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Charmed Baryons in Electron–Positron Collisions

E. Solovieva[a, b, c]

[a]Moscow Institute of Physics and Technology (State University), Dolgoprudny, Moscow oblast, 141700 Russia
[b]National Research Nuclear University MEPhI, Moscow, 115409 Russia
[c]Lebedev Physical Institute, Russian Academy of Sciences, Moscow, 119991 Russia
e-mail: lena@lebedev.ru

Abstract—Charmed baryons are classified, and the experimental data on charmed-baryon states are reviewed paying special attention to those obtained at the electron–positron colliders.

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The experimental and theoretical investigation of decays of charmed baryons lags behind that of charmed mesons for which more data and a variety of theoretical models are available. Nevertheless, the results of the Belle and BaBar experiments can stimulate the development of theoretical models for the decays of charmed baryons. They can also pave the way for further investigations of charmed baryons at future superfactories.

The observed mass levels of excited baryon states with $C = 1$ and their transitions to other excited or ground states are graphically depicted in Fig. 1.

The two lowest states, $\Lambda_c(2595)^+$ and $\Lambda_c(2625)^+$, have been thoroughly investigated. Their measured masses suggest that they are orbital excitations of the Λ_c^+ baryon with the light-quarks total orbital momentum $j = 1$. The ARGUS and CLEO experiments revealed that these states decay to $\Lambda_c^+\pi^+\pi^-$ rather than to $\Lambda_c^+\pi^0$, and, therefore, have zero rather than unit isospin and belong to the Λ_c rather than Σ_c family [1]. These states are assigned the quantum numbers of $J^P = \left(\frac{1}{2}\right)^-$ and $J^P = \left(\frac{3}{2}\right)^-$, respectively.

The next two states, $\Lambda_c(2765)^+$ and $\Lambda_c(2880)^+$, were discovered by CLEO in the $\Lambda_c^+\pi^+\pi^-$ decay channel [2]. The $\Lambda_c(2880)^+$ state was also found to decay to $\Sigma_c(2445)^{++,0}\pi^{-,+}$ [3]. Subsequently, the observation of $\Lambda_c(2880)^+$ decays to D^0p was reported by BaBar [4] as the first example of a charged-baryon decay to a charmed meson and a light baryon[1]. The same BaBar analysis revealed yet another state decaying to D^0p referred to as $\Lambda_c(2940)^+$. Since no corresponding peaks were observed in the D^+p invariant-mass spectrum, $\Lambda_c(2880)^+$ and $\Lambda_c(2940)^+$ were identified as the Λ_c^+ rather than Σ_c excitations. The angular analysis performed by Belle suggested the value of $\frac{5}{2}$ for the $\Lambda_c(2880)^+$ total angular momentum [3]. The ratio between the branching fractions of $\Lambda_c(2880)^+$ decays to Σ_c states was measured by Belle as $\mathcal{B}(\Lambda_c(2880)^+ \to \Sigma_c(2520)\pi^\pm)/\mathcal{B}(\Lambda_c(2880)^+ \to \Sigma_c(2455)\pi^\pm) = (0.225 \pm 0.062 \pm 0.025)$. When combined with the theoretical predictions based on the heavy-quark symmetry [5], this measurement suggests that the $\Lambda_c(2880)^+$ parity is positive.

For the Λ_c^+ family, we still have to determine the quantum numbers of almost all states and to clarify the nature of the $\Lambda_c(2765)^+$ baryon which can be explained either by the Σ_c^+ or Λ_c^+ excitation.

The $\Sigma_c(2520)^{++,+,0}$ baryon triplet has been studied rather well. In particular, for the doubly charged and neutral members of this triplet the Belle collaboration has accurately measured the mass differences $[\Delta M(\Sigma_c) = M(\Sigma_c) - M(\Lambda_c^+)]$ as $\Delta M(\Sigma_c(2520)^{++}) = (231.99 \pm 0.10 \pm 0.02)$ MeV/c^2 and $\Delta M(\Sigma_c(2520)^0) = (231.98 \pm 0.11 \pm 0.04)$ MeV/c^2, and the total decay widths as $\Gamma(\Sigma_c(2520)^{++}) = (14.77 \pm 0.25^{+0.18}_{-0.30})$ MeV/c^2 and $\Gamma(\Sigma_c(2520)^0) = (15.41 \pm 0.41^{+0.20}_{-0.32})$ MeV/c^2, respectively [6].

The short list of experimentally observed excited Σ_c baryons ends with the $\Sigma_c(2800)$ triplet detected by

[1] Excited charmed baryons usually decay to a charmed baryon and a light meson.

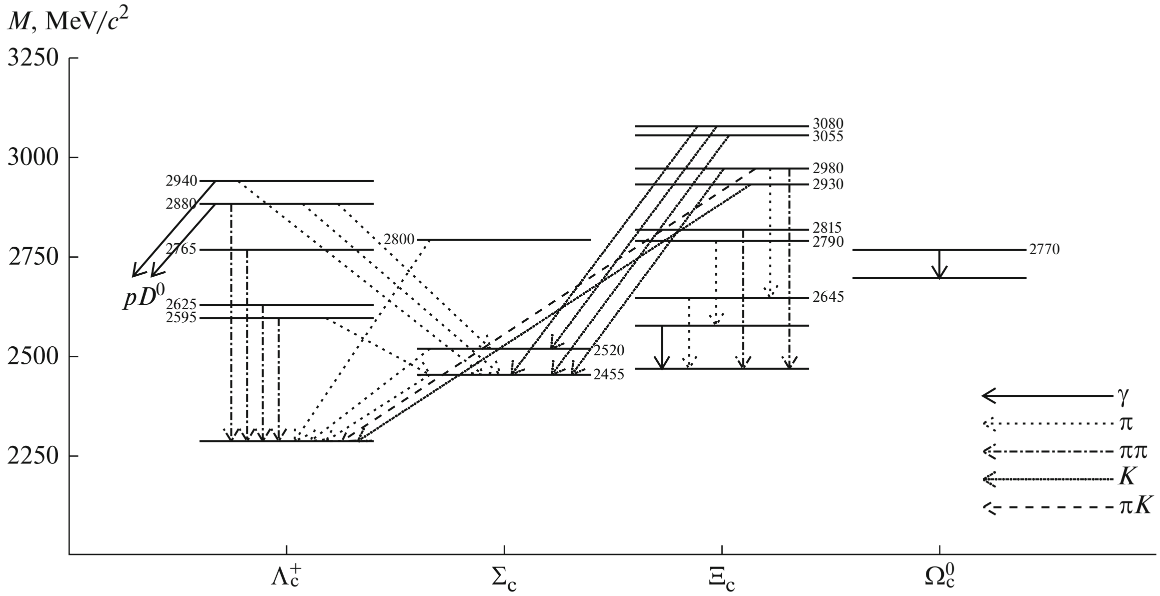

Fig. 1. Mass-level diagram for the known charmed baryon states and the transitions between them.

Belle [7]. Comparing the measured masses of these states with the theoretical predictions [8], they may be tentatively identified as the members of the predicted Σ_{c2} triplet with spin–parity of $\frac{3}{2}^{-}$. When studying the resonant structure of the decay $B^- \to \Lambda_c^+ \bar{p}\pi^-$, a significant signal was observed in the $\Lambda_c^+\pi^-$ invariant-mass spectrum in the BaBar experiment [9]. Its mean position differs from that measured by Belle by more than 3σ, but the Belle and BaBar measurements of the width are compatible within quoted errors.

Several new states with masses over 2900 MeV/c^2 decaying to $\Lambda_c^+K^-$ and $\Lambda_c^+K^{-,0}\pi^{+,-}$ have recently been added to the list of the Ξ_c excitations. Some of these were observed by both the Belle and BaBar groups, and therefore can be considered as reliably established (these include $\Xi_c(2980)^+$, $\Xi_c(3080)^{+,0}$ [10, 11], and $\Xi_c(3055)^+$ [11, 12]). All others need to be confirmed and studied more thoroughly. In particular, this applies to the $\Xi_c(2930)^0$ state detected in the $\Lambda_c^+K^-$ decay channel by BaBar [11].

The excited doubly strange charmed baryon, Ω_c^{*0}, has been observed by both BaBar [13] and Belle [14]. The Babar and Belle measurements of its decay width and of the mass difference $\Delta M(\Omega_c^{*0}) = M(\Omega_c^{*0}) - M(\Omega_c^0)$ are consistent with each other and with most theoretical predictions [15].

In summary, we wish to emphasize that the Belle and BaBar experiments have revealed the transitions between the Ξ_c and Λ_c families and the decays of highly excited Λ_c^+ states to a charmed meson and a proton.

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