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Hadronic Decays of the D/D_s Mesons

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Abstract. Recent results on the measurement, by the CLEO-c collaboration, of the hadronic decays of the D^0, D^+ and D_s are presented.

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1.Introduction

The D_s^+ meson, consisting of a c and anti s quark, is the least extensively studied of the ground state charmed mesons. Recent results from CLEO include measurements of a large number of hadronic exclusive decays and also the inclusive hadronic yields from D_s^+ decay. This together with results on semileptonic and leptonic decays provides a detailed overview of D_s^+ decays. The data comes from an integrated luminosity of 586pb^{-1} collected near the $D^{*}{}_s^+$ D_s^- peak production at an energy of Ecm = 4170 MeV by the CLEO-c detector. The analysis employs a double-tagging technique by first fully reconstructing a D_s^- in one of the three two-body hadronic decay modes: $D_s^- \to K^0_S K^-$, $D_s^- \to \varphi\pi^-$ and $D_s^- \to K^{*0}K^-$. (Mention of a specific mode implies the use of the charge conjugate mode)The tagged D_s^- candidate can be either the primary D_s^- or the secondary D_s^- from the decay $D^{*}{}_s^- \to \gamma D_s^-$. In addition a photon is required in the event. The reconstructed invariant mass of the D_s candidate, $M(D_s)$, the recoil mass recoiling against the D_s candidate and the recoil mass $M(D_s\gamma)$ are then used to select D_s^+ decays.

1.1 Inclusive Hadron Yields from D_s Decays

The decays of the D_s^+ selected as described previously are used to measure the inclusive yields[1] of D_s^+ decays to K^+X, K^-X, $K^0_S X$, π^+X, π^-X, π^0X, ηX, $\eta' X$, φX, ωX and $f^0(980)X$. In addition the inclusive yields of D_s^+ mesons into two kaons is measured by searching for the best kaon pair, based on particle identification likelihood or K^0_S mass,per mode recoiling against the tag. The kaon pair modes are $K^0_S K^0_S$, $K^0_S K^+$,$K^0_S K^-$, K^+K^-, K^+K^+ or K^-K^-.
Using the measurements of inclusive decays a conservative lower bound is set on production of final states by annihilation. After subtracting the production of $\mu\nu$ and $\tau\nu$ the result for B(Other Annihilation) is 13.3±3.0%, i.e., > 9.5% at 90% C.L.

1.2 D_s^+ Exclusive Decays Involving ω

The inclusive ω yield measured in the inclusive analysis, $D_s^+ \to \omega X$, is substantial (6.1± 1.4)% [1]. This is very surprising since the ω does not have a significant s anti s component. The study of ω production in D_s^+ decays is, therefore, of interest in shedding light on mechanisms of weak decay and their interplay with long distance(nonperturbative) physics . An analysis of D_s^+ exclusive hadronic decays involving an ω has been performed[2]. in final states with one, two, and three pions: $D_s^+ \to \pi^+\omega$, $D_s^+ \to \pi^+\pi^0\omega$, and $D_s^+ \to \pi^+\pi^+\pi^-\omega$ and also searching for $D_s^+ \to \pi^+\eta\omega$ and $D_s^+ \to K^+\omega$, $D_s^+ \to K^+\pi^0\omega$, $D_s^+ \to K^+\pi^+\pi^-\omega$, and $D_s^+ \to K^+\eta\omega$. These last four modes are Cabibbo-suppressed. The final results are $B(D_s^+ \to \pi^+\omega) = (0.21 \pm 0.09 \pm 0.01)\%$, $B(D_s^+ \to \pi^+\pi^0\omega) = (2.78 \pm 0.65 \pm 0.25)\%$, $B(D_s^+ \to \pi^+\pi^+\pi^-\omega) = (1.58 \pm 0.45 \pm 0.09)\%$, $B(D_s^+ \to \pi^+\eta\omega) = (0.85 \pm 0.54 \pm 0.06)\%$, $B(D_s^+ \to K^+\omega) < 0.24\%$, $B(D_s^+ \to K^+\pi^0\omega) < 0.82\%$, $B(D_s^+ \to K^+\pi^+\pi^-\omega) < 0.54\%$, and $B(D_s^+ \to K^+\eta\omega) < 0.79\%$. The upper limits are at 90% confidence level. This is the first observations of $D_s^+ \to \pi^+\pi^0\omega$ and $D_s^+ \to \pi^+\pi^+\pi^-\omega$ decays and evidence for the $D_s^+ \to \pi^+\eta\omega$ decay and the first upper limits on $D_s^+ \to K^+\omega$, $D^+_s \to K^+\pi^0\omega$, $D_s^+ \to K^+\pi^+\pi^-\omega$, and $D_s^+ \to K^+\eta\omega$ decays.. The sum of branching fractions of the four observed modes is (5.4±1.0)%, which accounts for most of the D_s inclusive ω decays of (6.1±1.4)% .

1.3 Measurements of D Meson Decays to Two Pseudoscalar Mesons

Continuing the analysis of D_s decays CLEO has measured the decays to two pseudoscalar mesons, $D_s \rightarrow$ PP modes and also using an 818pb^{-1} data sample taken at E_{cm} =3774 MeV measured D^0 and D^+ decays to two pseudoscalar mesons, $D \rightarrow$ PP modes. There are many possible exclusive decays of charmed D mesons to a pair of mesons from the lowest-lying pseudoscalar meson nonet. The decay can be to any pair of K^+, K^-, π^+, π^-, η, η', π^0, K^0, or anti K^0, with total charge 0 or ±1. Measurements of the complete set of decays can be used to test flavor topology and SU(3) predictions and to specify strong phases of decay amplitudes through triangle relations . Moreover, many CP asymmetries (expected to be less than $O(10^{-3})$ in the Standard Model) can be studied. The detectable neutral kaons are K^0_S and K^0_L so the observable decays are XK^0_S and XK^0_L. The Standard Model predicts that direct CP violation in D decays, e.g., a difference in the branching fractions for $D_s^+ \rightarrow K^+\eta$ and $D_s^- \rightarrow K^-\eta$, will be vanishingly small. The measurements measure or set upper limits on all branching fractions for Cabibbo-favored, singly-Cabibbo suppressed,and doubly-Cabibbo-suppressed D $\rightarrow$ PP decays, except modes involving K^0_L (and except $D^0 \rightarrow K^+\pi^-$). The results are normalized to the Cabibbo-favored D modes, $D^0 \rightarrow K^-\pi^+$, $D^+ \rightarrow K^-\pi^+\pi^+$, and $D^+_s \rightarrow K^+K^0_S$.Using the separate yields and efficiencies the asymmetries $A_{CP} = (B^+ - B^-)/(B^+ + B^-)$, which are sensitive to direct CP violation in D decays are calculated. All systematic uncertainties cancel in this ratio, with the exception of charged pion and kaon tracking and particle identification efficiencies. For D^0 vs. anti D^0, the only asymmetry measured is $K^-\pi^+$ vs. $K^+\pi^-$. That difference contains a component from the difference in the doubly-Cabibbo-suppressed decays $D^0 \rightarrow K^+\pi^-$ vs. anti $D^0 \rightarrow K^-\pi^+$ which is not subtracted.

1.4 Dalitz Plot Analysis of $D_s^+ \rightarrow K^+K^-\pi^+$

Dalitz plot analysis of the decay $D_s^+ \rightarrow K^+K^-\pi^+$ has been carried out by the CLEO collaboration[4] with 14400 candidates with a background of roughly 15%. The decay $D_s^+ \rightarrow K^+K^-\pi^+$ is among the largest known branching fractions for the D_s
meson. For some time the mode $D_s^+ \rightarrow \varphi(1020)\pi^+$ was used as the normalizing mode for D_s decay branching fractions, typically done by choosing events with the K^+K^- invariant mass near the narrow $\varphi(1020)$ peak. Observation of a large contribution from $D_s^+ \rightarrow f^0(980)\pi^+$ makes the selection of $D_s^+ \rightarrow \varphi(1020)\pi^+$ dependent on the range of K^+K^- invariant mass chosen; the observed yield of non-φ contributions can be larger than 10% which is an unacceptably large uncertainty for a normalizing mode. Therefore, what is required is a detailed analysis of the resonance contributions to the final state. The only Dalitz plot analysis [5] was published by E687 using 701 signal events. The CLEO-c analysis has much higher precision with over 12,000 signal events. The CLEO-c results are compared with the previous measurement from E687 using the isobar model and good agreement is found with the E687 parameters, however, the fit quality is significantly improved if an $f^0(1370)\pi^+$ contribution is included. The final fit with a $\chi^2/\nu = 178/117$ gives the magnitude, phase, and fit fraction of $K^*(892)^0K^+$, $\varphi(1020)\pi^+$, $K^{*0}(1430)K^+$, $f^0(980)\pi^+$, $f^0(1710)\pi^+$, and $f^0(1370)\pi^+$ contributions. Additional resonances do not have a significant amplitude, fit fraction, or significantly improve the fit quality and upper limits are given on their fit fractions at the 90% C.L.

2. Summary

The CLEO-c results have added substantially to the knowledge of D and D_s decays. These results are important for a complete understanding of weak decays and in helping to make precision measurements of other mesons which have decays involving the D or D_s.

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