Supplementary material for LHCb-PAPER-2019-005

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

Additional information on the $\chi_{c2}(3930)$ state

The $\chi_{c2}(3930)$ meson was first observed by the B-factories [1, 2] in the reaction $\gamma\gamma \to D\overline{D}$. The LHCb results for the mass and natural width of this resonance are compared to the B-factory values in Fig. 1. The mass measured here is 2σ lower than the world average whilst the natural width is 2σ higher.

The B-factories also reported evidence for a second state, the X(3915), that decays to $J/\psi\,\omega$ [4–7]. The Review of Particle Properties [3] gives the mass of this state as

$$m_{\mathrm{X}(3915)} = 3918.4 \pm 1.9\,\mathrm{MeV}/c^2\,.$$

Based upon an analysis of one-dimensional angular distributions [7] and the assumption that a $J^{PC} = 2^{++}$ state is produced only with helicity ± 2, as is expected for a pure charmonium state, the X(3915) was assigned spin-parity 0^{++}. A natural interpretation would then be that it is the $\chi_{c0}(2P)$ state. However, as discussed in Refs. [8–10], this assignment is problematic since the natural width of the $\chi_{c0}(2P)$ state is expected to be larger. In addition, the $\chi_{c0}(2P)$ state should have a large branching fraction to $D\overline{D}$ final state whereas there is no evidence for the X(3915) state decaying to open charm. Reference [10] proposes that the X(3915) and the $\chi_{c2}(3930)$ states are the same state with spin-parity assignment 2^{++}. This requires that the zero-helicity amplitude dominates due to a significant non-$c\bar{c}$ contribution to the wave function. The Belle collaboration has subsequently observed another state, $\chi_{c0}(3860)$, which has a large natural width and decays to $D\overline{D}$ final state. This is a better candidate to be the $\chi_{c0}(2P)$ state [11]. The question of the nature and existence of the X(3915) state remains open. It is interesting to note that the value of the mass measured here is roughly midway between the values the PDG quotes for the $\chi_{c2}(3930)$ and the X(3915) states. Further studies are needed to understand if there are one or two distinct charmonium states in this region.

Additional information on the $\psi(3770)$ mass

Figure 2 summarises the measurements of the $\psi(3770)$ mass used by the PDG to calculate its average. Our measurement is in good agreement. The PDG average does not include the BES-II measurement [12–14],

$$\mathrm{m}_{\psi(3770)} = 3772.0 \pm 1.9\,\mathrm{MeV}/c^2\,,$$

given in Ref. [12] since it does not include the effect of interference between resonant and non-resonant $D\overline{D}$ production. The PDG average and our measurement also agree with the analysis of available e^+e^- cross-section data in Ref. [15]

$$m_{\psi(3770)} = 3779.8 \pm 0.6\,\mathrm{MeV}/c^2\,.$$

The PDG also quotes a fit value that includes precision measurements of the mass difference between the $\psi(3770)$ and $\psi(2S)$ states made by the BES collaboration [12–14].

$$m_{\psi(3770)} = 3773.13 \pm 0.35\,\mathrm{MeV}/c^2\,.$$

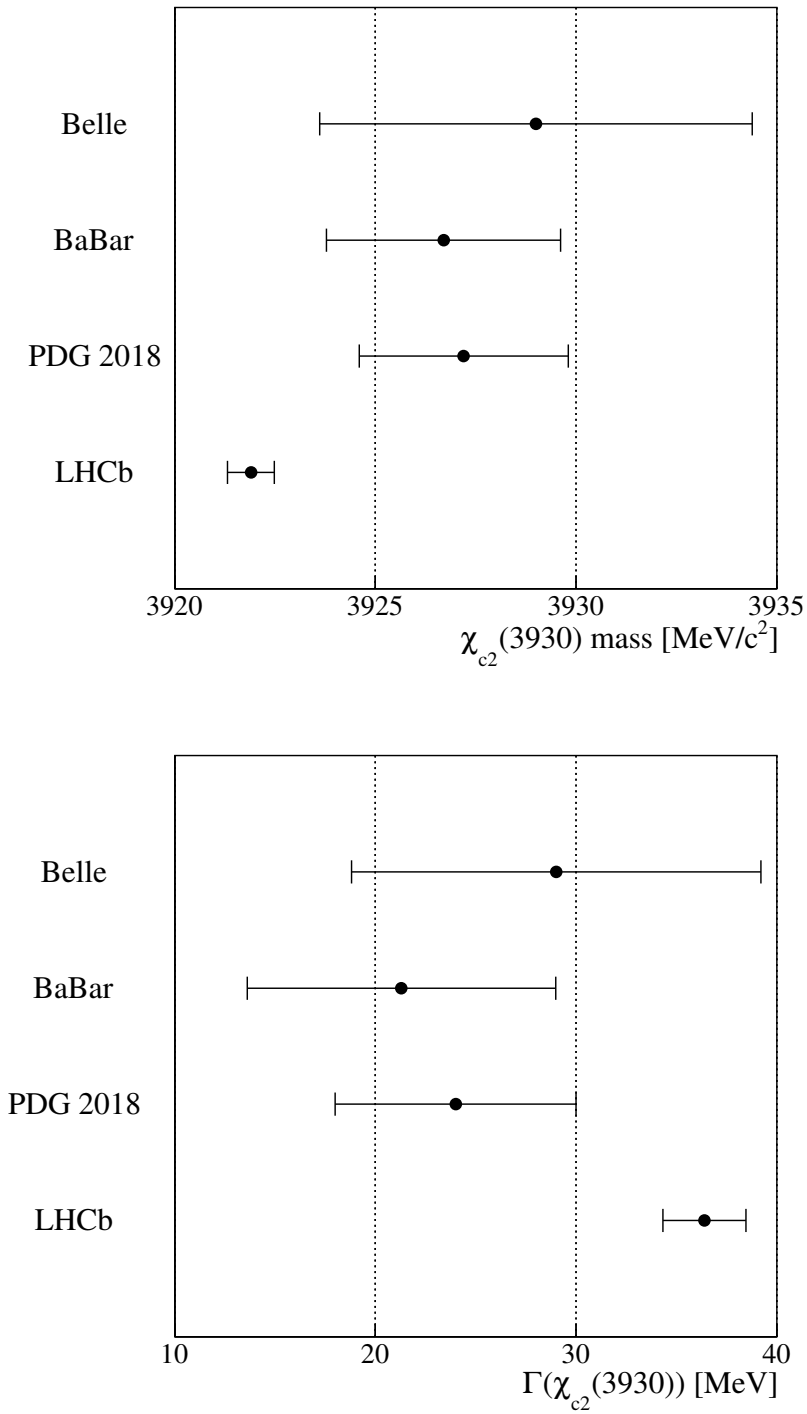

Figure 1: Measurements of the $\chi_{c2}(3930)$ (top) mass and (bottom) width by the Belle [1] and BaBar [2] collaborations together with the average calculated by the PDG [3] and the LHCb measurement.

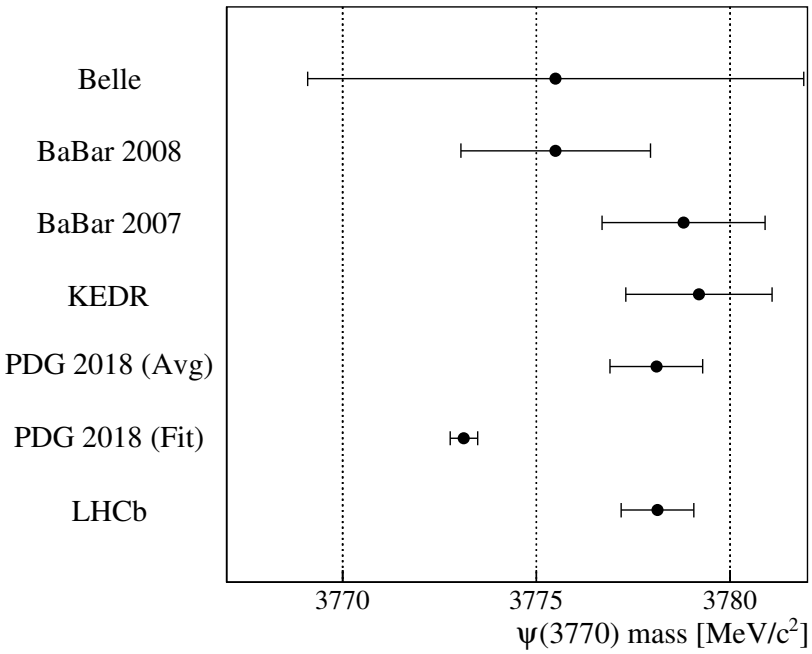

Figure 2: Measurements of the $\psi(3770)$ mass by the Belle [16], BaBar [17, 18] and KEDR [19] collaborations together with the average calculated by the PDG [3] and the LHCb measurement. The measurements are ordered according to decreasing total uncertainty, which is the sum of statistical and systematic uncertainties in quadrature. The PDG fit value is also shown.

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