Quantum number identification of $\Omega_c(3000)^0$ baryon

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Introduction

In the heavy-light quarks sector, many problems are still unresolved; the non-abelian character of QCD is still not understand fully in non-perturbative low-energy regime [1]. An ideal platform to understand the dynamics of QCD at low-energy is that to study the properties of hadrons containing one heavy-quark ((c) or (b)) [2, 3]. In 2017, the LHCb Collaboration observed five narrow excited Ω_c states such as $\Omega_c(3000)^0$, $\Omega_c(3050)^0$, $\Omega_c(3065)^0$, $\Omega_c(3090)^0$ and $\Omega_c(3120)^0$, in the $\Xi_c^+ K^-$ mass spectrum [6]. The Ω_c baryonic states containing one charm (c) quark and two strange (s) quarks, offers an excellent ground for testing the heavy-quark symmetry of the heavy-quark and the chiral symmetry of the light quarks [4, 5, 7, 8]. The quantum numbers of these excited Ω_c baryonic states are not assigned yet in PDG [9]. Our attempt is to assign a possible spin-parity to the recently observed $\Omega_c(3000)^0$ baryon [6, 10]. The PDG reported its world-average mass 3000.41 MeV, which is close to the theoretical predictions of $1P$-wave states obtained in various potential models [3, 7, 11, 12]. Here we want to analyze the decay $\Omega_c(3000)^0 \to \Xi_c^+ K^-$ into each possible quantum state of $1P$-wave. And, we try to compare the decay width of our calculation with the experimental value 4.5 ± 0.6 (stat) ± 0.3 (syst) MeV, measured with first statistical and second systematic uncertainties [6]. That can be used to confirm or reject the quantum number assignment of this newly observed $\Omega_c(3000)^0$ baryon.

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Phenomenological Approach: HHChPT

The strong decays of excited charmed baryons are most conveniently described by HHChPT, into which heavy-quark symmetry and chiral symmetry are incorporated [13, 14]. The partial decay widths are derived from the Lagrangian terms [8]:

$$\Gamma(\Omega_{c1}^0(1/2^-) \to \Xi_c^+ K^-) = \frac{h_4^2}{4\pi f_\pi^2} \frac{m_{\Xi_c^+}}{m_{\Omega_{c1}^0}} E_K^2 p_K, \quad (1)$$

$$\Gamma(\Omega_{c1}^0(3/2^-) \to \Xi_c^+ K^-) = \frac{h_9^2}{9\pi f_\pi^2} \frac{m_{\Xi_c^+}}{m_{\Omega_{c1}^0}} p_K^5, \quad (2)$$

Here p_K is the center-of-mass momentum of the kaon, $f_\pi = 130.2$ MeV is the pion decay constant [9], and $E_K = \frac{m^2_{\Omega_{c1}^0} - m^2_{\Xi_c^+} + m_K^2}{2m_{\Omega_{c1}^0}}$. The coupling h_4 represent the s-wave transition between S and P-wave baryons and h_9 is for the d-wave transition between S and P-wave baryons [7, 8]. The decay of $\Omega_{c1}(1/2^-, 3/2^-)$ states into $\Xi_c K$ mode is prohibited in the heavy-quark limit but could be allowed when heavy-quark symmetry is broken. At the hadronic level, the chiral symmetry breaking correction $1/m_Q$ can be crudely estimated to be of the order $p_K/m_{\Omega_c^0} \approx 0.1$ [15].

Results and Discussion

Figs. [1] and [2] shows the decay behavior of $\Omega_c(3000)^0$ baryon as $\Omega_{c1}^0(1/2^-)$ and as $\Omega_{c1}^0(3/2^-)$, respectively; calculated with the help of Eqs. [1] and [2]. From the Fig. [1], an experimental observed decay width 4.5 ± 0.6 (stat) ± 0.3 (syst) MeV of $\Omega_c(3000)^0$ is obtained with coupling $h_4^2 \approx 0.16$, which is much smaller than the predictions of Refs. [16–19]. On the other hand Figure 2 shows that the

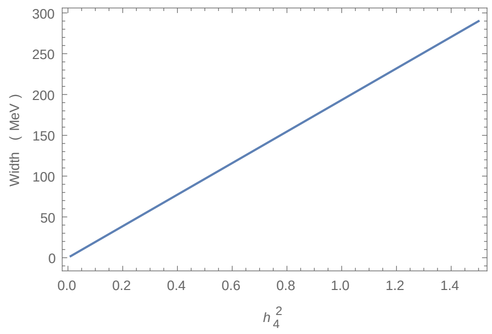

FIG. 1: The $\Omega_c(3000)^0$ as $\Omega^0_{c1}(1/2^-)$ decaying into $\Xi_c^+ K^-$, its decay widths is changing with respect to the square of the coupling h_4.

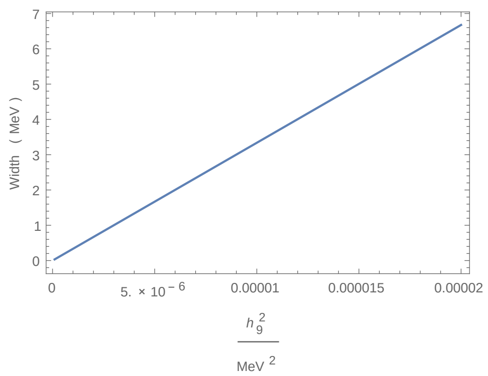

FIG. 2: The $\Omega_c(3000)^0$ as $\Omega^0_{c1}(3/2^-)$ decaying into $\Xi_c^+ K^-$, its decay widths is changing with respect to the square of the coupling h_9.

decay width is obtained with coupling $h_9^2 \approx 0.13 \times 10^{-4}$ MeV^{-2}, it is in agreement with the result $\leq 0.13 \times 10^{-4}$ MeV^{-2} of Refs. [16, 18]. Therefore, the $\Omega_c(3000)^0$ is more appropriate assigned as $\Omega^0_{c1}(3/2^-)$ quantum state rather than $\Omega^0_{c1}(1/2^-)$. We foresee to extend this scheme to analyze the strong decays of its ($\Omega_c(3000)^0$) experimentally observed sister states such as $\Omega_c(3050)^0$, $\Omega_c(3065)^0$, $\Omega_c(3090)^0$, and $\Omega_c(3120)^0$ [6, 10].

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