

1 Supplementary material for LHCb-PAPER-2020-034

2 This appendix contains supplementary material that will be posted on the public CDS
3 record but will not appear in the paper. Figure 1 shows a comparison of the spectrum of
4 D_s^+ mesons between theory and experiment. Figure 2 shows several mass projections in
5 the low $K^+\pi^-$ mass region with the result of the amplitude fit overlaid. Figure 3 shows
6 the amplitude fit result for the model without the $D_{s0}(2590)^+$ state.

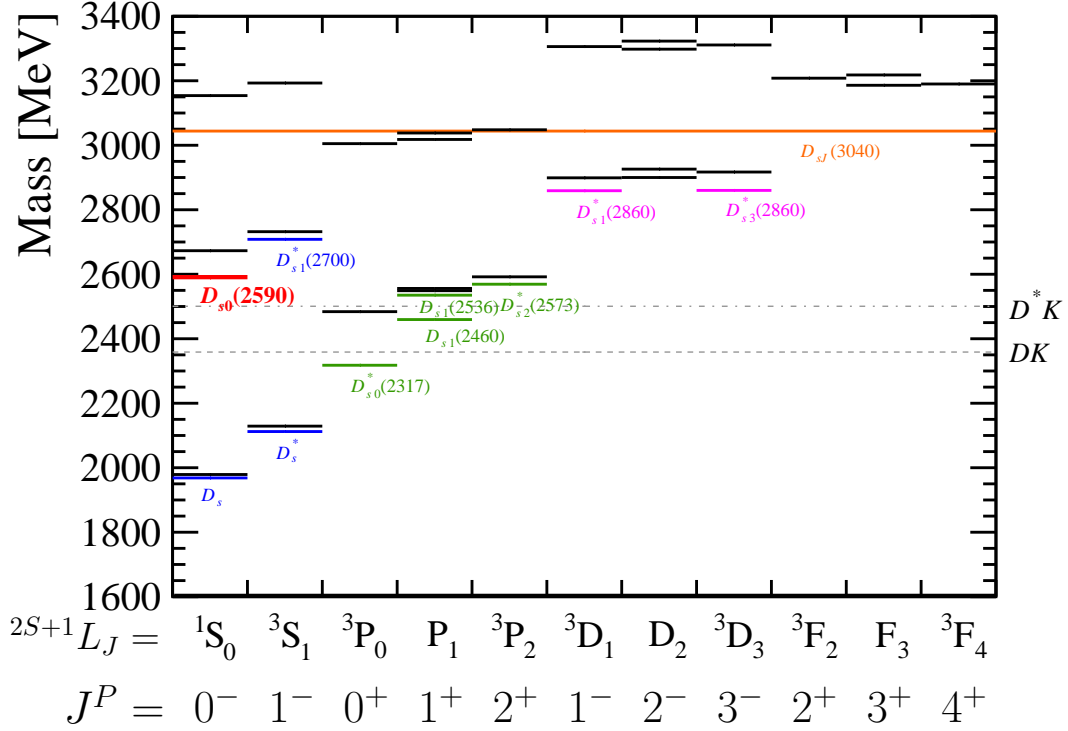


Figure 1: Comparison of the observed D_s^+ states from Ref. [1] (labelled with coloured lines) with predictions from Ref. [2] (black lines). Breit–Wigner masses are used for all cases except the $D_{s0}(2590)^+$ state, for which the pole mass reported in this analysis is used. The two dashed gray lines denote the DK and D^*K thresholds. Spectroscopic identification is made in terms of the quantum numbers $n^{2S+1}L_J$ of the constituent quark model where possible, although alternative explanations are possible in some cases. The spin-parity J^P of the $D_{sJ}(3040)^+$ state is not yet determined, but it appears likely to be a member of the 2P set of states. The $D_{s0}(2590)^+$ state, labelled by the red line, is identified as the radial excitation of the pseudoscalar D_s^+ ground-state meson.

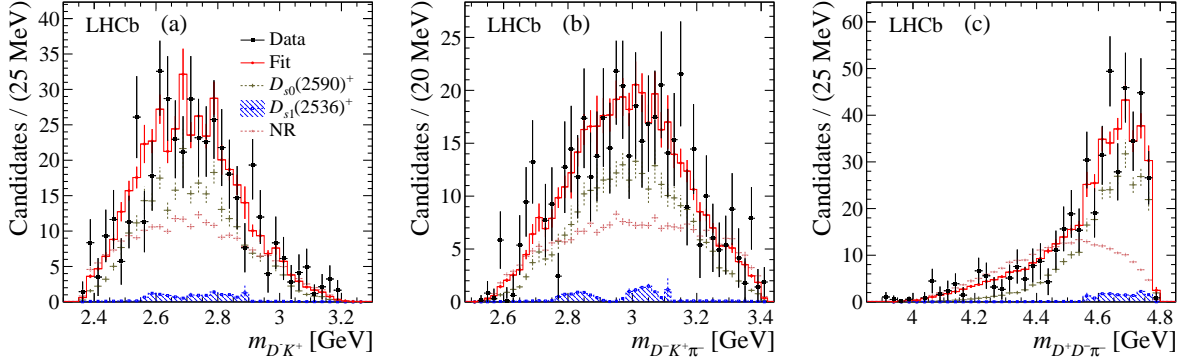


Figure 2: Mass projections of (a) D^-K^+ , (b) $D^-K^+\pi^-$ and (c) $D^+D^-\pi^-$ systems. Data points are shown in black with the background subtracted statistically using the *sPlot* method [3]. Results of the fit with the $D_{s0}(2590)^+$ ($J^P = 0^-$) model are overlaid as a solid red histogram, and individual contribution are shown as a dotted histogram. No signature of the charm-strange states, $X_0(2900)$ and $X_1(2900)$ [4, 5], is seen in the D^-K^+ mass.

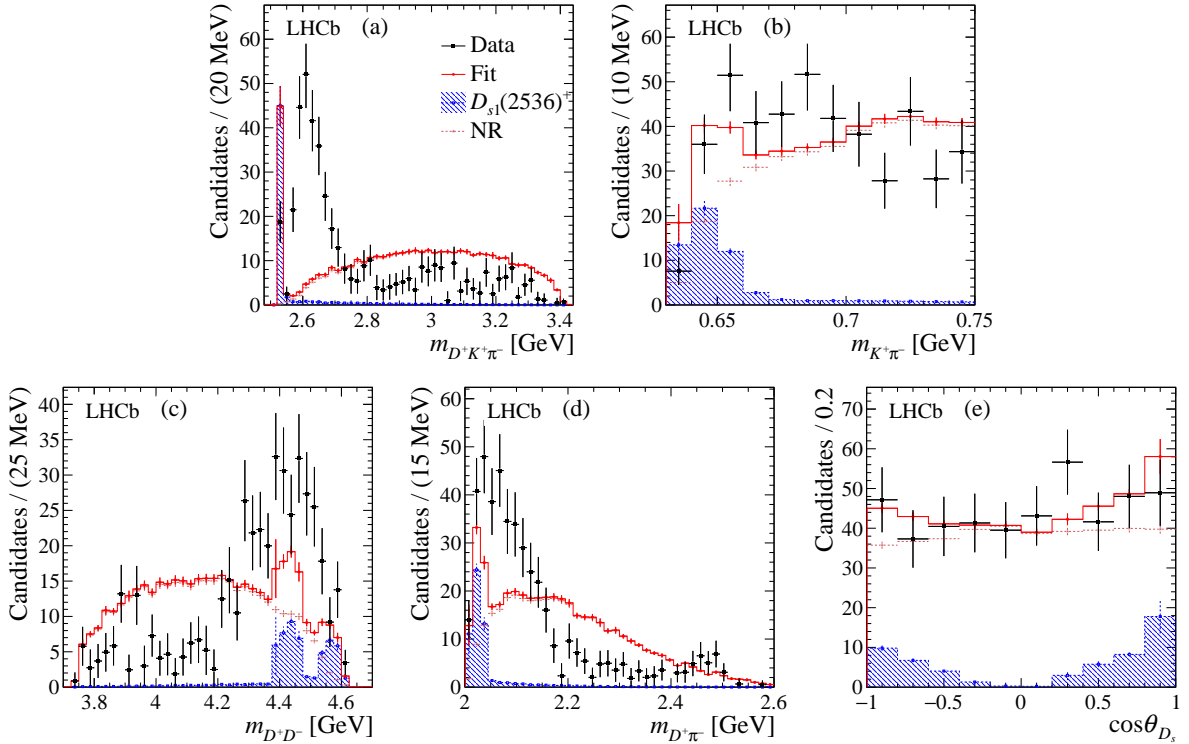


Figure 3: Distributions of (a) $m(D^+K^+\pi^-)$, (b) $m(K^+\pi^-)$, (c) $m(D^+D^-)$, (d) $m(D^+\pi^-)$ and (e) $\cos\theta_{D_s^+}$ for the null hypothesis. Data points are shown in black with the combinatorial background subtracted statistically using the *sPlot* method [3]. Fit results are overlaid as a solid red histogram, and each contribution is shown as a dotted histogram. In the absence of the $D_{s0}(2590)^+$ component the fit cannot describe the peak in $D^+K^+\pi^-$ mass, and also fails to describe associated structures at low $m_{D^+\pi^-}$ and high $m_{D^+D^-}$.

7 References

- 8 [1] Particle Data Group, P. A. Zyla *et al.*, *Review of particle physics*, Prog. Theor. Exp.
9 Phys. **2020** (2020) 083C01.
- 10 [2] S. Godfrey and K. Moats, *Properties of excited charm and charm-strange mesons*,
11 Phys. Rev. **D93** (2016) 034035, [arXiv:1510.08305](#).
- 12 [3] M. Pivk and F. R. Le Diberder, *sPlot: A statistical tool to unfold data distributions*,
13 Nucl. Instrum. Meth. **A555** (2005) 356, [arXiv:physics/0402083](#).
- 14 [4] LHCb collaboration, R. Aaij *et al.*, *A model-independent study of resonant structure*
15 *in $B^+ \rightarrow D^+ D^- K^+$ decays*, [arXiv:2009.00025](#), to appear in Phys. Rev. Lett.
- 16 [5] LHCb collaboration, R. Aaij *et al.*, *Amplitude analysis of the $B^+ \rightarrow D^+ D^- K^+$ decay*,
17 [arXiv:2009.00026](#), to appear in Phys. Rev. D.