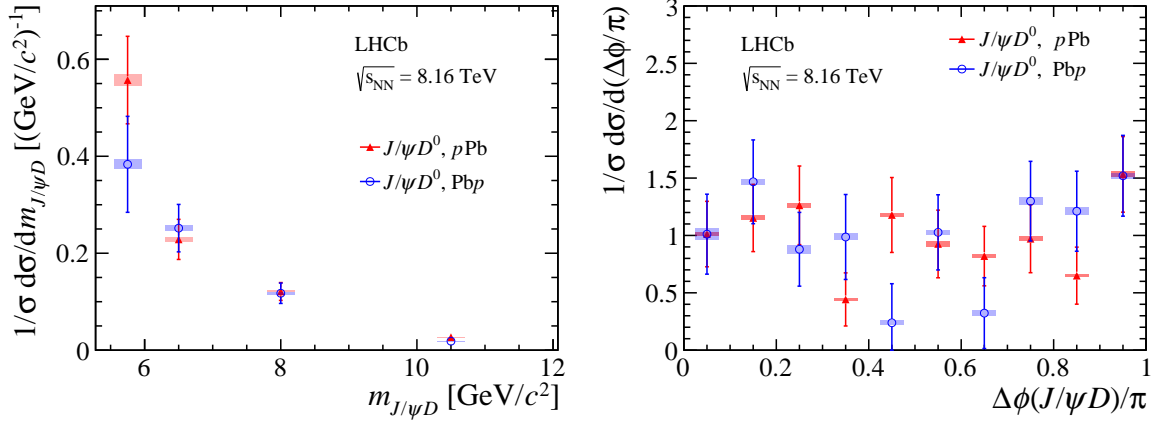


Figure S5: The (left)  $m_{DD}$  and (right)  $\Delta\phi$  distributions for  $J/\psi$ - $D^0$  pairs for (red)  $p\text{Pb}$  and (blue)  $\text{Pb}p$  data. Vertical bars (shaded area) are statistical (systematic) uncertainties.

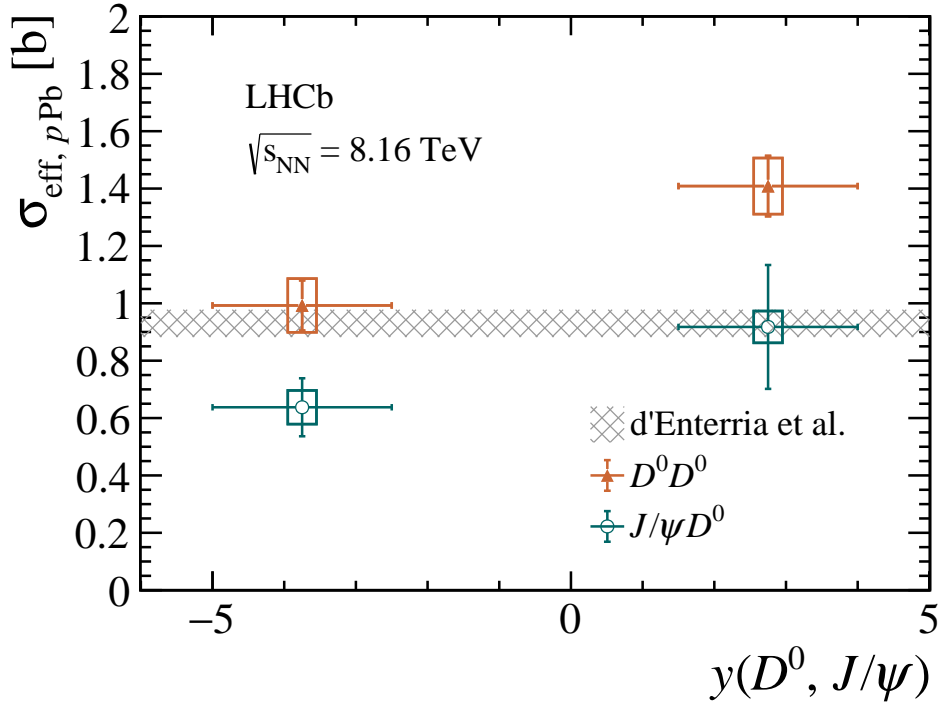


Figure S6: The effective cross-section  $\sigma_{\text{eff}, p\text{Pb}}$  obtained using  $J/\psi D^0$  and  $D^0 D^0$  pair production. The shaded area corresponds to  $\sigma_{\text{eff}, p\text{Pb}}$  extrapolated from  $pp$  data in Ref. [2], which incorporates about a factor of three enhancement for DPS production.

## References

- [1] LHCb collaboration, R. Aaij *et al.*, *Measurements of prompt charm production cross-sections in  $pp$  collisions at  $\sqrt{s} = 5$  TeV*, JHEP **06** (2017) 147, [arXiv:1610.02230](#).
- [2] D. d'Enterria and A. M. Snigirev, *Same-sign  $WW$  production in proton-nucleus collisions at the LHC as a signal for double parton scattering*, Phys. Lett. **B718** (2013) 1395, [arXiv:1211.0197](#).