Chinese Physics C

Volume 48 Number 12 December 2024 (End of Volume)

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国内统一刊号：CN 11－5641/O4　　国内邮发代号：2－522　　定价：150.00 元

PARTICLE AND NUCLEAR ASTROPHYSICS AND COSMOLOGY

Cover Story (Issue 12, 2024) | Doubly heavy meson puzzle: precise prediction of the mass spectra and hadronic decay with coupled channel effects to hunt for beauty-charm family

Author: Prof. Xing-Gang Wu (Department of Physics, Chongqing Key Laboratory for Strongly Coupled Physics, Chongqing University, Chongqing 401331, P.R. China; wuxg@cqu.edu.cn)

Doubly heavy meson, which is composed of two heavy flavor quarks such as beauty and (or) charm quarks, offers a unique platform to study the nature of strong interactions described by quantum chromodynamics (QCD) -- the underlying theory of the strong nuclear forces. Compared to other mesonic systems, our understanding of the flavored beauty-charm meson system is extremely limited, especially on the experimental aspect.

In different to J/ψ meson that has already been observed in 1974, it is hard to observe the beauty-charm meson at the electron-position colliders if we do not have enough integrated luminosities [1]. In 1993, Ref. [2] pointed out the cross-sections at the hadronic colliders as Tevatron and LHC are sufficiently large for observing the beauty-charm meson. Five years later, the CDF Collaboration announced their first observation of the ground state B_c meson via its "golden decay channels" [3]. Till now, the ATLAS, CMS and LHCb collaboration at the LHC have announced many more observations. However, only three members of beauty-charm meson family have been firmly identified. The existence of a fourth member Bc*(1S) has been indirectly suggested, but its mass and lifetime remain unknown. This highlights the critical need for both theoretical and experimental studies of the mass spectrum, production mechanisms, and decay properties of beauty-charm mesons.

A recent study detailed in an article [4] provides an important step forward of the field, which systematically explores the mass spectra and their two-body hadronic decays of the beauty-charm meson family within the coupled channel effects. Compared to previous results based on the traditional quark model, this work investigates the beauty-charm system within a coupled-channel framework under an unquenched picture. In this approach, the beauty-charm mesons are no longer treated as traditional two-quark systems but also include components of bottomed meson–charmed meson molecular states. Using the QCD-inspired pair-creation mechanism, the authors have found that such coupling channel effect is particularly significant for higher excited states, contributing notably to the mass shifts and the strong decay widths. This property enriches our understanding of the meson structure.

The paper also explores the mixing effects among physical states with the same quantum numbers and addresses practical issues such as the experimental search for highly excited beauty-charm states which have not yet been discovered. These efforts are instrumental in establishing the beauty-charm meson family, understanding their internal structures, and shedding light on the color confinement mechanism in QCD.

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