PROCEEDINGS OF SCIENCE

Study of spin-parity of the $\Lambda_c(2765)^+$

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The $\Lambda(1405)$ resonance is difficult to describe in terms of an ordinary three quark state. One promising explanation is that $\Lambda(1405)$ actually consists of two poles which couple to the $\bar{K}$N and $\pi\Sigma$ channel, respectively This overlap might be separated in charm sector so that we can actually find two states, since mass difference between $\pi\Sigma_c$ and DN is larger than in the strange sector. $\Lambda_c(2593)^+$ has the same spin-parity as the $\Lambda(1405)$, and can be considered as the $\pi\Sigma_c$ resonance. A corresponding DN bound state candidate is the $\Lambda_c(2765)^+$, whose spin-parity is yet unknown.

We use the Belle experiment full data to assign spin and parity of the $\Lambda_c(2765)^+$. For the verification of our analysis method, we studied the decay of the $\Lambda_c(2880)^+$ for the cross check that its spin is assgied to 5/2. The analysis result is consistent with previous study, the study of spin, parity and isospin of $\Lambda_c(2765)^+$ is on progress.

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1. Introduction

The $\Lambda(1405)$ is a negative parity baryon with one-half spin and zero isospin. Its discovery [1] in 1961 spurred great interest in the theoretical and experimental community due the difficulty to explain it within the ordinary three-quark model. One hypothesis is the chiral dynamics [2] according to which the $\Lambda(1405)$ resonance is the overlap of two poles, one of which mostly couples to $\bar{K}$N and the other to $\pi\Sigma$. We expect that this overlap could be separated in the charm sector because the mass difference between $\pi\Sigma_c$ and DN is larger than in the strange sector.

A few candidates of the separated states have been discovered [3]. $\Lambda_c(2593)^+$ has the same spin-parity as the $\Lambda(1405)$, and can be considered as a $\pi\Sigma_c$ resonance. A corresponding DN bound state candidate is the $\Lambda_c(2765)^+$, whose quantum number is yet unknown. To assigned the spin of the $\Lambda_c(2765)^+$, we need to study the angular distribution fo $\Lambda_c(2765)^+ \to \Sigma_c(2455)\pi$ decay. We studied the angular distrituion of $\Lambda_c(2880)^+ \to \Sigma_c(2455)\pi$ decay since the spin of the $\Lambda_c(2880)^+$ is assigned to 5/2 so that we can check the verification of the analysis method.

2. KEKB and BELLE

The data were collected with the Belle [4] detector at the KEKB [5] asymmetric energy e^+e^- storage ring. The Belle detector is a large-solid-angle magnetic spectrometer that consists of a silicon vertex detector (SVD), a 50-layer cylindrical drift chamber (CDC), an array of aerogel threshold Cherenkov counter (ACC), a barrel-like array of time-of-flight scintillation counters (TOF), an array of CsI(TI) crystals (ECL), and a superconducting solenoidal coil that contains every detectors and produces 1.5T magnetic field.

3. Event Selection Criteria and Reconstruction

In this analysis, we used the full data set that corresponds to an integrated luminosity of 980 fb^{-1} at $\Upsilon(1\text{-}5S)$ resonances and nearby continuum energies. Charged hadron candidates are required to originate from the interaction point(IP). For charged hadron identification (PID), the likelihood information from the dE/dx in the CDC, the time of flight and the cherenkov light yield information in ACC were used.

The Λ_c^+ baryons are reconstructed using the $\Lambda_c^+ \to pK^+\pi^-$ channel. The invariant mass of $\Lambda_c^+ \to pK^+\pi^-$ combination is required to be within $\pm$ 8MeV/c^2 (1.6σ) of the mass of Λ_c^+. We perform a mass constraint fit to the $pK^+\pi^-$ vertex to improve Λ_c^+ momentum measurement. Then Λ_c^+ candidates are combined with the remaining $\pi^+\pi^-$ to reconstruct $\Lambda_c(2765)^+$. To reduce the combinational background in $\Lambda_c^+\pi^+\pi^-$ reconstruction, the scaled momentum was required to be higher than 0.7 where scaled momentum is defined as $x_p = p^*/p_{\max}$ with p^* being the momentum of the $\Lambda_c(2765)^+$ candidate, $p_{\max} = \sqrt{E_{beam}^2 - M^2}$, E_{beam} being the beam energy in the center of mass frame and M being the mass of $\Lambda_c(2765)^+$ candidate. There are intermediate states $\Sigma_c(2455)^{++/0}$ and $\Sigma_c(2520)^{++/0}$ states that are visible in the $\Lambda_c^+\pi^{+/-}$ mass spectrum. The signal region for $\Sigma_c(2455)$ is defined as $|$M($\Lambda_c^+\pi$) - M($\Sigma_c(2455)$)$|$ < $5MeV/c^2$. The reconstructed $\Lambda_c^+\pi^+\pi^-$ mass histogram is shown in Fig. 1.

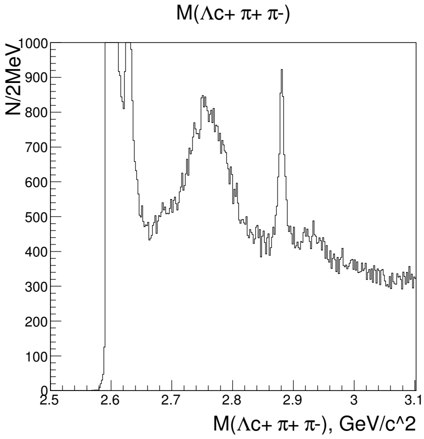

Figure 1: $M(\Lambda_c^+\pi^+\pi^-)$ with $\Sigma_c(2455)$ signal region.

A unbinned extended maximum likelihood fit is performed to get the yield, mass and width of the signals. For each signal, a Gaussian convoluted Breit-Wiegner probability distribution function was used. The gaussian is for the detector resolution which is from Monte Carlo simulation. The the width of the gaussian describes The detector resolution, which we estimated from Monte-Carlo simulations. For the background, a third order polynomial was used. We got 24,254 signal yield of $\Lambda_c(2765)^+$, 3,479 signal yield of $\Lambda_c(2880)^+$.

4. Decay angle analysis - cross check

We studied the angular distribution of decay $\Lambda_c(2765)^+ \to \Sigma_c(2455)\pi$ to determine the spin of $\Lambda_c(2765)^+$. The decay angle θ was defined as the angle between two vectors, the $\Lambda_c(2765)^+$ momentum vector in the beam center of mass frame and the π momentum vector in the $\Lambda_c(2765)^+$ rest frame. The θ distribution with spin 1/2, 3/2, 5/2 hypotheses are shown below.[7]

$$W_{1/2} = constant \tag{4.1}$$

$$W_{3/2} = 3/4[\rho_{33} sin^2\theta + \rho_{11}(1/3 + cos^2\theta)] \tag{4.2}$$

$$\begin{aligned} W_{5/2} = \; & 3/16[\rho_{55}5(1-cos^2\theta)^2 + \rho_{33}(-15cos^4\theta + 14cos^2\theta + 1) \\ & + \rho_{11}2(5cos^4\theta - 2cos^2\theta + 1)] \end{aligned} \tag{4.3}$$

where ρ_{ii} normalization is given by $\sum_{i>0} \rho_{ii} = 1/2$.

The study of decay of $\Lambda_c(2880)^+$ is useful because the spin of $\Lambda_c(2880)^+$ is assigned to 5/2, and can be studied using the same method with $\Lambda_c(2765)^+$. We studied the angular distribution study of $\Lambda_c(2880)^+ \to \Sigma_c(2455)\pi$ with our data set for the cross theck. We defined ρ_{11} as $1/2 - \rho_{33} - \rho_{55}$ and set ρ_{33} and ρ_{55} as fitting parameters in spin 5/2 hypothesis. The fitting results are shown in Table. 1. The result is consistent with the previous result, fitting parameter lies in the range of previous result within uncertainty, and statistical uncertainties are smaller or similar than previous result. We are sure that our analysis method is right and we can apply it to the $\Lambda_c(2765)^+$ decay angle analysis, the study of spin of $\Lambda_c(2765)^+$ is on progress.

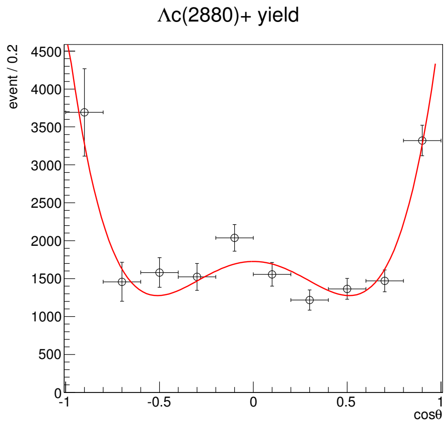

Figure 2: $\Lambda_c(2880)^+$ $\cos\theta$ distribution with spin hypothesis 5/2 fit.

	statistics	chi2/ndf	prob	ρ_{11}	ρ_{33}	ρ_{55}
Previous	553 fb^{-1}	12.2/7	0.094	0.41±0.04	0.00±0.03	0.088±0.024
Cross check	980 fb^{-1}	13.3/7	0.065	0.43±0.04	0.00±0.03	0.071±0.015

Table 1: Fitting result of $\Lambda_c(2880)^+$ decay angle θ distribution. The error is the statistical error.

5. Summary & Prospect

In this paper we reconstructed the $\Lambda_c^+\pi^+\pi^-$ mass spectrum and confirm the peak of $\Lambda_c(2765)^+$. We've got 24254 signal yield of $\Lambda_c(2765)^+$, 3479 signal yield of $\Lambda_c(2880)^+$. The decay angle analysis of $\Lambda_c(2880)^+ \to \Sigma_c(2455)\pi$ is performed for cross check and the result agrees with the previous study. $\Lambda_c(2765)^+ \to \Sigma_c(2455)\pi$ decay angle analysis, the study of parity and isospin are in progress.

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