1 - 7 Hadronic Loop Effect to $\Upsilon(5S) \to \chi_{bJ}\omega$ Decays*

Chen Dianyong

Very recently, Belle announced their observation of $\Upsilon(5S) \to \chi_{bJ}\omega$ ($J = 0,1,2$), indicating that the $\Upsilon(5S) \to \chi_{bJ}\omega$ decays also have large decay widths, *i.e.*, the measured branch ratios of $\Upsilon(5S) \to \chi_{bJ}\omega$ are $< 3.4\times10^{-3}$, $(1.64\pm0.23^{+0.30}_{-0.22})\times10^{-3}$, and $(0.57\pm0.22\pm0.07)\times10^{-3}$ with $J=0,1,2$, respectively[1]. It should be noticed that even though the tree level contributions to $\Upsilon(5S) \to \chi_{bJ}\omega$ ($J = 0,1,2$) should be strongly suppressed due to the Okubo-Zweig-Iizuka (OZI) rule, such large decay widths are observed, which again inspires our interest in understanding such quantities. In this work, we propose that the contribution from the hadronic loop should be considered in studying $\Upsilon(5S) \to \chi_{bJ}\omega$.

$\Upsilon(5S)$ as a higher bottomonium is above the threshold of a pair of bottom mesons, and it mainly decays into $B^{(*)}\bar{B}^{(*)}$, which means that there exists the strong coupling between $\Upsilon(5S)$ and a bottom meson pair. Thus, the hadronic loop effect can play an important role in the decay of $\Upsilon(5S)$. Under the hadronic loop mechanism, these discussed $\Upsilon(5S) \to \chi_{bJ}\omega$ processes occur via the intermediate $B^{(*)}$ meson loops.

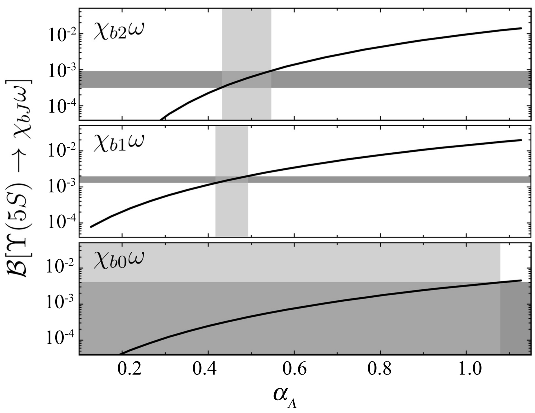

Fig. 1 The branching ratios of $\Upsilon(5S) \to \chi_{bJ}\omega$ dependent on the parameter α_Λ. The horizontal bands are the experimental data measured by the Belle Collaboration, while the vertical bands indicate the α_Λ range when our results overlap with the Belle data.

We utilize the effective Lagrangians based on heavy quark limit and chiral symmetry to depict the interactions between the involved bottomonia and bottom mesons[2–5]. With these effective Lagrangians, we can obtain the amplitudes related to the hadronic loop contributions to $\Upsilon(5S) \to \chi_{bJ}\omega$. In the amplitudes, we introduce a form factor in the monopole form to depict the internal structures as well as the offshell effect of the exchanged bottom mesons, where the form factor is taken as $\mathcal{F}(\Lambda) = (m_E^2-\Lambda^2)/(q^2-\Lambda^2)$ with m_E the exchanged boson mass. In the heavy quark limit, B and B^* are degenerate and the space wave functions of B and B^* are the same. Thus, in present work we parameterize the cutoff Λ as $\Lambda = (m_B+m_{B^*})/2+\alpha_\Lambda\Lambda_{QCD}$ with $\Lambda_{QCD} = 0.22$ GeV.

With the above preparations, we can evaluate the hadronic loop contributions to the $\Upsilon(5S) \to \chi_{bJ}\omega$ decays. The α_Λ is introduced as a free parameter in the cutoff Λ of the form factor. This parameter is usually dependent on particular process and taken to be of the order of unity. In Fig. 1 , we present the α_Λ dependence of the branching ratio of $\Upsilon(5S) \to \chi_{bJ}\omega$. The experimental data from the Belle Collaboration[1] are also presented in comparison with our calculated results.

From Fig. 1, we notice that our theoretical estimate can reproduce the experimental data given by the Belle Collaboration[1]. For $\Upsilon(5S) \to \chi_{b0}\omega$, only the upper limit was given by the experimental measurement, which is $\mathcal{B}(\Upsilon(5S) \to \chi_{b0}\omega) < 3.4\times10^{-3}$, where our result overlaps with the experimental data when taking the range $\alpha_\Lambda < 1.09$. As for the discussed $\Upsilon(5S) \to \chi_{b1}\omega$ and $\Upsilon(5S) \to \chi_{b2}\omega$ decays, our calculation can be fitted to the corresponding experimental values by taking $0.41 < \alpha_\Lambda < 0.48$ and $0.43 < \alpha_\Lambda < 0.54$, respectively. Moreover, we need to emphasize that there exists a common α_Λ range $0.43 < \alpha_\Lambda < 0.48$ for all $\Upsilon(5S) \to \chi_{bJ}\omega$ decays, which reflects the similarity among these three decays. With this common α_Λ range, we can further restrict the branching ratio of $\Upsilon(5S) \to \chi_{b0}\omega$, which is $3.00\times10^{-4} < \mathcal{B}(\Upsilon(5S) \to \chi_{b0}\omega) < 4.05\times10^{-4}$, where this branching ratio is about one order smaller than the corresponding upper limit reported by Belle[1], which can be tested in the future experiment.

References

[1] X. H. He, et al. [Belle Collaboration], Phys. Rev. Lett, **113** (2014) 14, 142001. [arXiv:1408.0504 [hep-ex]].

[2] O. Kaymakcalan, S. Rajeev, J. Schechter, Phys. Rev. D, 30(1984)594.

[3] Y. S. Oh, T. Song, S. H. Lee, Phys. Rev. C, 63(2001)034901. [arXiv:nucl-th/0010064].

[4] R. Casalbuoni, A. Deandrea, N. Di Bartolomeo, et al., Phys. Rept, 281(1997)145. [arXiv:hep-ph/9605342].

[5] P. Colangelo, F. De Fazio, T. N. Pham, Phys. Lett. B, 42(2002)71. [arXiv:hep-ph/0207061].

* Foundation item: National Natural Science Foundation of China(11375240)