Supplementary material for LHCb-PAPER-2018-018

1 Additional plots

Figure 1 shows the $\chi_{c1}K^+K^-$ and $\chi_{c2}K^+K^-$ invariant-mass distributions after the loose selection criteria but before the neural network selection. Although a clear $\overline{B}{}^0_s \to \chi_{c1}K^+K^-$ peak can be seen (shifted and broadened by the incorrect mass constraint in the right-hand plot) no clear $\overline{B}{}^0_s \to \chi_{c2}K^+K^-$ signal is present.

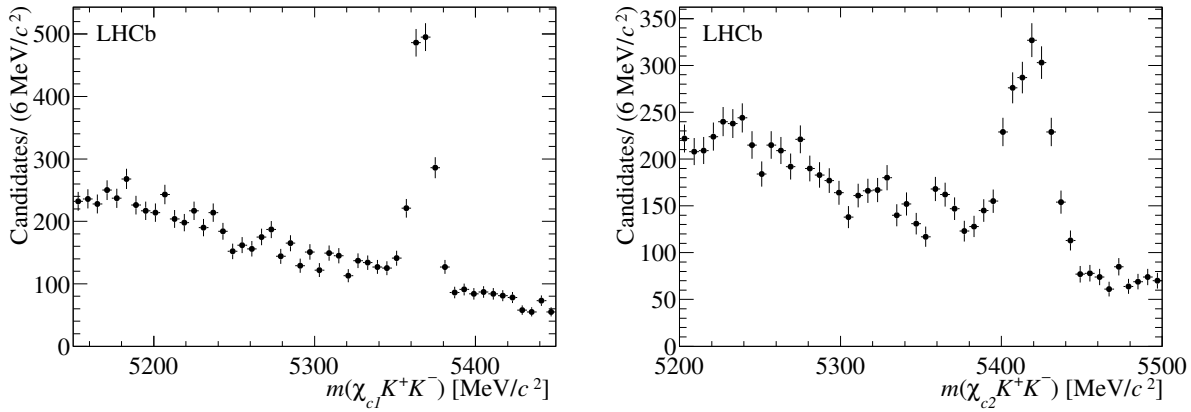

Figure 1: Invariant-mass distributions for (left) $\chi_{c1}K^+K^-$ with a χ_{c1} mass constraint applied to the $J/\psi\gamma$ four-momenta and (right) $\chi_{c2}K^+K^-$ with a χ_{c2} mass constraint applied. In both cases only the loose selection criteria are applied.

2 Additional information on B^0_s mass measurement

The LHCb experiment has previously measured the B^0_s mass in the $\overline{B}{}^0_s \to J/\psi\phi$ [1] and $\overline{B}{}^0_s \to J/\psi\phi\phi$ modes [2]. The LHCb results are combined, taking the statistical uncertainties and those related to the fit procedure to be uncorrelated and those due to the knowledge of the detector material and K^+ mass to be fully correlated. The uncertainty due to the momentum scale in Ref. [2] is also taken to be fully correlated, whereas in Ref. [1] a different procedure was used and so the corresponding uncertainty is considered to be uncorrelated with the other measurements. The result of the combination is

$$m(B^0_s) = 5366.91 \pm 0.18\,(\text{stat}) \pm 0.15\,(\text{syst})\,\text{MeV}/c^2\,.$$

In Fig. 2 the LHCb results are shown together with this average.

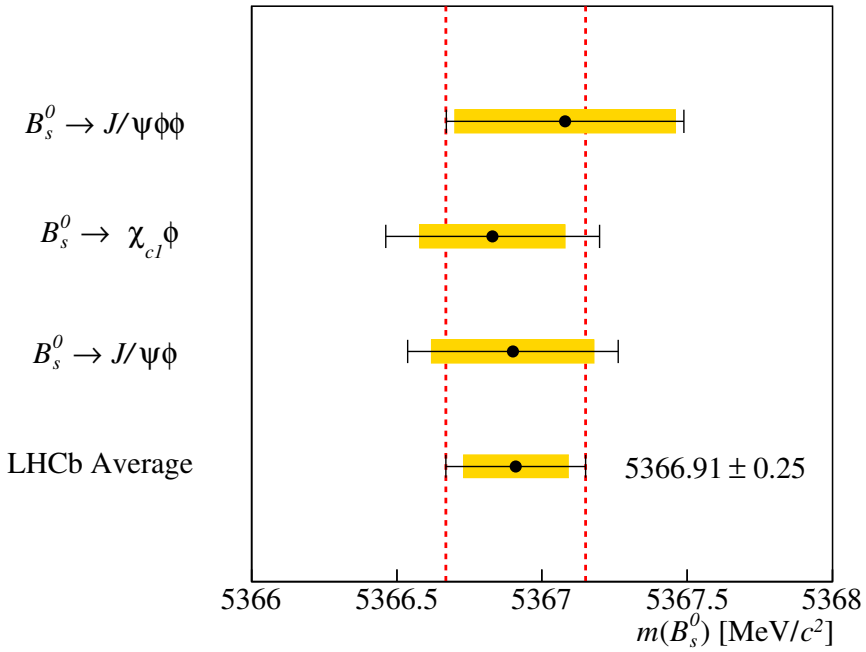

Figure 2: LHCb measurements of the B_s^0 mass. The previous measurements in the $\overline{B}_s^0 \to J/\psi\phi$ and $\overline{B}_s^0 \to J/\psi\phi\phi$ decay modes are taken from Refs. [1] and [2], respectively. The measurements are averaged taking into account correlations and are ordered according to decreasing uncertainty. The statistical uncertainties are shown by the yellow boxes whilst the black lines and whiskers indicate the quadrature sum of the statistical and systematic uncertainties.

The combined LHCb value is shown together with the values from other experiments used in the combination made by the Review of Particle Properties (PDG) [3] in Fig. 3. Taking the weighted average of these numbers gives

$$m(B_s^0) = 5366.80 \pm 0.23\,\text{MeV}/c^2\,,$$

with a χ^2 of 5.6 for 7 measurements. The PDG [3] has a procedure for checking if measurements are in agreement. If they are not, the uncertainties are increased by a scale factor, S, defined as

$$S = \left(\frac{\chi^2}{N-1}\right)^{\frac{1}{2}}.$$

In the estimation of the χ^2 the PDG select only measurements for which $\delta x_i < 3\sqrt{N}\delta\overline{x}$, where δx_i is the uncertainty on an individual measurement and $\delta\overline{x}$ is the unscaled uncertainty of the mean of all the experiments. In this case the PDG procedure gives a χ^2 of 3.7 for the three most precise measurements, corresponding to $S = 1.4$.

The new average can be compared to the value reported in Ref. [3]

$$m(B_s^0) = 5366.84 \pm 0.30\,\text{MeV}/c^2\,,$$

where the PDG has chosen to apply the scale factor of 1.2. It should also be noted that the PDG average does not properly take into account the correlations between the previous LHCb measurements.

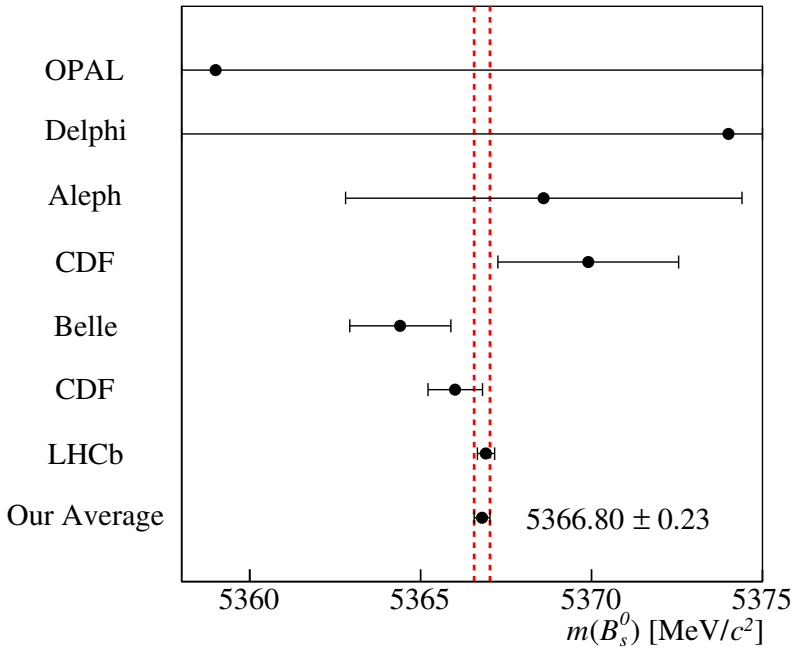

Figure 3: Measurements of the B_s^0 mass by the OPAL [4], Delphi [5], Aleph [6], Belle [7], CDF [8, 9] and the LHCb collaborations. The LHCb value is the average reported in the text. The measurements are ordered according to decreasing total uncertainty, which is the sum of statistical and systematic uncertainties in quadrature. The weighted average is also shown.

References

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[7] Belle collaboration, R. Louvot *et al.*, *Measurement of the decay $B_s^0 \to D_s^- \pi^+$ and evidence for $B_s^0 \to D_s^\mp K^\pm$ in e^+e^- annihilation at $\sqrt{s} \approx 10.87$ GeV*, Phys. Rev. Lett. **102** (2009) 021801, arXiv:0809.2526.

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