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Study of Ω_c^0 and Ω_c^{*0} baryons at Belle

Belle Collaboration

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ABSTRACT

We report results from a study of the charmed double strange baryons Ω_c^0 and Ω_c^{*0} at Belle. The Ω_c^0 is reconstructed using the $\Omega_c^0 \to \Omega^-\pi^+$ decay mode, and its mass is measured to be $(2693.6 \pm 0.3^{+1.8}_{-1.5})$ MeV/c^2. The Ω_c^{*0} baryon is reconstructed in the $\Omega_c^0\gamma$ mode. The mass difference $M_{\Omega_c^{*0}} - M_{\Omega_c^0}$ is measured to be $(70.7 \pm 0.9^{+0.1}_{-0.9})$ MeV/c^2. The analysis is performed using 673 fb^{-1} of data on and near the $\Upsilon(4S)$ collected with the Belle detector at the KEKB asymmetric-energy e^+e^- collider.

1. Introduction

The experimental study of charmed baryons, including measurement of their masses, widths and decay modes, is an important test of many theoretical models that provide quantitative predictions for the properties of heavy hadrons.

Unlike the $\Lambda_c^+, \Sigma_c^{++,+,0}, \Xi_c^{+,0}$ and even their excited states, a thorough experimental study of the charmed double strange baryon Ω_c^0 is long overdue. The Ω_c^0 ($J^P = (\frac{1}{2})^+$) is the heaviest known singly charmed hadron that decays weakly. The quark content of the Ω_c^0 is $c\{ss\}$, where the ss pair is in a symmetric state. There are many theoretical models that predict the mass of the Ω_c^0. However, the range of these predictions is rather wide: 2610–2786 MeV/c^2 [1]. Among several published measurements of the Ω_c^0 mass only three report a statistically significant signal: E687 obtains $(2699.9 \pm 1.5 \pm 2.5)$ MeV/c^2 in the $\Omega_c^0 \to \Sigma^+K^-K^-\pi^+$ channel [2], using five decay modes CLEO reports $(2694.6 \pm 2.6 \pm 1.9)$ MeV/c^2 [3], BaBar quotes (2693.3 ± 0.6) MeV/c^2 in their analysis of $\Omega_c^{*0} \to \Omega_c^0\gamma$ [4]. The world-average value of the Ω_c^0 mass is (2697.5 ± 2.6) MeV/c^2 [5].

The decay mode $\Omega_c^0 \to \Omega^-\pi^+$ was observed for the first time by E687 [6]. They reported 10.3 ± 3.9 events over the background of 5.8 events. With 13.7 fb^{-1} of data CLEO also found a signal of 13.3 ± 4.1 events in this channel [3]. FOCUS observes 23 ± 7 events of this decay mode [7]. With a data sample of 230.7 fb^{-1} BaBar reports a raw signal of 156 ± 15 events [4].

The spin excited $J^P = (\frac{3}{2})^+$ Ω_c^{*0} state was observed by BaBar only recently [4]. They measured the difference between the masses of the Ω_c^{*0} and Ω_c^0 to be $(70.8 \pm 1.0 \pm 1.1)$ MeV/c^2. Different QCD-based models yield a rather wide range of predictions for the mass difference, from 50 MeV/c^2 to 70 MeV/c^2 [8]. A lattice QCD calculation finds the value (94 ± 10) MeV/c^2 [9].

In this work we present our results on the measurement of the Ω_c^0 mass using the decay $\Omega_c^0 \to \Omega^-\pi^+$.[1] We also confirm the recent BaBar observation of $\Omega_c^{*0} \to \Omega_c^0\gamma$ [4].

2. Data and selection criteria

The data used for this analysis were taken on the $\Upsilon(4S)$ resonance and in the nearby continuum using the Belle detector at the e^+e^- asymmetric-energy collider KEKB [10]. The integrated luminosity of the sample is equal to 605 fb^{-1} of on-resonance data and 68 fb^{-1} of data below the $\Upsilon(4S)$.

Belle is a general-purpose detector based on a 1.5 T superconducting solenoid; a detailed description can be found elsewhere [11]. Tracking is performed by a silicon vertex detector (SVD) composed of concentric layers of double-sided silicon strip detectors, and a 50 layer drift chamber (CDC). Particle identification for charged hadrons, important for the measurement of final states with kaons and/or protons, is based on the combination of energy loss measurements (dE/dx) in the drift chamber, time-of-flight measurements (TOF) and aerogel Cherenkov counter (ACC) information. For each charged particle, measurements from these three subdetectors are combined to form likelihood ratios in the range from 0 to 1,

$$P(A/B) = \mathcal{L}(A)/\big(\mathcal{L}(A) + \mathcal{L}(B)\big),$$

where $\mathcal{L}(A)$ and $\mathcal{L}(B)$ are the likelihood values assigned to the K, π or p identification hypothesis for a given track. From now on we use these likelihood ratios to identify protons, charged kaons and pions with criteria that have efficiencies greater than 85% for $p/K/\pi$. The probability for each particle species to be misidentified as one of the other two is less than 12%.

An electromagnetic calorimeter (ECL) is used to detect photons, which are reconstructed from isolated ECL clusters that have no corresponding charged track, and a shower shape that is consistent with that of a photon.

Λ hyperons are reconstructed in the $\Lambda \to p\pi^-$ decay mode, fitting the p and π tracks to a common vertex and requiring an invariant mass in a ± 4 MeV/c^2 ($\approx 4\sigma$) interval around the nominal Λ mass value [5]. We then apply the following cuts on the Λ decay vertex:

- the difference Δz_Λ in the z-coordinate between the proton and pion at the decay vertex should satisfy $\Delta z_\Lambda < 2$ cm, where the z-axis is parallel to the e^+ beam direction;
- the distance between the vertex position and interaction point (IP) in the plane transverse to the beam direction (Δr_Λ^{xy}) should be greater than 0.5 cm;
- the angle β_Λ, between the Λ momentum vector and the vector pointing from the IP to the Λ decay vertex, should satisfy $\cos\beta_\Lambda > 0.0$;
- the vertex fit should have an acceptable χ^2.

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[1] Charge-conjugate modes are implicitly included throughout this Letter.