PROCEEDINGS OF SCIENCE

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 Λ_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.

XXIX International Symposium on Lepton Photon Interactions at High Energies - LeptonPhoton2019
August 5-10, 2019
Toronto, Canada

*Speaker.

†I would like to thank for the support by the National Natural Science Foundation of China (Grants No. 11575094).

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PoS(LeptonPhoton2019)178

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^+ (Λ_c^+) and D_s^- (Λ_c^-), while ST means reconstructing only one D_s^+ (Λ_c^+) or D_s^- (Λ_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 Λ_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 $D_s^+ \to \omega\pi^+/K^+$

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

2.2 $D_s^+ \to p\bar{n}$

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 ± 17 $D_s^+ \to p\bar{n}$ signal events. And the absolute BF is $\mathscr{B}_{D_s^+\to p\bar{n}} = (1.21 \pm 0.10_{stat.} \pm 0.05_{sys.}) \times 10^{-3}$ [4]. The first evidence was reported by CLEO with a signal of 13.0 ± 3.6 events with BF $\mathscr{B}_{D_s^+\to p\bar{n}} = (1.30 \pm 0.36 \pm^{0.12}_{0.16}) \times 10^{-3}$ [5].

2.3 $D_s^+ \to K_S^0 K^+$ and $K_L^0 K^+$

The interference of the decay amplitudes of the Cabibbo-favored (CF) transition $D \to \bar{K}^0 K$ and the doubly-Cabibbo-suppressed (DCS) transition $D \to K^0 K$ 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 $D_s^+ \to K_S^0 K^+$ gives a signal yield of 1782 ± 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 ± 61 events. The absolute BFs results are $\mathscr{B}_{D_s^+\to K_S^0K^+} = (1.425\pm0.038\pm0.031)\%$ and $\mathscr{B}_{D_s^+\to K_L^0K^+} = (1.485\pm0.039\pm0.046)\%$. The branching fraction of $D_s^+ \to K_S^0K^+$ is compatible with the world average and that of $D_s^+ \to K_L^0K^+$ is measured for the first time.

We also measure the direct CP asymmetries of $D_s^\pm \to K_S^0K^\pm$ and $D_s^\pm \to K_L^0K^\pm$. Moreover, we present the first measurement of the $K_S^0 - K_L^0$ asymmetry in the decays $D_s^+ \to K_{S,L}^0K^+$. The results are all consistent with zero [7].

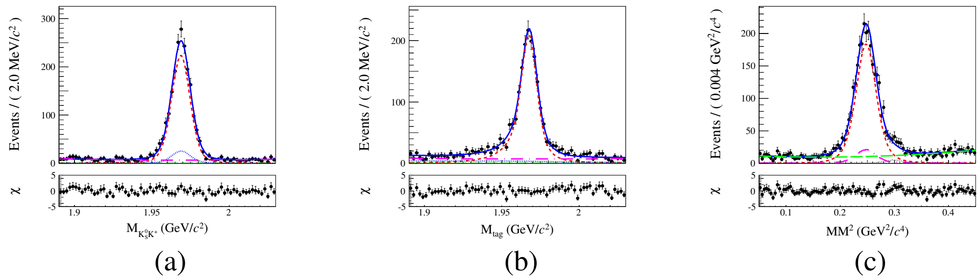

Figure 1: Distributions of $M_{K_S^0K^+}$ (a), M_{tag} (b), and MM^2 (c), with the fit result superimposed. The data are shown as the dots with error bars, the blue solid line is the total fit result, the red short-dashed line is the signal component of the fit. The green long-dashed line, the blue dotted line and the magenta dotted-dashed line in (a) and (b) are the three background components mentioned in [7]. The magenta dotted-dashed line, the grey dotted line and the green long-dashed line in (c) are the component of the peaking background from $D_s^+ \to K_S^0K^+$ decays, $D_s^+ \to \eta K^+$ decays, and non-peaking background component, respectively. The residual χ between the data and the total fit result, normalized by the uncertainty, is shown beneath the figures.

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 $(97.7\pm0.5)\%$. We observe for the first time the pure W-annihilation decays $D_s^+ \to a_0(980)^+\pi^0$ and $D_s^+ \to a_0(980)^0\pi^+$. We measure the absolute BFs $\mathscr{B}_{D_s^+\to a_0(980)^{+(0)}\pi^{0(+)},a_0(980)^{+(0)}\to\pi^{+(0)}\eta} = (1.46\pm0.15\pm0.23)\%$, 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.

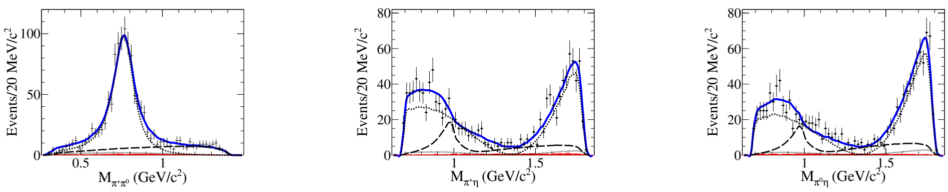

Figure 2: The dots with error bars and the solid line are data and the total fit, respectively. The dashed, dotted, and long-dashed lines are the contributions from $D_s^+ \to \rho^+\eta$, $D_s^+ \to (\pi^+\pi^0)_V\eta$, and $D_s^+ \to a_0(980)\pi$, respectively.

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

We measure the absolute BF of the inclusive decay of $\Lambda_c^+ \to \Lambda X$ to be $\mathscr{B}_{\Lambda_c^+\to\Lambda X} = (38.2\pm^{2.8}_{2.2}$ $\pm0.6)\%$ 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 ± 17 $\Lambda_c^+ \to \Lambda\eta\pi^+$ events and 54 ± 11 $\Lambda_c^+ \to \Sigma(1385)^+\eta$ events with a ST technique. And the BFs are measured to be $\mathscr{B}_{\Lambda_c^+\to\Lambda\eta\pi^+} = (1.84\pm0.21\pm0.15)\%$ and $\mathscr{B}_{\Lambda_c^+\to\Sigma(1385)^+\eta} = (0.91\pm0.18\pm0.09)\%$, 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 2.5σ and 3.2σ, respectively. Using BESIII measurements of the BFs of the reference decays, we determine $\mathscr{B}_{\Lambda_c^+\to\Sigma^+\eta} = (0.41\pm0.19\pm0.05)\%(<0.68\%$ at 90% C.L.) and $\mathscr{B}_{\Lambda_c^+\to\Sigma^+\eta'} = (1.34\pm0.53\pm0.19)\%(<1.9\%$ 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 $E_{cm} = 4.6$GeV as well as $E_{cm} = 3.773$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.

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