1 Supplementary material

The responses of the multivariate classifiers used for the $\Xi_{cc}^{++} \rightarrow \Lambda^{+}_{c} K^{-}\pi^{+}\pi^{+}$ and $\Xi_{cc}^{++} \rightarrow \Xi^{+}_{c} \pi^{+}$ decays are shown in Fig. 3. The classifier for the $\Xi_{cc}^{++} \rightarrow \Lambda^{+}_{c} K^{-}\pi^{+}\pi^{+}$ decay is based on a Boosted Decision Tree (BDT) algorithm and the classifier for the $\Xi_{cc}^{++} \rightarrow \Xi^{+}_{c} \pi^{+}$ decay is based on a Multilayer Perceptron (MLP).

![Figure 3: Classifier outputs for (left) the $\Xi_{cc}^{++} \rightarrow \Lambda^{+}_{c} K^{-}\pi^{+}\pi^{+}$ decay, and (right) the $\Xi_{cc}^{++} \rightarrow \Xi^{+}_{c} \pi^{+}$ decay. The black dashed lines indicate the optimised thresholds of selections.](image)

The mass distributions of $\Lambda^{+}_{c}$ and $\Xi^{+}_{c}$ candidates are displayed for $\Xi_{cc}^{++}$ candidates in a mass range from 3440 MeV/$c^2$ to 3770 MeV/$c^2$ and satisfying the BDT selection. The $\Xi^{+}_{c}$ candidates are in the $\Xi_{cc}^{++}$ mass range from 3350 MeV/$c^2$ to 3800 MeV/$c^2$ and satisfy the MLP selection.

![Figure 4: Mass distributions of (left) $\Lambda^{+}_{c}$ and (right) $\Xi^{+}_{c}$ candidates. The $\Lambda^{+}_{c}$ candidates are displayed for $\Xi_{cc}^{++}$ candidates in a mass range from 3440 MeV/$c^2$ to 3770 MeV/$c^2$ and satisfying the BDT selection. The $\Xi^{+}_{c}$ candidates are in the $\Xi_{cc}^{++}$ mass range from 3350 MeV/$c^2$ to 3800 MeV/$c^2$ and satisfy the MLP selection.](image)

The mass distributions of $\Lambda^{+}_{c}$ and $\Xi^{+}_{c}$ candidates after the full selection are shown in Fig. 4. The $m_{\text{cand}}(\Xi^{+}_{cc})$ mass distribution of the selected $\Xi_{cc}^{++} \rightarrow \Lambda^{+}_{c} K^{-}\pi^{+}\pi^{+}$ candidates in an enlarged mass range from 3440 MeV/$c^2$ to 3800 MeV/$c^2$ are shown in Fig. 5. The $m_{\text{cand}}(\Xi^{+}_{cc})$ mass distribution of the selected $\Xi_{cc}^{++} \rightarrow \Lambda^{+}_{c} K^{-}\pi^{+}\pi^{+}$ candidates is shown in Fig. 6 in a wide mass range from 3400 MeV/$c^2$ to 5000 MeV/$c^2$ for 2016 and 2018 data. The 2017 data is not included as a mass cut of 3420–3820 MeV/$c^2$ was introduced in the trigger for that year.
Figure 5: Mass distribution of the selected $\Xi_{cc}^{++} \rightarrow \Lambda_c^+ K^- \pi^+ \pi^+$ candidates in the mass range from 3440 MeV/$c^2$ to 3800 MeV/$c^2$. The blue dashed lines indicate the mass-fit window from 3470 MeV/$c^2$ to 3770 MeV/$c^2$.

Figure 6: Mass distribution of the selected $\Xi_{cc}^{++} \rightarrow \Lambda_c^+ K^- \pi^+ \pi^+$ candidates in the mass range from 3800 MeV/$c^2$ to 5000 MeV/$c^2$. The blue dashed lines indicate the mass-fit window from 3470 MeV/$c^2$ to 3770 MeV/$c^2$. 

LHCb 2016 and 2018