Hadronic Charm Decays at BESIII

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The BESIII experiment at the Beijing Electron Positron Collider (BEPCII) has accumulated the world’s largest samples of $e^+e^-$ collisions in the tau-charm region. Based on the threshold open charm data samples of $D_{(s)}$ and $\Lambda^+_c$, we can study the hadronic charm decays under a uniquely clean background. Many important results have been achieved with much-improved precision or for the first time. In this paper, we will review some recent results on the hadronic charm decays. Finally, a summary will be given.
1. Introduction

Except for a single tag (ST) technique used in Sec. 2.6, all other items use a double tag (DT) technique to perform event selection. DT means reconstructing both \(D_s^+ (\Lambda_c^+)\) and \(D_s^- (\Lambda_c^-)\), while ST means reconstructing only one \(D_s^+ (\Lambda_c^+)\) or \(D_s^- (\Lambda_c^-)\). DT technique provides a clean environment with no additional hadron and also provides access to absolute branching fractions (BFs). ST technique can achieve more data yields.

Besides, the variable Missing-mass-squared \((MM^2)\) mentioned below are defined here. \(MM^2 = (P_{e^+e^-} - P_{D_s^+} - P_\gamma - P_{K^{+}})^2\), where \(P_{e^+e^-}\) is the four-momentum of the \(e^+e^-\) initial state and \(P_i (i = D_s^-, \gamma, K^+)\) is the four-momentum of the corresponding particle.

2. Hadronic Charm Decays

There are seven analyses listed below. The first four items are about \(D_s\) decays, which is based on 3.19 fb\(^{-1}\) data set accumulated at \(E_{cm} = 4.18\) GeV by BESIII detector in 2016. And the rest three items are about \(\Lambda_c\) decays, which is based on 567\(pb^{-1}\) data sample taken at \(E_{cm} = 4.6\) GeV with the BESIII detector from February to March of 2014.

2.1 \(D_s^+ \rightarrow \omega \pi^+ / K^+\)

This is a pure \(W\) annihilation process, which is sensitive to direct CP violation. We obtain 65.0 \(\pm\) 11.6 \(D_s^+ \rightarrow \omega \pi^+\) signal events and 28.5 \(\pm\) 7.8 \(D_s^+ \rightarrow \omega K^+\) signal events with statistical significances of 6.7\(\sigma\) and 4.4\(\sigma\), respectively. The BF of \(D_s^+ \rightarrow \omega \pi^+\) is \(\mathcal{B}_{D_s^+ \rightarrow \omega \pi^+} = (1.77 \pm 0.32_{\text{stat}} \pm 0.13_{\text{sys}}) \times 10^{-3}\) which is consistent with CLEO’s measurement \([1]\), but more precise. The BF of \(D_s^+ \rightarrow \omega K^+\) is \(\mathcal{B}_{D_s^+ \rightarrow \omega K^+} = (1.77 \pm 0.32_{\text{stat}} \pm 0.13_{\text{sys}}) \times 10^{-3}\) which is the first evidence \([2]\).

2.2 \(D_s^+ \rightarrow p\bar{n}\)

This is the only kinematically allowed hadronic decay involving baryons. The short-distance contribution is expected to be small: BF \(\sim 10^{-6}\), due to the chiral suppression by a factor of \((m_\pi/m_{D_s})^4\). But long-distance effects can enhance the BF to a level of \(10^{-3}\) \([3]\). We obtain 193 \(\pm\) 17 \(D_s^+ \rightarrow p\bar{n}\) signal events. And the absolute BF is \(\mathcal{B}_{D_s^+ \rightarrow p\bar{n}} = (1.21 \pm 0.10_{\text{stat}} \pm 0.05_{\text{sys}}) \times 10^{-3}\) \([4]\). The first evidence was reported by CLEO with a signal of 13.0 \(\pm\) 3.6 events with BF \(\mathcal{B}_{D_s^+ \rightarrow p\bar{n}} = (1.30 \pm 0.36 \pm 0.12_{0.16}) \times 10^{-3}\) \([5]\).

2.3 \(D_s^+ \rightarrow K_s^0 K^+\) and \(K_L^0 K^+\)

The interference of the decay amplitudes of the Cabibbo-favored (CF) transition \(D \rightarrow K_0^0 K\) and the doubly-Cabibbo-suppressed (DCS) transition \(D \rightarrow K^0 L\) can result in a measurable \(K_s^0 - K_L^0\) asymmetry. Additionally, as pointed out in Ref. \([6]\), the interference between CF and DCS amplitudes can also lead to a new CP violation effect, which is estimated to be an order of 10\(^{-3}\).

The 2D fit for \(D_s^+ \rightarrow K_s^0 K^+\) gives a signal yield of 1782 \(\pm\) 47. And the projections of \(M_{K_s^0 K^+}\) with the fit results superimposed are shown in Fig. 1(a,b). The fit to the \(MM^2\) distribution is shown in Fig. 1(c). And the signal yield determined by the fit is 2349 \(\pm\) 61 events. The absolute BFs results
are $\mathcal{B}_{D_s^+\to K_S^0 K^+} = (1.425 \pm 0.038 \pm 0.031)\%$ and $\mathcal{B}_{D_s^+\to K_0^0 K^+} = (1.485 \pm 0.039 \pm 0.046)\%$. The branching fraction of $D_s^+ \to K_S^0 K^+$ is compatible with the world average and that of $D_s^+ \to K_0^0 K^+$ is measured for the first time. We also measure the direct CP asymmetries of $D_s^+ \to K_S^0 K^+$ and $D_s^+ \to K_0^0 K^+$. Moreover, we present the first measurement of the $K_S^0 - K_0^0$ asymmetry in the decays $D_s^+ \to K_S^0 K^+$. The results are all consistent with zero [7].

2.4 Amplitude analysis of $D_s^+ \to \pi^+ \pi^0 \eta$

We retain a sample of 1239 $D_s^+ \to \pi^+ \pi^0 \eta$ candidates that has a purity of $(97.7 \pm 0.5)\%$. We observe for the first time the pure W-annihilation decays $D_s^+ \to (a_0(980))^0 \pi^0$ and $D_s^+ \to a_0(980)^0 \pi^+$. We measure the absolute BFs $\mathcal{B}_{D_s^+\to a_0(980)^0 \pi^0}, \mathcal{B}_{a_0(980)^0 \pi^0 \to \pi^+ \pi^0 \eta} = (1.46 \pm 0.15 \pm 0.23)\%$, which is larger than the BFs of other measured pure W-annihilation decays by at least one order of magnitude [8]. The fit projections are shown in Fig. 2.

2.5 $\Lambda_c^+ \to \Lambda X$

We measure the absolute BF of the inclusive decay of $\Lambda_c^+ \to \Lambda X$ to be $\mathcal{B}_{\Lambda_c^+\to \Lambda X} = (38.2^{+2.8}_{-2.2} \pm 0.6)\%$ using the double tag method. Also, we search for direct CP violation in the charge asymmetry of this inclusive decay for the first time. The result is consistent with zero [9].
2.6 \( \Lambda_c^+ \to \Lambda \eta \pi^+ \) and \( \Lambda_c^+ \to \Sigma(1385)^+ \eta \)

We obtain \( 154 \pm 17 \Lambda_c^+ \to \Lambda \eta \pi^+ \) events and \( 54 \pm 11 \Lambda_c^+ \to \Sigma(1385)^+ \eta \) events with a ST technique. And the BFs are measured to be \( \mathcal{B}_{\Lambda_c^+ \to \Lambda \eta \pi^+} = (1.84 \pm 0.21 \pm 0.15)\% \) and \( \mathcal{B}_{\Lambda_c^+ \to \Sigma(1385)^+ \eta} = (0.91 \pm 0.18 \pm 0.09)\% \), constituting the most precise measurements to date [10].

2.7 \( \Lambda_c^+ \to \Sigma^+ \eta / \eta' \)

They are CF decays, which proceed through non-factorizable internal W-mission. We find evidence for the decays \( \Lambda_c^+ \to \Sigma^+ \eta \) and \( \Lambda_c^+ \to \Sigma^+ \eta' \) with statistical significance of 2.5\( \sigma \) and 3.2\( \sigma \), respectively. Using BESIII measurements of the BFs of the reference decays, we determine \( \mathcal{B}_{\Lambda_c^+ \to \Sigma^+ \eta} = (0.41 \pm 0.19 \pm 0.05)\% (< 0.68\% \text{ at 90\% C.L.}) \) and \( \mathcal{B}_{\Lambda_c^+ \to \Sigma^+ \eta'} = (1.34 \pm 0.53 \pm 0.19)\% (< 1.9\% \text{ at 90\% C.L.}) \). The BF of \( \Lambda_c^+ \to \Sigma^+ \eta \) is consistent with the previous measurement, and the BF of \( \Lambda_c^+ \to \Sigma^+ \eta' \) is measured for the first time [11].

3. Summary

Our results include new measurements, have confirmed and improved the precisions over the previous results. We are planning to take more data at/near \( E_{cm} = 4.6 \text{GeV} \) as well as \( E_{cm} = 3.773 \text{GeV} \) soon, which will allow us to even improve further precisions and rare forbidden searches in \( D(s)/\Lambda_c \) decays. More measurements in \( D(s)/\Lambda_c \) hadronic decays are coming.

References