RECENT HEAVY FLAVOR PHYSICS FROM CLEO

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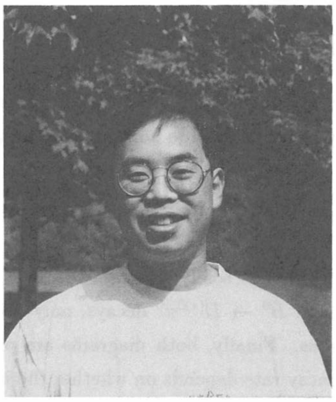


Abstract

CLEO has fully reconstructed a large sample of B meson decays to two-body final states involving a D, D^*, or ψ mesons. Precision measurements of branching fractions allow us to measure the magnitude and sign of the color-suppressed amplitude and to test factorization and spin symmetry. We have observed eight excited charm mesons and charm baryons which have one unit of orbital angular momentum. Finally, we have measured the absolute branching fraction for $D^0 \to K^-\pi^+$ and $D^+ \to K^-\pi^+\pi^+$ to new precision.

1 Introduction

The CLEO II detector at the Cornell e^+e^- storage ring CESR operates on and just below the $\Upsilon(4S)$ resonance. CESR is currently the highest luminosity e^+e^- machine in the world and has delivered to date a total of $\sim$ 4 fb^{-1} of data. This corresponds to roughly 3 million $B\bar{B}$ and 5 million $c\bar{c}$ events. The CLEO II detector [1] is a large solenoidal detector with 67 tracking layers and a CsI electromagnetic calorimeter that provides efficient π^0 reconstruction. Pions, kaons, and protons are identified using time-of-flight and dE/dx information.

2 B Hadronic Decays

CLEO has fully reconstructed about 400 B^0 and 800 B^- mesons decaying into two-body final states [2]. These decay channels include both external and internal spectator decays:

$$B \to D^{(*)}h^-, \quad h = \pi, \rho, a_1$$
$$B \to \psi K^{(*)}$$

The decay $\bar{B}^0 \to D^{(*)+}\pi^-$ proceeds solely through an external (color-allowed) spectator diagram. For $B \to \psi K^{(*)}$ and $\bar{B}^0 \to D^{(*)0}\pi^0$ decays, only the internal (color-suppressed) spectator diagram contributes. Finally, both diagrams are present in B^- meson decays. The magnitude of the B^- decay rate depends on whether the interference is constructive or destructive.

We select charm mesons through their decay modes: $D^{*+} \to D^0\pi^+$; $D^{*0} \to D^0\pi^0$; $D^0 \to K^-\pi^+$, $K^-\pi^+\pi^0$, and $K^-\pi^+\pi^-\pi^+$; and $D^+ \to K^-\pi^+\pi^+$. Charmonium is selected by its decay into pairs of identified leptons (e^+e^- or $\mu^+\mu^-$). Kaons are chosen from their decays $K^{*0} \to K^+\pi^-$; $K^{*-} \to K^-\pi^0$ and $K^0_s\pi^-$; and $K^0_s \to \pi^+\pi^-$.

To extract the signals we profit from the fact that the pair of B mesons from $\Upsilon(4S)$ decays are nearly at rest; extra fragmentation pions are not produced. Hence, we select B candidates by requiring the measured sum of charged and neutral energies from the reconstructed B meson to be equal to the beam energy, E_{beam}, within 2.5σ of the experimental resolution. This resolution is 14–46 MeV/c^2, depending on the decay mode. Thus we can differentiate between B meson decays that differ by a single pion.

We next form the beam-constrained mass

$$M_B^2 = E_{beam}^2 - \left(\sum_i \vec{p_i}\right)^2 \tag{1}$$

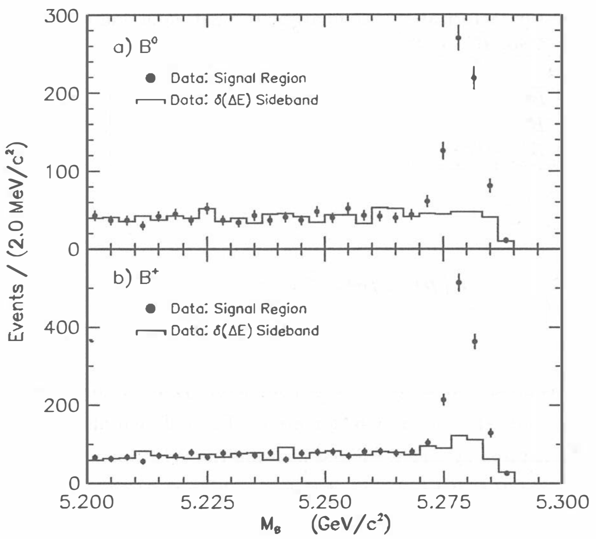


Figure 1: Beam-constrained mass spectrum for two-body decays of B^0 and B^+ mesons.

where $\sum \vec{p_i}$ is the sum of the B candidate's daughter momentum. The resolution on M_B is 2-3 MeV/c^2, about a factor of ten smaller than the invariant mass resolution. Shown in Fig. 1a and 1b are the mass spectra for fully reconstructed B^0 and B^+ mesons, respectively.

Our large sample of B mesons enables us to test a number of physics processes including factorization, spin symmetry, and the magnitude and sign of the color suppressed amplitude. Factorization forms the basis of most theories on B meson decays. For semileptonic decays, the decay amplitude factorizes into the product of a hadronic and a leptonic current. Two-body B decays that proceed through an external spectator diagram, such as $\bar{B}^0 \to D^{*+}\pi^-$, are also believed to be factorizable into two hadronic currents: one associated with the charm meson, the other from the hadronization of the W^- propagator. The decay rate $\Gamma(\bar{B}^0 \to D^{*+}\pi^-)$ can be simply related to the semileptonic decay rate $\Gamma(\bar{B}^0 \to D^{*+}\ell^-\bar{\nu})$ so long as the kinematics of the W^- propagator are the same, *i.e.* when the $\ell\bar{\nu}$ system satisfies

Table 1: Test of factorization: Comparison of right-hand and left-hand side of Eqn. 2 for $\bar{B}^0 \to D^{*+}h^-$

	$R_{exp}(GeV^2)$	$R_{theory}(GeV^2)$
$\bar{B}^0 \to D^{*+}\pi^-$	$1.1 \pm 0.1 \pm 0.2$	1.2 ± 0.2
$\bar{B}^0 \to D^{*+}\rho^-$	$3.0 \pm 0.4 \pm 0.6$	3.3 ± 0.5
$\bar{B}^0 \to D^{*+}a_1^-$	$4.0 \pm 0.6 \pm 0.5$	3.0 ± 0.5

$q^2 = m_\pi^2$. In this case

$$R = \frac{\Gamma\left(\bar{B}^0 \to D^{*+}\pi^-\right)}{\frac{d\Gamma}{dq^2}\left(\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}\right)\Big|_{q^2=m_\pi^2}} = 6\pi^2 c_1^2 f_\pi^2 |V_{ud}|^2 \tag{2}$$

where $c_1 = 1.1 \pm 0.1$ is a calculated QCD correction factor, f_π is the pion decay constant, and V_{ud} is the $W^- \to \bar{u}d$ term in the CKM matrix. The differential q^2 distribution for $\Gamma(\bar{B}^0 \to D^{*+}\ell^-\bar{\nu})$ is measured by CLEO [3] and fit using the WSB model. We can compare the experimental value of R (left-hand side of Equation 2) with the theoretical value of R (right-hand side). Table 1 shows that factorization is valid to about $\pm 20\%$ in the range of $0 < q^2 < m_{a_1}^2$.

Heavy Quark Effective Theory (HQET) predicts that in certain modes, the B decay rate is relatively independent of the spin alignment of the charm quark. In other words

$$\Gamma\left(\bar{B}^0 \to D^+\pi^-\right) \equiv \Gamma\left(\bar{B}^0 \to D^{*+}\pi^-\right) \tag{3}$$

CLEO measures $\frac{\Gamma(\bar{B}^0 \to D^+\pi^-)}{\Gamma(\bar{B}^0 \to D^{*+}\pi^-)} = 1.12 \pm 0.19 \pm 0.24$ and $\frac{\Gamma(\bar{B}^0 \to D^+\rho^-)}{\Gamma(\bar{B}^0 \to D^{*+}\rho^-)} = 1.10 \pm 0.14 \pm 0.28$. Both ratios are consistent with predictions from HQET spin symmetry.

The collection of two-body B meson decays can also be used to extract the coefficients of the color-allowed and the color-suppressed amplitudes, a_1 and a_2, respectively. The branching fractions for $\bar{B}^0 \to D^{*+}\pi^-$, $D^+\pi^-$, $D^{*+}\rho^-$, and $D^+\rho^-$ are proportional to a_1^2. A fit yields

$$|a_1| = 1.15 \pm 0.04 \pm 0.05 \pm 0.09 \tag{4}$$

where the second systematic error is due to uncertainties in the B^-/B^0 lifetimes and production in $\Upsilon(4S)$ decays. Our only evidence for color-suppressed B decays comes from our signals in $B \to \psi K^-$, ψK_s^0, ψK^{*-}, and ψK^{*0}, a total of ~ 100 fully reconstructed decays, for which we obtain

$$|a_2| = 0.26 \pm 0.01 \pm 0.01 \pm 0.02 \tag{5}$$

Table 2: Color-suppressed amplitude: Determining the sign of a_2/a_1

Ratio	$a_2/a_1 = -0.24$	$a_2/a_1 = +0.24$	CLEO II
$\mathcal{B}(B^- \to D^0\pi^-)/\mathcal{B}(\bar{B}^0 \to D^+\pi^-)$	0.50	1.68	$1.89 \pm 0.26 \pm 0.32$
$\mathcal{B}(B^- \to D^0\rho^-)/\mathcal{B}(\bar{B}^0 \to D^+\rho^-)$	0.71	1.34	$1.67 \pm 0.27 \pm 0.30$
$\mathcal{B}(B^- \to D^{*0}\pi^-)/\mathcal{B}(\bar{B}^0 \to D^{*+}\pi^-)$	0.48	1.72	$2.00 \pm 0.37 \pm 0.28$
$\mathcal{B}(B^- \to D^{*0}\rho^-)/\mathcal{B}(\bar{B}^0 \to D^{*+}\rho^-)$	0.41	1.85	$2.27 \pm 0.41 \pm 0.41$

We do not observe other color-suppressed modes such as $\bar{B}^0 \to D^{(*)0}\pi^0$, but our most stringent limit $\mathcal{B}(\bar{B}^0 \to D^0\pi^0)/\mathcal{B}(\bar{B}^0 \to D^+\pi^-) < 0.09$ (90% CL) is still above the predictions in most models. The sign of a_2/a_1 can be extracted by comparing B^- and B^0 decays, since both diagrams contribute to B^- decays and will interfere. Table 2 displays the ratio of branching fractions for $\mathcal{B}(B^-)/\mathcal{B}(\bar{B}^0)$ from the CLEO II data and the theoretical expectations for constructive interference ($a_2/a_1 > 0$) and destructive interference ($a_2/a_1 < 0$). The best fit yields

$$\frac{a_2}{a_1} = +0.24 \pm 0.04 \pm 0.04 \pm 0.10 \tag{6}$$

The sign of a_2/a_1 is somewhat contrary to theoretical extrapolations of its value in charm decays.

3 Charm Meson Spectroscopy

The D^{**} mesons consist of one charm quark and one light quark with a relative orbital angular momentum $L = 1$. There are four spin-parity states ($J^P = 0^+, 1^+, 1^+$, and 2^+), which are labeled D_0^*, D_1 for both 1^+ states, and D_2^*.

Parity and angular momentum conservation impose restrictions on the strong decay of D_J into $D^*\pi$ and $D\pi$. The 2^+ state can decay into both $D^*\pi$ and $D\pi$ through a D-wave amplitude; the 1^+ states can only decay into $D^*\pi$ through S-wave and D-wave decays; and the 0^+ state can only decay into $D\pi$ through an S-wave decay. HQET further suppresses the S-wave decay in one of the 1^+ states and the D-wave decay in the other 1^+ state. We expect that the two states $(1^+, 2^+)$ which decay via D-wave will be relatively narrow ($\Gamma \sim$ tens of MeV/c^2), while the other two states $(0^+, 1^+)$ which decay via S-wave will be broad ($\Gamma \sim$ hundreds of MeV/c^2).

The spin of the parent particle D_J can be further analyzed from the angular distribution of the D^* in the decay chain $D_J \to D^*\pi$ with $D^* \to D\pi$. The helicity angle, α, is defined

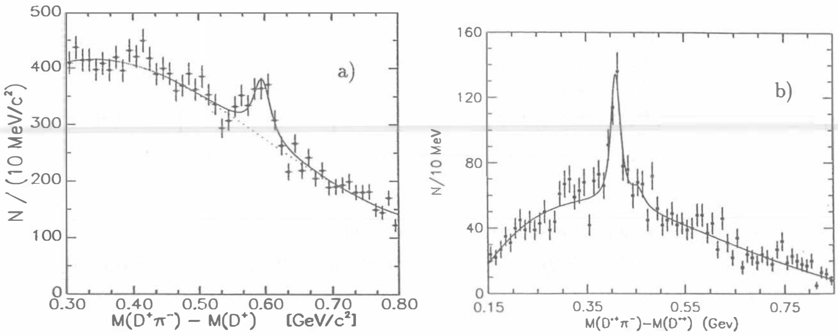


Figure 2: Mass difference distribution: a) $M(D^+\pi^-) - M(D^+)$ shows the D_2^{*0} signal and b) $M(D^{*+}\pi^-) - M(D^{*+})$ shows the D_1^0 signal. The high mass shoulder is from the D_2^{*0}.

as the angle between the D_J and D momenta both measured in the rest frame of the D^*. Independent of the polarization of the D_J, the helicity angular distribution will be

$$\frac{dN}{d\cos\alpha} \propto \begin{cases} \sin^2\alpha, & 2^+ \text{ state} \\ 1, & 1^+ \text{ state, pure S-wave decay} \\ 1 + 3\cos^2\alpha, & 1^+ \text{ state, pure D-wave decay} \end{cases} \tag{7}$$

CLEO has observed all six narrow excited states: the neutral D_J^0, the charged D_J^+, and the charmed strange D_{sJ}^+ [4, 5, 6, 7]. The two neutral D_J^0 states, the $D_1(2420)^0$ and $D_2^*(2460)^0$, were first identified by E691 and also seen by ARGUS, CLEO, and E687. We have remeasured the 2^+ state via its decay $D_2^{*0} \to D^+\pi^-$. After requiring the scaled momentum $x_p(D_2^{*0}) > 0.65$, we observe 486^{+103}_{-119} events. The mass difference $\Delta M = M(D^+\pi^-) - M(D^+)$ is plotted in Fig. 2a. The mass and width of the $D_2^*(2460)^0$, along with the other D^{**} mesons, are listed in Table 3.

We reconstruct the 1^+ state from its decay chain $D_1(2420)^0 \to D^{*+}\pi^-$ with $D^{*+} \to D^0\pi^+$. The 2^+ state can decay similarly and appears as a high mass shoulder. We reduce this contribution significantly by applying a helicity angle cut of $|\cos\alpha| > 0.8$. The mass difference $\Delta M = M(D^{*+}\pi^-) - M(D^{*+})$ for $x_p(D_1^0) > 0.60$ is plotted in Fig. 2b. The fit yields 286^{+51}_{-46} events.

The observed helicity angular distribution agrees well with the spin-parity assignments of the $D_1(2420)^0$ and $D_2^*(2460)^0$ states. The D_1^0 state fits best to a 1^+ pure D-wave decay; the isotropic, $\sin^2\alpha$ ($J_P = 2^+$), and $\cos^2\alpha$ ($J_P = 0^-$) are ruled out. However, it is still possible

Table 3: Mass and width of the $L = 1$ excited charm mesons

	Mass (MeV/c²)	Width (MeV/c²)
D_2^{*0}	$2465 \pm 3 \pm 3$	$28^{+8}_{-7} \pm 6$
D_1^0	$2421 \pm 2 \pm 2$	$20^{+6}_{-5} \pm 3$
D_2^{*+}	$2463 \pm 3 \pm 3$	$25^{+8}_{-7} \pm 4$
D_1^+	$2426 \pm 2 \pm 2$	$27^{+11}_{-8} \pm 5$
D_{s2}^{*+}	$2573.2 \pm 1.7 \pm 0.8 \pm 0.5$	$16^{+5}_{-4} \pm 3$
D_{s1}^+	2535.1 ± 0.6	< 2.3 (90% CL)

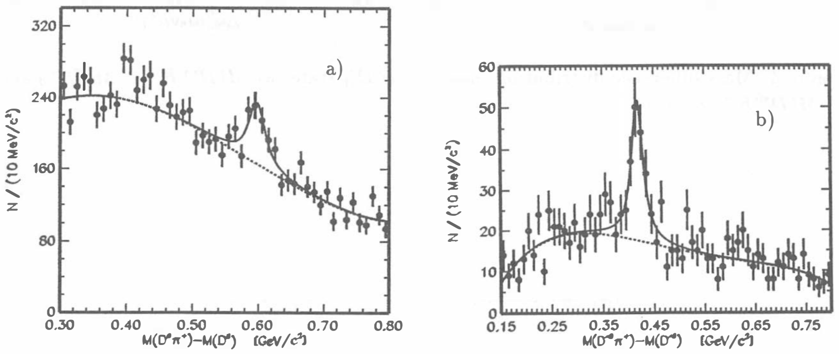


Figure 3: Mass difference distribution: a) $M(D^0\pi^+) - M(D^0)$ shows the D_2^{*+} signal and b) $M(D^{*0}\pi^+) - M(D^{*0})$ shows the D_1^+ signal.

for the D_1^0 to have a significant S-wave contribution if the relative phase between the S- and D-wave amplitudes are nonzero. Finally, both D_J^0 states have relatively narrow widths, as expected for D-wave decays.

The two charged D_J^+ states are somewhat less established. ARGUS and E687 have both observed the $D_2^*(2470)^+$, but no previous experiment has fully reconstructed the D_1^+. CLEO has identified both states and measured their helicity angular distribution, using methods analogous to those used for their isospin partners, the D_J^0 states. We observe 312^{+98}_{-79} events in the decay $D_2^*(2470)^+ \to D^0\pi^+$ for $x_p > 0.65$. The 1^+ state is observed through its decay $D_1(2430)^+ \to D^{*0}\pi^+$ with $D^{*0} \to D^0\pi^0$. After requiring $x_p > 0.6$ and $|\cos\alpha| > 0.8$ to reduce the contribution from $D_2^{*+} \to D^{*0}\pi^+$, the mass difference spectrum yields 89 ± 21 signal events. Fig. 3 displays the mass difference spectra for both states.

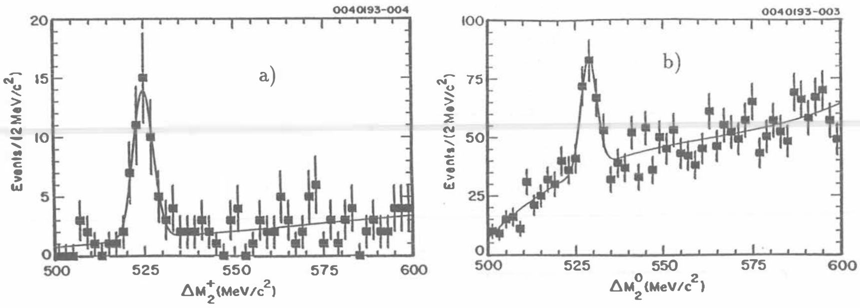


Figure 4: Mass difference distribution showing the D_{s1}^{+} state: a) $M(D^{*+}K_s^0) - M(D^{*+})$ and b) $M(D^{*0}K^+) - M(D^{*0})$

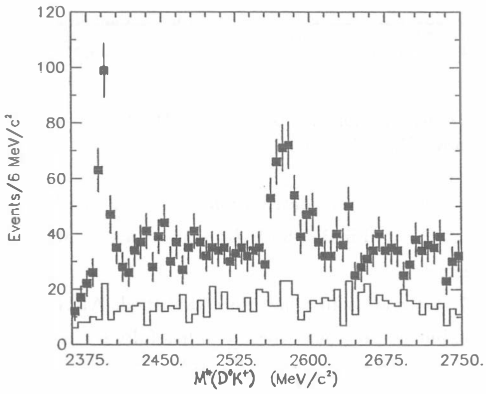


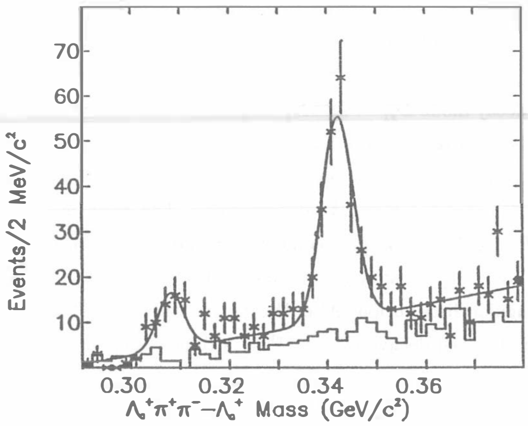
Figure 5: The $M(D^0K^+)$ distribution showing the D_{s2}^{*+} state at 2573 MeV/c^2. The peak at 2392 MeV/c^2 is feeddown from the D_{s1}^{+}. The histogram is from the D^0 sidebands.

The excited states of D_s^+ with one unit of orbital angular momentum can only decay into D^*K or DK. They are forbidden to decay into $D_s^+\pi^0$ and $D_s^+\pi\pi$ due to isospin conservation and OZI suppression, respectively. The $D_{s1}(2536)^+$ was discovered by ARGUS and confirmed by CLEO from the decay mode $D_{s1}^+ \to D^{*+}K_s^0$ with $D^{*+} \to D^0\pi^+$. We have remeasured this mode and observe 44 ± 8 events in the mass difference plot $\Delta M = M(D^{*+}K_s^0) - M(D^{*+})$ for $x_p(D_{s1}^+) > 0.6$ (Fig. 4). We also observe a new mode $D_{s1}^+ \to D^{*0}K^+$ with $D^{*0} \to D^0\pi^0$, with 134 ± 22 events in the ΔM distribution. The ratio of branching fractions, $\mathcal{B}(D^{*0}K^+)/\mathcal{B}(D^{*+}K^0)$, is 1.1 ± 0.3, in agreement with isospin and phase space. For the first time, we have ruled out a spin-parity assignment of 0^- or 2^+ for the $D_{s1}(2536)^+$ from our measured helicity angular distribution. Also, the narrow width ($\Gamma < 2.3$ MeV/c^2 at the 90% CL) and the lack of observed decays $D_{s1}^+ \to D^0K^+$ strongly suggests that the D_{s1}^+ is the 1^+ state.

We have recently discovered the 2^+ partner of the $D_{s1}(2536)^+$ via its decay $D_{s2}^{*+} \to D^0K^+$. For $x_p(D_{s2}^{*+}) > 0.7$ we observe a signal of 217 ± 38 events at a mass of $2573.2 \pm 1.7 \pm 0.8 \pm 0.5$ MeV/c^2 (Fig. 5). A feeddown peak at 2392 MeV/c^2 is also present from the decay $D_{s1}^+ \to D^{*0}K^+$, where the π^0 from the D^{*0} is missing. We do not observe the decay $D_{s2}^{*+} \to D^{*0}K^+$ or $D^{*+}K_s^0$ since it is heavily phase space suppressed, and hence we cannot perform a proper spin-parity analysis. However, this new state must be the normal series ($0^+\ 1^-\ 2^+\ 3^- \ldots$). Moreover, the width is narrow and the D_{sJ}^+ mass splitting, 38.1 ± 1.7 ± 0.8 MeV/c^2, is comparable to that of D_J^0 and D_J^+, leading to the conclusion that this new meson $D_{s2}^*(2573)^+$ is the 2^+ partner of $D_{s1}(2536)^+$.

4 Excited Charm Baryons

In the past year, two new excited states of the charm baryon Λ_c^+ have been observed, both states decaying into $\Lambda_c^+\pi^+\pi^-$ [8, 9]. ARGUS discovered the $\Lambda_c^{*+}(2630)$; CLEO confirmed this state and soon discovered a lower mass excited state, the $\Lambda_c^{*+}(2590)$. Fig. 6 shows the mass difference distribution, $\Delta M = M(\Lambda_c^+\pi^+\pi^-) - M(\Lambda_c^+)$. There are 167 ± 17 events in the higher ΔM peak at 342.1 ± 0.4 ± 0.5 MeV/c^2, and 39 ± 9 events in the lower ΔM peak at 308.0 ± 0.4 ± 2.0 MeV/c^2. Here, we use a sample of Λ_c^+'s from four decay modes: $pK^-\pi^+$, pK_s^0, $\Lambda\pi^+$, and $\Lambda\pi^+\pi^-\pi^+$, where we require $x_p > 0.4 - 0.5$, depending on the mode. Furthermore, we observe that the $\Lambda_c^{*+}(2590)$ state decays predominantly to $\Sigma_c^{++}\pi^-$ and $\Sigma_c^0\pi^+$, whereas the $\Lambda_c^{*+}(2630)$ exhibits no resonant substructure. When we require one of the $\Lambda\pi$ combination to be consistent with coming from a Σ_c, only the lower mass peak remains. We also observe 57 ± 15 events in a second decay mode of $\Lambda_c^{*+}(2630)$ to $\Lambda_c^+\pi^0\pi^0$.



Figu e 6: The $M(\Lambda_c^+\pi^+\pi^-) - M(\Lambda_c^+)$ mass difference distribution. The histogram is from the Λ_c^+ sidebands.

These two excited Λ_c^+ states are believed to be the P-wave baryons in which the diquark is in an $L = S = 0$ state and orbits the charm quark with one unit of orbital angular momentum. Coml ined with the spin of the charm quark, the doublet has spin-parity $J_P = \frac{1}{2}^+$ and $\frac{3}{2}^+$. The $\frac{1}{2}^+$ state $\Lambda_c^{*+}(2590)$ decays preferentially to $\Sigma_c\pi$; the $\frac{3}{2}^+$ state $\Lambda_c^{*+}(2630)$ would like to decay to $\Sigma_c^*\pi$ but is kinematically forbidden.

5 Absolute Branching Fraction for D^0 and D^+

It is important to know the absolute branching fraction $\mathcal{B}(D^0 \to K^-\pi^+)$ and $\mathcal{B}(D^+ \to K^-\pi^+\pi^+)$ to high precision, since these two decay modes are invariably used to normalize branching fractions for all other D^0 and D^+ decay modes. Furthermore, we rely on these values to accurately compute the branching fractions for B meson decays.

CI EO has recently measured $\mathcal{B}(D^0 \to K^-\pi^+)$ using a D^{*+} tag [10]. Although measuring the exclusive decay rate $D^{*+} \to D^0\pi^+$ with $D^0 \to K^-\pi^+$is relatively easy, measuring the total number of $D^{*+} \to D^0\pi^+$ decays is difficult. CLEO accomplishes this by identifying the slow π^+ from $D^{*+} \to D^0\pi^+$ decays, which typically has $\lesssim 50$ MeV/c of momentum transverse to the thrust axis in $c\bar{c}$ events. We plot $\sin^2\alpha$ for 8 slices in P_π from 225 to 425 MeV/c, where α is the angle between the slow π^+ and the thrust axis. Pions from D^{*+} peak at zero,

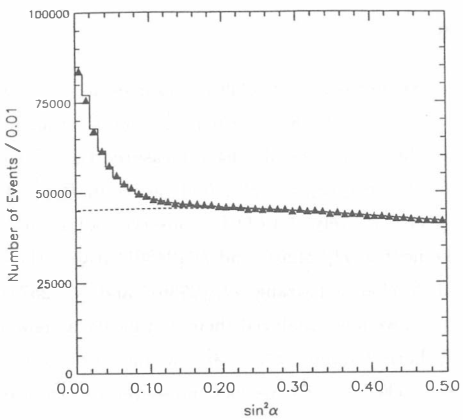


Figure 7: The $\sin^2\alpha$ distribution (triangles) for low momentum pions with $P_\pi = 225 - 425$ MeV/c. The solid histogram is a fit to the signal and background. The dashed histogram is the contribution from background.

as seen in Fig. 7. We compute the absolute branching fraction to be

$$\mathcal{B}(D^0 \to K^-\pi^+) = (3.95 \pm 0.08 \pm 0.17)\% \tag{8}$$

which includes final state radiation. Our measurement is the most precise to date.

We obtain the absolute branching fraction $\mathcal{B}(D^+ \to K^-\pi^+\pi^+)$ by measuring the ratio of yields, $N_{K\pi\pi}$ and $N_{K\pi}$, from the exclusive decay chains $D^{*+} \to D^0\pi^+$ with $D^+ \to K^-\pi^+\pi^+$ and $D^{*0} \to D^0\pi^0$ with $D^0 \to K^-\pi^+$, respectively [11]. This ratio can be written as

$$\frac{N_{K\pi\pi}}{N_{K\pi}} = \frac{N_D^{*+}}{N_D^{*+}} \frac{\mathcal{B}(D^{*+} \to D^+\pi^0)}{\mathcal{B}(D^{*+} \to D^0\pi^+)} \frac{\mathcal{B}(D^+ \to K^-\pi^+\pi^+)}{\mathcal{B}(D^0 \to K^-\pi^+)} \frac{\epsilon_{K\pi\pi}}{\epsilon_{K\pi}} \tag{9}$$

where $\epsilon_{K\pi\pi}$ and $\epsilon_{K\pi}$ are the efficiencies of reconstructing the exclusive decays. We measure $N_{K\pi\pi} = 1502 \pm 99$ events and $N_{K\pi} = 5452 \pm 104$ events. From phase space and isospin we compute $\mathcal{B}(D^{*+} \to D^+\pi^0)/\mathcal{B}(D^{*+} \to D^0\pi^+) = 2.21 \pm 0.07$. Using our value of $\mathcal{B}(D^0 \to K^-\pi^+)$ we obtain

$$\mathcal{B}(D^+ \to K^-\pi^+\pi^+) = (9.3 \pm 0.6 \pm 0.8)\% \tag{10}$$

which includes final state radiation. Our measurement agrees well with the Mark III result, $(9.1 \pm 1.3 \pm 0.4)\%$, but is larger than the ACCMOR result, $(6.4 \pm 1.5)\%$.

6 Conclusions

CLEO has fully reconstructed approximately 1200 B meson decays into two-body final states involving a D, D^*, or ψ mesons. We have tested the factorization hypothesis and spin symmetry in HQET to the 20% level. We also have measured the relative color-suppressed to color-allowed amplitudes to be $a_2/a_1 = 0.24 \pm 0.11$; hence in $B^- \rightarrow D^{(*)0}\pi^-$ decays, the two amplitudes interfere constructively. CLEO has observed all six narrow $L = 1$ excited charm mesons, namely the neutral $D_1(2420)^0$ and $D_2^*(2460)^0$ states, the charged $D_1(2430)^+$ and $D_2^*(2470)^+$ states, and the charmed-strange $D_{s1}(2536)^+$ and $D_{s2}^*(2573)^+$ states. From the helicity angular distributions, we have analyzed their spin-parity assignments. We also have observed two new excited charm baryon states with one unit of orbital angular momentum: the $\Lambda_c^{*+}(2590)$ and the $\Lambda_c^{*+}(2630)$. Finally, we have measured to new precision the absolute branching fraction for $D^0 \rightarrow K^-\pi^+$ to be $(3.95 \pm 0.08 \pm 0.17)\%$ and $D^+ \rightarrow K^-\pi^+\pi^+$ to be $(9.3 \pm 0.6 \pm 0.8)\%$.

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