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Measurement of exclusive *B* decays to final states containing a charmed baryon

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Using data collected by the CLEO detector in the $\Upsilon(4S)$ region, we report new measurements of the exclusive decays of B mesons into final states of the type $\Lambda_c^+ \overline{p} n(\pi)$, where $n=0,1,2,3$. We find signals in modes with one, two and three pions and an upper limit for the two-body decay $\Lambda_c^+ \overline{p}$. We also make the first measurements of exclusive decays of B mesons to $\Sigma_c \overline{p} n(\pi)$, where $n=0,1,2$. We find signals in modes with one and two pions and an upper limit for the two-body decay $\Sigma_c \overline{p}$. Measurements of these modes shed light on the mechanisms involved in B decays to baryons.

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A distinctive feature of the B system is that the large mass of the b quark allows weak decays of the B mesons to proceed via the creation of a baryon-antibaryon pair. The mechanisms for baryon production have been the subject of several studies in the last decade. The dominant decay mechanism is expected to be $b \to c\overline{u}d$ transitions via internal or external W decay. This can lead to final states, including a charm meson as well as a baryon-antibaryon pair, as recently observed by CLEO [1] and Belle [2]. However, the simplest decay diagrams lead to states of the form $\overline{B} \to \Lambda_c \overline{N} X$, where $\overline{N}$ represents an anti-nucleon. Charge-conjugate processes are implied throughout this paper. Inclusive studies of Λ_c^+ production from B decays indicate a branching fraction of around 5%, and the soft Λ_c^+ momentum spectrum indicates that multi-body decays dominate [3,4]. In 1996, CLEO made the first exclusive measurements [5] of decays of this type, and found $\mathcal{B}(B^- \to \Lambda_c^+ \overline{p} \pi^-) = (0.62^{+0.23}_{-0.21} \pm 0.11 \pm 0.10) \times 10^{-3}$ and $\mathcal{B}(\overline{B^0} \to \Lambda_c^+ \overline{p} \pi^+ \pi^-) = (1.33^{+0.46}_{-0.42} \pm 0.31 \pm 0.21) \times 10^{-3}$. The analysis presented here uses a larger CLEO data sample and improved analysis techniques to make further measurements of this type, confirming the previous observations and measuring new modes $B^- \to \Lambda_c^+ \overline{p} \pi^+ \pi^- \pi^-$ and $B^- \to \Lambda_c^+ \overline{p} \pi^- \pi^0$. Furthermore, by investigation of the resonant substructure of these decays, the first exclusive decays of the form $\overline{B} \to \Sigma_c \overline{N} X$ have been measured. Comparisons of the branching fractions of these modes give information on the underlying mechanisms involved.

The data were collected with two detector configurations, CLEO II [6] and CLEO II.V [7], at the Cornell Electron Storage Ring (CESR). The data comprise 9.17 fb^{-1} taken at the $\Upsilon(4S)$ which corresponds to $9.74 \times 10^6 B\overline{B}$ pairs, together with 4.6 fb^{-1} taken in the e^+e^- continuum below the $\Upsilon(4S)$ that are used to evaluate possible backgrounds. We assume that the produced B^+B^- rate is the same as $B^0\overline{B^0}$ at the $\Upsilon(4S)$.

The signal B meson candidates are fully reconstructed by combining detected photons, protons, and charged kaons and pions. The tracking system consisted of several concentric detectors operating inside a 1.5 T solenoid. For CLEO II, the tracking system consisted of a 6-layer straw tube chamber, a 10-layer precision drift chamber, and a 51-layer main drift chamber. The main drift chamber also provided a measurement of the specific ionization, dE/dx, used for particle identification. For CLEO II.V, the straw tube chamber was replaced by a 3-layer, double-sided silicon vertex detector, and the gas in the main drift chamber was changed from an argon-ethane to a helium-propane mixture. In both configurations, photons were detected by an electromagnetic calorimeter consisting of 7800 thallium-doped CsI crystals.

Λ_c^+ candidates are reconstructed in the modes $pK^-\pi^+, pK_S^0$ and $\Lambda\pi^+$, where $K_S^0 \to \pi^+\pi^-$ and $\Lambda \to p\pi^-$. The K_S^0 and Λ candidates are reconstructed from oppositely charged tracks which form a vertex well detached from the main event vertex in the plane transverse to the beam direction. The invariant mass of the $K_S^0(\Lambda)$ candidate is required to be within 8 (3.5) MeV/c^2 of the known mass. Neutral pion candidates are formed from pairs of showers detected in the calorimeter which yield a $\gamma\gamma$ invariant mass within 2 standard deviations of the known π^0 mass. The Λ, K_S^0 and π^0 candidates were then all kinematically constrained to their known masses.

Particle identification of p, K^-, and π^+ candidates was performed using specific ionization measurements in the drift chamber, and when present, time-of-flight measurements. For each mass hypothesis, a combined χ^2 probability P_i was formed $(i = \pi, K, p)$. Using these P_i's, a normalized probability ratio L_i was evaluated, where $L_i = P_i/(P_\pi + P_K + P_p)$. Real protons have L_p of close to 1.0, whereas tracks due to other particles are concentrated near $L_p = 0.0$. For a track to be used as a proton daughter of a $\Lambda_c^+ \to pK^-\pi^+$ or pK_S^0 decay, we require it to have $L_p > 0.9$, which eliminates much of the background but with considerable diminution of efficiency. For kaons we applied a slightly looser and more efficient requirement of $L_K > 0.7$. We have chosen these selection criteria using a Monte Carlo simulation program to maximize the significance of the Λ_c^+ signals. The candidate anti-proton which is the direct daughter of the B meson has a looser requirement of $L_p > 0.1$ as it has a higher momentum distribution and lower backgrounds than the decay daughter of the Λ_c^+. The proton from the $\Lambda \to p\pi^-$, and all the pion candidates, are required to have particle identification parameters consistent with their hypothesis. Tracks with no particle identification information are assumed to be due to pions.

To suppress the continuum background, the normalized Fox-Wolfram second moment [8] is required to be less than 0.35. The number of Λ_c^+ candidates from the $\Upsilon(4S)$ data, after the contribution from continuum events is accounted for by a subtraction of scaled continuum data, is $7100 \pm 350 (12100 \pm 450)$ from the CLEO II (CLEO II.V) detector configurations.

To reconstruct exclusive B decays we select Λ_c^+ candidates whose mass is within 2σ of the nominal mass. The mass resolution, σ, was calculated for each of the three decay modes and two detector configurations separately by use of a GEANT-based Monte Carlo simulation program [9]. We constrain the mass of these Λ_c^+ candidates to the Λ_c^+ peak value using a kinematic fitting program, and combine them with an anti-proton candidate and a number of pion candidates. We define the beam-constrained mass as $M_B = \sqrt{E_{\text{beam}}^2 - (\Sigma_i p_i)^2}$, where p_i is the 3-momentum vector for the ith daughter of the B candidate and E_{beam} is the beam energy. The resolution in M_B is dominated by the spread in the CESR beam energy and is much better than the resolution in the invariant mass of the combination.

For each combination, we calculated the energy difference $\Delta E = E_{\text{meas}} - E_{\text{beam}}$, where E_{meas} is the measured energy of the combination. A correctly reconstructed B meson has a ΔE distribution with a maximum at 0 GeV. The ΔE resolution, $\sigma_{\Delta E}$, was calculated for each mode and detector configuration separately using the Monte Carlo simulation program, and combinations were required to have $|\Delta E| < 2\sigma_{\Delta E}$. A further reduction in background is achieved by cutting on Θ_B, the polar angle of the B in the laboratory frame with respect to the e^+e^- axis. The distribution of

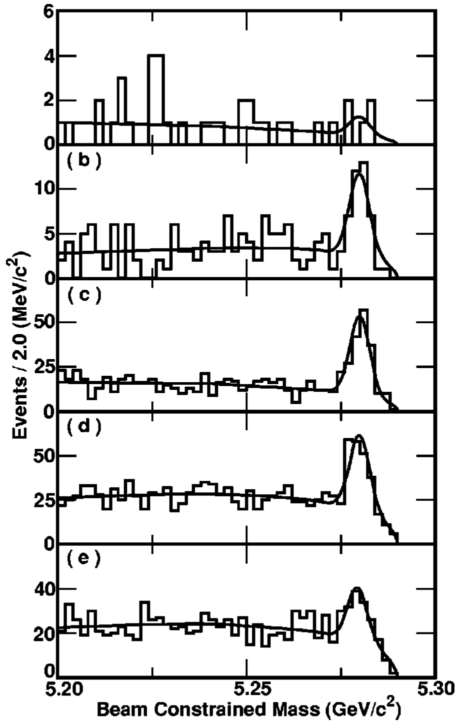

FIG. 1. Beam-constrained mass distributions for (a) $\Lambda_c^+\overline{p}$, (b) $\Lambda_c^+\overline{p}\pi^-$, (c) $\Lambda_c^+\overline{p}\pi^-\pi^+$, (d) $\Lambda_c^+\overline{p}\pi^-\pi^+\pi^-$, and (e) $\Lambda_c^+\overline{p}\pi^-\pi^0$.

$\cos\Theta_B$ is proportional to $\sin^2\Theta_B$ for $e^+e^-\to\Upsilon(4S)\to B\overline{B}$, whereas background events are distributed nearly isotropically. We require $|\cos\Theta_B|<0.9$. If there are multiple candidates in an event with $M_B>5.2$ GeV/c^2 for a given decay channel, the entry with the smallest absolute value of ΔE is selected.

The M_B distributions, after all selection criteria have been applied, are displayed in Fig. 1 for all modes investigated.

TABLE I. The results for the yields of each mode. The yield of events for each of the substructures listed is a subset of those in the main modes.

Mode	Substructure	Total yield	Substructure yield
$\Lambda_c^+\overline{p}$		<8	
$\Lambda_c^+\overline{p}\pi^-$		31 ± 7	
	$\Sigma_c^0\overline{p}$		<5.3
$\Lambda_c^+\overline{p}\pi^-\pi^+$		147 ± 15	
	$\Sigma_c^0\overline{p}\pi^+$		14 ± 4
	$\Sigma_c^{++}\overline{p}\pi^-$		23 ± 5
	$\Lambda_{c1}^+\overline{p}$		<2.3
$\Lambda_c^+\overline{p}\pi^-\pi^+\pi^-$		145 ± 17	
	$\Sigma_c^0\overline{p}\pi^+\pi^-$		19 ± 5
	$\Sigma_c^{++}\overline{p}\pi^-\pi^-$		12 ± 4
	$\Lambda_{c1}^+\overline{p}\pi^-$		<2.3
$\Lambda_c^+\overline{p}\pi^-\pi^0$		89 ± 15	
	$\Sigma_c^0\overline{p}\pi^0$		13 ± 4

Strong signals are found in the modes $\Lambda_c^+\overline{p}\pi^-$ and $\Lambda_c^+\overline{p}\pi^-\pi^+$, confirming the previous observation of these modes. Signals are also found in the new modes $\Lambda_c^+\overline{p}\pi^-\pi^+\pi^-$, which has a 13.0σ significance,[1] and $\Lambda_c^+\overline{p}\pi^-\pi^0$, which has an 8.2σ significance. There is no statistically significant signal in the two-body decay $\overline{B^0}\to\Lambda_c^+\overline{p}$. Each M_B distribution is fit to a fixed width Gaussian signal function, and a background function of an exponential with phase-space threshold suppression. The signal yields from these fits are shown in Table I, where the uncertainties are statistical only. We have verified that similar distributions made with Λ_c^+ sidebands, ΔE sidebands, or continuum data show no peaking in the B mass region.

Knowledge of the substructure of the multi-particle final states is very important. From a purely practical point of view, the substructure changes the efficiency for detecting a final state. This is particularly true when the intermediate particles are Λ_{c1} and Σ_c baryons which in turn decay strongly with low Q^2 decays to Λ_c^+ baryons. Furthermore, knowledge of the substructure gives information on the underlying mechanisms involved.

To search for $\Sigma_c^{++}\to\Lambda_c^+\pi^+$ and $\Sigma_c^0\to\Lambda_c^+\pi^-$, we require that the combination has a beam constrained mass within $2\sigma_{M_B}$ of the B mass peak to select events in which a B meson decays to a Λ_c^+. We then combine this Λ_c^+ with a charged pion daughter of the B decay and plot the $M(\Lambda_c^+\pi)-M(\Lambda_c^+)$ mass difference (Fig. 2). We fit these distributions with a Breit-Wigner function of width defined by the CLEO measurements of the Σ_c widths [10], convoluted with a Gaussian resolution function obtained from Monte Carlo studies, together with a polynomial background function. We find good evidence for both Σ_c^{++} and Σ_c^0 production in $\Lambda_c^+\overline{p}\pi^+\pi^-$ and $\Lambda_c^+\overline{p}\pi^+\pi^-\pi^+$, and for Σ_c^0 in $\Lambda_c^+\overline{p}\pi^0\pi^-$. All these signals have a statistical significance greater than 5σ. Using analogous plots of those combinations in the M_B distributions outside the B mass peak, we find negligible background from true Σ_c baryons that are not the daughters of the B decay mode in question. For the $\Sigma_c^0\overline{p}$ mode there are two events in the signal region which would suggest a branching fraction of the order of 0.25×10^{-4}. Our expected background in this mode, which is 0.12 events, has a 0.6% chance of fluctuating to the observed events. We feel that this significance is not sufficient to claim to have found a signal in this mode and we prefer to present a 90% confidence level upper limit. There are no events consistent with the production of $\Lambda_{c1}(2593)\to\Lambda_c^+\pi^+\pi^-$ or $\Lambda_{c1}(2625)\to\Lambda_c^+\pi^+\pi^-$ in these decays which allows us to calculate 90% confidence level (CL) upper limits on their production.

Table II shows the final results for the efficiencies and branching fractions for all the modes. The efficiencies are

[1]We define our significance as the probability, expressed in normal distribution sigma, of our expected background to fluctuate to our signal's central value. Poisson (Gaussian) statistics are used for expected backgrounds with less (greater) than 30 events.

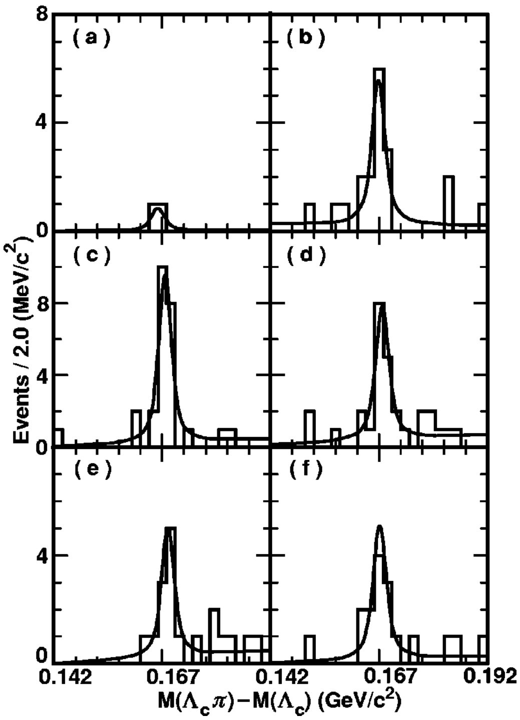

FIG. 2. $M(\Lambda_c^+\pi)$-$M(\Lambda_c^+)$ mass differences for combinations within 2σ of the B peak in the $M(B)$ distribution. (a) $M(\Lambda_c^+\pi^-)-M(\Lambda_c^+)$ within $\Lambda_c^+\overline{p}\pi^-$, (b) $M(\Lambda_c^+\pi^-)-M(\Lambda_c^+)$ within $\Lambda_c^+\overline{p}\pi^-\pi^+$, (c) $M(\Lambda_c^+\pi^+)-M(\Lambda_c^+)$ within $\Lambda_c^+\overline{p}\pi^-\pi^+$, (d) $M(\Lambda_c^+\pi^-)-M(\Lambda_c^+)$ within $\Lambda_c^+\overline{p}\pi^-\pi^+\pi^-$, (e) $M(\Lambda_c^+\pi^+)-M(\Lambda_c^+)$ within $\Lambda_c^+\overline{p}\pi^-\pi^+\pi^-$, and (f) $M(\Lambda_c^+\pi^-)-M(\Lambda_c^+)$ within $\Lambda_c^+\overline{p}\pi^-\pi^0$.

calculated by our Monte Carlo simulation program. In this simulation, the Λ_c^+ decays were generated only into the three decay modes reconstructed, using the measured branching ratios. To convert the quoted efficiencies to efficiencies, which include the branching fractions of these modes, they need to be multiplied by the absolute branching fraction of $\Lambda_c^+\to pK^-\pi^+$ of $5.0\pm1.3\%$ [11]. The yield from the Σ_c decay modes has been subtracted from the non-resonant yields so that the resonant and non-resonant components can have different efficiency corrections applied.

Table II includes systematic uncertainties. Major contributors to these are uncertainties due to fitting techniques, and uncertainties due to the efficiency calculation. We take the fitting technique uncertainty as the maximum difference obtained from different fitting methods. These techniques included using a scaled M_B distribution from ΔE sidebands for the background function, and fitting the ΔE distribution directly having first selected the B mass in the M_B distribution. The uncertainties from this source are 5–17 %, dependent upon the mode. The uncertainty in the efficiency calculation is 5–8 % due to uncertainties in the detection of the charged and neutral particles. In addition, there is a difference in efficiency due to possible substructure such as Λ_c^*, Σ_c^*, ρ and Δ intermediate states. These all give a slightly reduced efficiency and thus give an asymmetric systematic uncertainty. The systematic uncertainty due to the uncertainty in the $\Lambda_c^+\to pK^-\pi^+$ branching fraction is expressed as a third uncertainty.

TABLE II. The efficiencies and branching fractions or 90% C.L. upper limits for each mode. The second error in the branching fraction is due to all systematic uncertainties except for the uncertanty due to the measurement of the $\Lambda_c^+\to pK^-\pi^+$ branching fraction, which is kept separate and appears as a third uncertainty. All systematic uncertainties have been included in the upper limits.

Mode	Efficiency (%)	$\mathcal{B}$ (10^{-4})	Previous result (10^{-4}) [5]
$\Lambda_c^+\overline{p}$	14.9	<0.9	<2.1
$\Lambda_c^+\overline{p}\pi^-$	15.8	$2.4\pm0.6^{+0.19}_{-0.17}\pm0.6$	6 ± 3
$\Sigma_c^0\overline{p}$	10.0	<0.8	
$\Lambda_c^+\overline{p}\pi^-\pi^+$	12.7	$16.7\pm1.9^{+1.9}_{-1.6}\pm4.3$	13 ± 6
$\Sigma_c^0\overline{p}\pi^+$	8.0	$2.2\pm0.6\pm0.4\pm0.6$	
$\Sigma_c^{++}\overline{p}\pi^-$	7.8	$3.7\pm0.8\pm0.7\pm1.0$	
$\Lambda_{c1}^+\overline{p}$	3.2	<1.1	
$\Lambda_c^+\overline{p}\pi^-\pi^+\pi^-$	9.3	$22.5\pm2.5^{+2.4}_{-1.9}\pm5.8$	<15
$\Sigma_c^0\overline{p}\pi^+\pi^-$	5.4	$4.4\pm1.2\pm0.5\pm1.1$	
$\Sigma_c^{++}\overline{p}\pi^-\pi^-$	5.3	$2.8\pm0.9\pm0.5\pm0.7$	
$\Lambda_{c1}^+\overline{p}\pi^-$	1.9	<1.9	
$\Lambda_c^+\overline{p}\pi^-\pi^0$	6.8	$18.1\pm2.9^{+2.2}_{-1.6}\pm4.7$	<31
$\Sigma_c^0\overline{p}\pi^0$	3.8	$4.2\pm1.3\pm0.4\pm1.1$	

Our limit on the branching fraction of the two-body decay $\overline{B^0}\to\Lambda_c^+\overline{p}$ is 0.9×10^{-4} at the 90% confidence level. This is tighter than the previous CLEO limit of 2.0×10^{-4}. A recent theoretical treatment by Cheng and Yang [12] using a bag model predicts a branching fraction of this order, whereas older theoretical predictions [13] predicted larger numbers by a factor of at least 4 over our experimental limit. Our measurement of the three-body branching fraction $B^-\to\Lambda_c^+\overline{p}\pi^-$ and $\overline{B^0}\to\Lambda_c^+\overline{p}\pi^-\pi^+$ are both consistent with, and much more precise than, the previous measurements. The three three-body decays $\overline{B^0}\to\Sigma_c^{++}\overline{p}\pi^-$, $\overline{B^0}\to\Sigma_c^0\overline{p}\pi^+$ and $\overline{B^-}\to\Sigma_c^0\overline{p}\pi^0$ have essentially identical phase-space, but only the Σ_c^{++} decay can proceed via both external and internal W decay diagrams, whereas the Σ_c^0 decays can only proceed via an internal W. We find the rate of all three decays to be of the same order. This implies that the external W decay diagram does not dominate over the internal W decay diagram, although naively we would expect the latter to be color suppressed.

In conclusion, we have measured branching fractions of B mesons into the decay modes $\Lambda_c^+\overline{p}\pi^-$, $\Lambda_c^+\overline{p}\pi^-\pi^+$, $\Lambda_c^+\overline{p}\pi^-\pi^+\pi^-$, and $\Lambda_c^+\overline{p}\pi^-\pi^0$. The first two of these confirm, with greater precision, the previous measurements. The latter two are the first observations of these decay modes. We find a limit on the two-body decay $\overline{B^0}\to\Lambda_c^+\overline{p}$, which discriminates between theoretical models. We make the first measurements of exclusive states that include Σ_c^{++} or Σ_c^0 baryons. Our measurements indicate that external W diagram decays do not dominate over the competing internal *W* diagram decays in Cabibbo-favored baryonic *B* decays.

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[1] CLEO Collaboration, S. Anderson *et al.*, Phys. Rev. Lett. **86**, 2732 (2001).
[2] Belle Collaboration, K. Abe *et al.*, Phys. Rev. Lett. **88**, 181803 (2002).
[3] ARGUS Collaboration, H. Albrecht *et al.*, Phys. Lett. B **210**, 263 (1988).
[4] CLEO Collaboration, G. Crawford *et al.*, Phys. Rev. D **45**, 752 (1992).
[5] CLEO Collaboration, X. Fu *et al.*, Phys. Rev. Lett. **79**, 3125 (1997).
[6] CLEO Collaboration, Y. Kubota *et al.*, Nucl. Instrum. Methods Phys. Res. A **320**, 66 (1992).
[7] T. Hill *et al.*, Nucl. Instrum. Methods Phys. Res. A **418**, 32 (1998).
[8] G.C. Fox and S. Wolfram, Phys. Rev. Lett. **41**, 1581 (1978).
[9] R. Brun *et al.*, ‘‘GEANT, Detector Description and Simulation Tool,’’ CERN Program Library Long Writeup W5013, 1993.
[10] CLEO Collaboration, M. Artuso *et al.*, Phys. Rev. D **65**, 071101(R) (2002).
[11] Particle Data Group, D.E. Groom *et al.*, Eur. Phys. J. C **15**, 1 (2000).
[12] H.Y. Cheng and K.C. Yang, Phys. Rev. D **65**, 054028 (2002).
[13] P. Ball and H.G. Dosch, Z. Phys. C **51**, 445 (1991); M. Jarfi *et al.*, Phys. Rev. D **43**, 1599 (1991); V.L. Chernyak and I.R. Zhitnitsky, Nucl. Phys. **B345**, 137 (1990).