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Study of $\bar{B} \rightarrow \Xi_c \bar{\Lambda}_c^-$ and $\bar{B} \rightarrow \Lambda_c^+ \bar{\Lambda}_c^- \bar{K}$ decays at *BABAR*

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We report measurements of B-meson decays into two- and three-body final states containing two charmed baryons using a sample of 230×10^6 $\Upsilon(4S) \to B\bar{B}$ decays. We find significant signals in two modes, measuring branching fractions $\mathcal{B}(B^- \to \Lambda_c^+ \bar{\Lambda}_c^- K^-) = (1.14 \pm 0.15 \pm 0.17 \pm 0.60) \times 10^{-3}$ and

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$\mathcal{B}(B^- \to \Xi_c^0 \bar{\Lambda}_c^-) \times \mathcal{B}(\Xi_c^0 \to \Xi^- \pi^+) = (2.08 \pm 0.65 \pm 0.29 \pm 0.54) \times 10^{-5}$, where the uncertainties are statistical, systematic, and from the branching fraction $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$, respectively. We also set upper limits at the 90% confidence level on two other modes: $\mathcal{B}(\bar{B}^0 \to \Xi_c^+ \bar{\Lambda}_c^-) \times \mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+) < 5.6 \times 10^{-5}$ and $\mathcal{B}(\bar{B}^0 \to \Lambda_c^+ \bar{\Lambda}_c^- \bar{K}^0) < 1.5 \times 10^{-3}$. We observe structure centered at an invariant mass of 2.93 GeV/c^2 in the $\Lambda_c^+ K^-$ mass distribution of the decay $B^- \to \Lambda_c^+ \bar{\Lambda}_c^- K^-$.

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Bottom (B) mesons are heavy enough to decay into charmed baryons, and do so at a rate of roughly 5% [1,2]. The dominant decay mechanism is via $b \to cW^-$ transitions, with W^- coupling to $\bar{c}s$ or $\bar{u}d$ [3], both of which are Cabibbo-allowed. Theoretical predictions for the branching fractions of B mesons to baryon-antibaryon pairs have been made within the diquark model [4] and with QCD sum rules [5]. These suggest that decays to two charmed baryons ($\bar{B} \to X_{c1}\bar{X}_{c2}$) and to one charmed baryon and one light baryon ($\bar{B} \to X_{c1}\bar{X}_2$) have comparable branching fractions, of the order of 10^{-3} for individual modes.

Several inclusive measurements of B-meson decays to charmed baryons have been made [1]. In particular, the *BABAR* Collaboration recently performed an inclusive analysis of Λ_c^+ production in which flavor tag information was used to identify whether the Λ_c^+ came from a B or a $\bar{B}$ meson [6]. It was found that about a third of all Λ_c^+ were from B mesons with anticorrelated flavor content (i.e. $\bar{b} \to c$ rather than $b \to c$ transitions), consistent with a substantial rate of $b \to c\bar{c}s$ decays. Inclusive studies of the Ξ_c^0 and Λ_c^+ momentum spectrum [2,7,8] also support a substantial rate of baryonic $b \to c\bar{c}s$ decays such as $B^- \to \Xi_c^0\bar{\Lambda}_c^-$. However, inclusive studies alone cannot fully establish this, since the momentum distributions can also be reproduced with carefully tuned sums of $b \to c\bar{u}d$ processes. Therefore, exclusive measurements are needed. These require very large samples of B-meson decays and have only recently become feasible.

The Belle Collaboration has reported results on B decays to final states with two charmed baryons in both two- and three-body modes [9,10]. They measured $\mathcal{B}(B^- \to \Xi_c^0\bar{\Lambda}_c^-) \times \mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+) = (4.8^{+1.0}_{-0.9} \pm 1.1 \pm 1.2) \times 10^{-5}$ and $\mathcal{B}(\bar{B}^0 \to \Xi_c^+\bar{\Lambda}_c^-) \times \mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+) = (9.3^{+3.7}_{-2.8} \pm 1.9 \pm 2.4) \times 10^{-5}$ [9]. Assuming that $\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)$ and $\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+)$ are of the order of 1%–2% [11], these results are compatible with the prediction that $\mathcal{B}(B^- \to \Xi_c^0\bar{\Lambda}_c^-)$ and $\mathcal{B}(\bar{B}^0 \to \Xi_c^+\bar{\Lambda}_c^-)$ are $\mathcal{O}(10^{-3})$. This is in stark contrast to the branching fractions of singly charmed decays, such as that of $\bar{B}^0 \to \Lambda_c^+\bar{p}$ which is $(2.2 \pm 0.8) \times 10^{-5}$, smaller by 2 orders of magnitude [12]. The branching fractions of the three-body processes $\bar{B} \to \Lambda_c^+\bar{\Lambda}_c^-\bar{K}$ were also found to be large: $\mathcal{B}(B^- \to \Lambda_c^+\bar{\Lambda}_c^-K^-) = (0.65^{+0.10}_{-0.09} \pm 0.11 \pm 0.34) \times 10^{-3}$ $\mathcal{B}(\bar{B}^0 \to \Lambda_c^+\bar{\Lambda}_c^-\bar{K}^0) = (0.79^{+0.29}_{-0.23} \pm 0.12 \pm 0.42) \times 10^{-3}$ [10]. Explanations for these widely varying values have been proposed [13,14]. It was suggested that a kinematic suppression may apply to decays in which the two baryons have high relative momentum, since this requires the exchange of two high-momentum gluons. The rate of $\bar{B} \to \Lambda_c^+\bar{\Lambda}_c^-\bar{K}$ decays could also be enhanced by final-state interactions, or by intermediate charmonium resonances.

In this paper, we present measurements of the branching fraction of the decays $B^- \to \Lambda_c^+\bar{\Lambda}_c^-K^-$, $B^- \to \Xi_c^0\bar{\Lambda}_c^-$, $\bar{B}^0 \to \Xi_c^+\bar{\Lambda}_c^-$, and $\bar{B}^0 \to \Lambda_c^+\bar{\Lambda}_c^-\bar{K}^0$, and investigate three-body decays for the possible presence of intermediate resonances. The data were collected with the *BABAR* detector [15] at the PEP-II asymmetric-energy e^+e^- storage rings and represent an integrated luminosity of approximately 210 fb^{-1} collected at a center-of-mass energy $\sqrt{s} = 10.58$ GeV, corresponding to the mass of the $\Upsilon(4S)$ resonance. The *BABAR* detector is a magnetic spectrometer with 92% solid angle tracking coverage in the center-of-mass frame. Charged particles are detected and their momenta are measured in a five-layer double-sided silicon vertex tracker and a 40-layer drift chamber, both operating in a 1.5 T magnetic field. Charged particle identification (PID) is provided by the average energy loss (dE/dx) in the tracking devices and by an internally reflecting ring-imaging Cherenkov detector. Photons are detected with a CsI(Tl) electromagnetic calorimeter. The instrumented flux return for the solenoidal magnet provides muon identification. Simulated events with B mesons decaying into the relevant final states are generated with EVTGEN [16] and PYTHIA [17], while GEANT4 [18] is used to simulate the detector response. Inclusive Monte Carlo (MC) samples of $\Upsilon(4S)$ and $e^+e^- \to q\bar{q}$ ($q = u, d, s, c$) events at $\sqrt{s} = 10.58$ GeV are also used, corresponding to more than 1.5 times the integrated luminosity of the data.

The Λ_c^+ candidates are reconstructed in the three decay modes $pK^-\pi^+$, pK_S^0, and $\Lambda\pi^+$; Ξ_c^0 candidates in the two decay modes $\Xi^-\pi^+$ and $\Lambda K^-\pi^+$; and Ξ_c^+ candidates in the decay mode $\Xi^-\pi^+\pi^+$. We begin by reconstructing the long-lived strange hadrons: $K_S^0 \to \pi^+\pi^-$ and $\Lambda \to p\pi^-$ candidates are reconstructed from two oppositely charged tracks, and $\Xi^- \to \Lambda\pi^-$ from a Λ candidate and a negatively charged track. In each case, we fit the daughters to a common vertex and compute their invariant mass. The mass is required to be within 3σ of the central value, where σ is the experimental resolution and 3σ is approximately 4.0, 4.5, and 6.0 MeV/c^2 for K_S^0, Λ, and Ξ^-, respectively. Candidates with a χ^2 probability below 10^{-4} are rejected. For Λ candidates, we also require the daughter proton to satisfy PID criteria. The mass of the K_S^0, Λ, or Ξ^- candidate is constrained to its nominal value [1] for subsequent fits.

We suppress background by requiring the transverse displacement between the event and decay vertices to be greater than 0.2 cm for K_S^0, Λ, and Ξ^-, each of which travels several centimeters on average. We also require that the scalar product of the displacement and momentum vectors of each hadron be greater than zero, and that the transverse component of the displacement vector of a Ξ^- candidate be smaller than that of its Λ daughter.

Next, we reconstruct the charmed baryons Λ_c^+, Ξ_c^0, and Ξ_c^+ in the decay modes listed previously. In each case, we fit their daughters to a common vertex, require the invariant mass of the charmed baryon candidate to be within 18 MeV/c^2 (approximately 3 times the experimental resolution) of the nominal mass [1], reject candidates with a χ^2 probability below 10^{-4}, and then constrain the masses to their nominal values. We also require that daughter kaons and protons of the charmed baryons satisfy the PID criteria for that hypothesis.

We reconstruct $\bar{B}$-meson candidates in the following final states: $\Lambda_c^+ \bar{\Lambda}_c^- K^-$, $\Xi_c^0 \bar{\Lambda}_c^-$, $\Xi_c^+ \bar{\Lambda}_c^-$, and $\Lambda_c^+ \bar{\Lambda}_c^- K_S^0$, fitting the daughters to a common vertex and requiring that the χ^2 probability is at least 10^{-4}. We also apply the kinematic and PID requirements mentioned above to the K_S^0 and K^- daughters of the B mesons. Because the branching fraction and efficiency are higher for $\Lambda_c^+ \to pK^-\pi^+$ than for the other Λ_c^+ decay modes, we use only final states in which at least one Λ_c^+ or $\bar{\Lambda}_c^-$ decays to $pK^-\pi^+$ or $\bar{p}K^+\pi^-$. For each B-meson candidate, we compute the energy-substituted mass $\mathrm{m_{ES}} \equiv (s/4 - p_B^{*2})^{1/2}$ and the energy difference $\Delta\mathrm{E} \equiv E_B^* - \sqrt{s}/2$, where p_B^*, E_B^*, and $\sqrt{s}$ are the momentum and energy of the B meson and the e^+e^- collision energy, respectively, all calculated in the e^+e^- center-of-mass frame. For a correctly reconstructed signal decay, the m_{ES} distribution peaks near the nominal mass of the B meson with a resolution of approximately 2.5 MeV/c^2, and ΔE peaks near zero with a resolution of 6.0–7.8 MeV depending on the final state. Figure 1 shows the m_{ES} and ΔE distributions for $B^- \to \Lambda_c^+ \bar{\Lambda}_c^- K^-$ candidates.

Background arises from several sources, including misreconstructed B decays to two charmed baryons, B decays to a single charmed baryon, $e^+e^- \to c\bar{c}$ events containing charmed baryons, and random combinations of tracks. We use inclusive MC simulations and events from the sidebands of m_{ES}, ΔE, and charmed baryon mass in data to study the background. We consider as background B-meson decays with the same final state that do not proceed via an intermediate charmed baryon—for example, $B^- \to \Xi_c^0 \bar{p} K^+ \pi^-$ misinterpreted as $B^- \to \Xi_c^0 \bar{\Lambda}_c^-$. Decays of this kind are distributed as signal in m_{ES} and ΔE but have a smooth distribution for the mass spectrum of the misreconstructed charmed baryon, unlike signal decays which also peak in the charmed baryon mass.

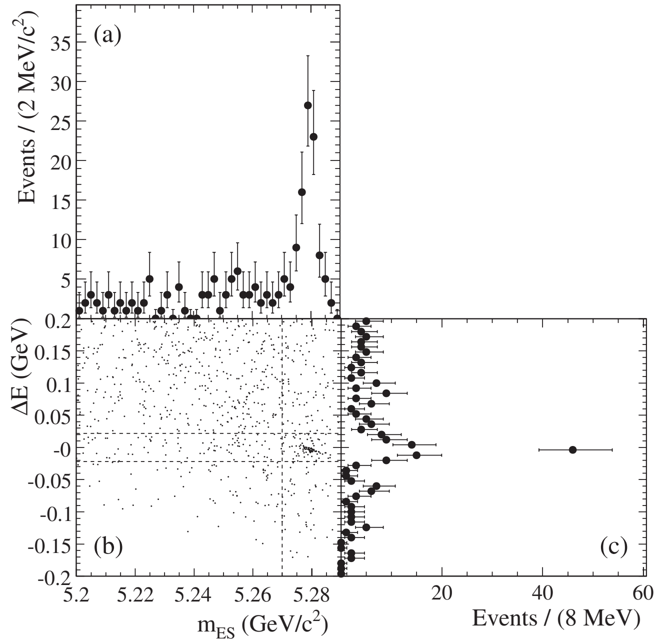

FIG. 1. The m_{ES} and ΔE distributions for $B^- \to \Lambda_c^+ \bar{\Lambda}_c^- K^-$ candidates, summing over five different final states. Plot (b) shows the scatterplot of m_{ES} vs ΔE, and (a) and (c) show the m_{ES} and ΔE projections for $|\Delta\mathrm{E}| < 0.022$ GeV and for $\mathrm{m_{ES}} > 5.27$ GeV/c^2, respectively. The dashed horizontal and vertical lines in (b) indicate the signal regions used for the projection in (a) and (c), respectively.

In studies of the Ξ_c and Λ_c mass sidebands, we find no evidence for these processes and conclude that their contribution is negligible.

Another important source of background is feed-down from related processes. The B meson can undergo a quasi-two-body decay via an excited charmed baryon such as $\bar{B} \to \Xi_c^* \bar{\Lambda}_c^-$, or a nonresonant multibody decay such as $\bar{B} \to \Xi_c \bar{\Lambda}_c^- \pi$. These events have similar distributions to the signal for m_{ES} and the charmed baryon invariant masses, but are displaced in ΔE by an amount that depends on the final state but is generally more than 50 MeV. We remove these backgrounds by requiring that signal candidates satisfy $|\Delta\mathrm{E}| < 22$ MeV. Finally, we require $5.2 < \mathrm{m_{ES}} < 5.3$ GeV/c^2. The average number of reconstructed B candidates per selected event varies between 1.00 and 1.14 depending on the final state. In events with more than one candidate, the one with the smallest $|\Delta\mathrm{E}|$ is chosen. We verify with MC and events from data sidebands that this does not introduce any bias in the signal extraction. Studies of simulated events show that 1%–3% of signal events are incorrectly reconstructed with one or more tracks originating from the other B in the event; this effect is taken into account implicitly by the efficiency correction described later.

The signal yields are extracted from an unbinned extended maximum likelihood fit to the m_{ES} distribution. We use separate probability density functions (PDFs) for signal and background events. The likelihood function for the N candidates in the event sample is given by

$$\mathcal{L} = \frac{e^{-(n_S+n_B)}}{N!} \prod_{i=1}^{N} (n_S \mathcal{P}_S(\mathrm{m_{ES}}_i) + n_B \mathcal{P}_B(\mathrm{m_{ES}}_i)), \quad (1)$$

where S here denotes the signal and B the background, $\mathcal{P}$ is the PDF (normalized to unit integral), and n is the yield. The signal PDF is parametrized as a Gaussian function with σ fixed to a value obtained from a fit to simulated signal events. The Gaussian mean is also fixed to the value obtained with simulated signal events, except for $B^- \to \Lambda_c^+ \bar{\Lambda}_c^- K^-$ where there is sufficient signal in the data to fit this parameter. The background PDF is parametrized as an ARGUS function [19]. We allow the ARGUS shape parameter to vary within a physically reasonable range in the fit to the data.

The fitted m_{ES} distributions of the four final states are shown in Fig. 2. Clear signals are seen in the $B^- \to \Lambda_c^+ \bar{\Lambda}_c^- K^-$ and $B^- \to \Xi_c^0 \bar{\Lambda}_c^-$ decay modes. A measure of the significance of each peak is given by $S = \sqrt{2\Delta \ln \mathcal{L}}$ [1], where $\Delta \ln \mathcal{L}$ is the difference in likelihood (incorporating the fitting systematic uncertainty) for fits where the signal yield is allowed to vary and where it is fixed to zero, respectively. The results of the fits are shown in Table I.

The efficiency is determined by applying the same analysis procedure to simulated signal events. For the three-body B-meson decays, the efficiency depends upon the distribution in the Dalitz plane. We weight the simulated events to reproduce the efficiency-corrected, background-subtracted distribution seen in data for $B^- \to \Lambda_c^+ \bar{\Lambda}_c^- K^-$. As a cross-check, we also compute the efficiency assuming a phase-space distribution and find a difference of less than 10% in each case.

We then obtain each branching fraction as

$$\mathcal{B}(\bar{B} \to X_c \bar{\Lambda}_c^- [\bar{K}]) = \frac{\sum_j n_{Sj}}{N_{\bar{B}} \sum_j (\varepsilon_j \prod_i \mathcal{B}_{ij})} \quad (2)$$

where X_c is the charmed baryon (Λ_c^+, Ξ_c^0, or Ξ_c^+), n_{Sj} is the signal yield extracted from the fit to the data for the j^{th} submode, $\prod_i \mathcal{B}_{ij}$ is the product of the daughter branching fractions, $N_{\bar{B}}$ is the number of neutral or charged B mesons, and ε_j is the signal detection efficiency. We assume equal decay rates of the $\Upsilon(4S)$ to B^+B^- and $B^0\bar{B}^0$ [1].

The branching fraction $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$ has been measured previously to be $(5.0 \pm 1.3)\%$ [1]. Because the branching fractions of Ξ_c^0 and Ξ_c^+ decays have not been determined experimentally, we quote the products of the

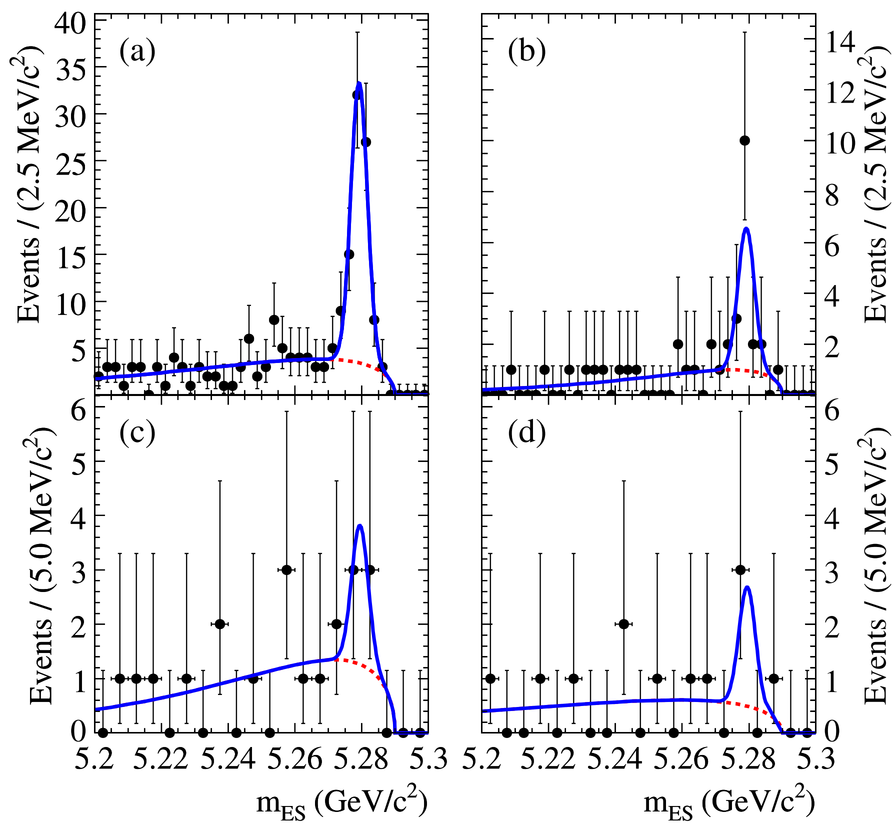

FIG. 2 (color online). The fitted m_{ES} distributions observed for the decay modes (a) $B^- \to \Lambda_c^+ \bar{\Lambda}_c^- K^-$, combining 5 exclusive final states; (b) $B^- \to \Xi_c^0 \bar{\Lambda}_c^-$, combining 2 exclusive final states; (c) $\bar{B}^0 \to \Xi_c^+ \bar{\Lambda}_c^-$; (d) $\bar{B}^0 \to \Lambda_c^+ \bar{\Lambda}_c^- \bar{K}^0$. Points with error bars represent the data, dashed lines the background PDF, and solid lines the sum of the signal and background PDFs.

TABLE I. Fitted signal yield, detection efficiency ε, significance S, measured branching fraction $\mathcal{B}$, and (for $S < 2$) the upper limit on $\mathcal{B}$ for each decay mode. The uncertainties on $\mathcal{B}$ are statistical, systematic, and the uncertainty from the branching fraction $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$. For final states containing Ξ_c^0 or Ξ_c^+, $\mathcal{B}$ includes a factor of $\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)$ or $\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+)$, respectively.

Decay mode	Signal yield	ε (%)	S	$\mathcal{B}$	Upper limit on $\mathcal{B}$
$B^- \to \Lambda_c^+\bar{\Lambda}_c^- K^-$	74.6 ± 9.8	⋯	9.6	$(1.14 \pm 0.15 \pm 0.17 \pm 0.60) \times 10^{-3}$	
$\Lambda_c^+ \to pK^-\pi^+$, $\bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$	42.7 ± 7.7	7.1	7.1	$(1.07 \pm 0.19 \pm 0.16 \pm 0.56) \times 10^{-3}$	
$\Lambda_c^+ \to pK^-\pi^+$, $\bar{\Lambda}_c^- \to \bar{p}K_S^0$	14.5 ± 4.0	8.8	5.9	$(1.81 \pm 0.50 \pm 0.30 \pm 0.94) \times 10^{-3}$	
$\Lambda_c^+ \to pK_S^0$, $\bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$	11.4 ± 3.7	8.8	4.8	$(1.42 \pm 0.45 \pm 0.24 \pm 0.74) \times 10^{-3}$	
$\Lambda_c^+ \to pK^-\pi^+$, $\bar{\Lambda}_c^- \to \bar{\Lambda}\pi^-$	2.5 ± 1.8	6.3	2.0	$(0.55 \pm 0.40 \pm 0.09 \pm 0.28) \times 10^{-3}$	
$\Lambda_c^+ \to \Lambda\pi^+$, $\bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$	3.5 ± 2.0	6.4	2.7	$(0.74 \pm 0.43 \pm 0.12 \pm 0.38) \times 10^{-3}$	
$B^- \to \Xi_c^0\bar{\Lambda}_c^-$	14.0 ± 4.4	⋯	6.4	$(2.08 \pm 0.65 \pm 0.29 \pm 0.54) \times 10^{-5}$	
$\Xi_c^0 \to \Xi^-\pi^+$, $\bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$	8.0 ± 2.8	4.3	6.1	$(2.51 \pm 0.89 \pm 0.29 \pm 0.65) \times 10^{-5}$	
$\Xi_c^0 \to \Lambda K^-\pi^+$, $\bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$	6.0 ± 3.4	4.5	2.1	$(1.70 \pm 0.93 \pm 0.30 \pm 0.44) \times 10^{-5}$	
$\bar{B}^0 \to \Xi_c^+\bar{\Lambda}_c^-$	2.8 ± 2.0	2.6	1.8	$(1.50 \pm 1.07 \pm 0.20 \pm 0.39) \times 10^{-5}$	$<5.6 \times 10^{-5}$ @ 90% C.L.
$\bar{B}^0 \to \Lambda_c^+\bar{\Lambda}_c^-\bar{K}^0$	3.3 ± 2.7	4.4	1.4	$(0.38 \pm 0.31 \pm 0.05 \pm 0.20) \times 10^{-3}$	$<1.5 \times 10^{-3}$ @ 90% C.L.

branching fractions, $\mathcal{B}(B^- \to \Xi_c^0\bar{\Lambda}_c^-) \times \mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)$ and $\mathcal{B}(\bar{B}^0 \to \Xi_c^+\bar{\Lambda}_c^-) \times \mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+)$. For the $\Xi_c^0 \to \Lambda K^-\pi^+$ decay mode we scale the measured branching fraction by the ratio $\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)/\mathcal{B}(\Xi_c^0 \to \Lambda K^-\pi^+) = 1.07 \pm 0.14$ [1] so that its value can also be expressed as the product of the same two branching fractions.

For each decay mode, Table I gives the values of n_S, ε, the significance, and the branching fraction. For each mode with a significance below 2 standard deviations, we calculate the Bayesian upper limit [1] on the branching fraction including systematic uncertainties and obtain $\mathcal{B}(\bar{B}^0 \to \Lambda_c^+\bar{\Lambda}_c^-\bar{K}^0) < 1.5 \times 10^{-3}$ and $\mathcal{B}(\bar{B}^0 \to \Xi_c^+\bar{\Lambda}_c^-) \times \mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+) < 5.6 \times 10^{-5}$ at the 90% confidence level.

Table II lists the main systematic uncertainties and their sum in quadrature. The largest uncertainty is from the charged track reconstruction efficiency, evaluated with control samples of τ decays. A small correction is also included due to a known data/MC difference in tracking efficiency. Other sources of systematic uncertainty considered include: the number of $B\bar{B}$ pairs in the data sample; the limited size of the signal MC samples; the PID efficiency, which is evaluated with control samples of $\Lambda \to p\pi^-$, $D^{*+} \to D^0(K^-\pi^+)\pi^+$, and $\phi \to K^+K^-$ decays; possible differences in ΔE resolution between data and MC, which are estimated with control samples of $\bar{B} \to D\bar{D}\bar{K}$ decays; charmed baryon branching ratios relative to the control modes [1]; the Λ branching fraction [1]; the presence of intermediate resonances in the charmed baryon decay and possible structure in the 3-body B-meson decays; and the assumption that $\mathcal{B}(\Upsilon(4S) \to B^0\bar{B}^0) = \mathcal{B}(\Upsilon(4S) \to B^+B^-) = 0.5$. For fit parameters which are fixed to values from fits to the signal MC, we vary the value by the uncertainty and take the largest change as a systematic uncertainty. Dividing out the absolute Λ_c^+ branching fraction also introduces a large systematic uncertainty, which we quote separately.

TABLE II. Summary of relative systematic uncertainties (%) on the branching fractions (BFs). The uncertainty on the Λ_c^+ BF is 26% and is quoted separately.

Source	$\Lambda_c^+\bar{\Lambda}_c^-K^-$	$\Xi_c^0\bar{\Lambda}_c^-$	$\Xi_c^+\bar{\Lambda}_c^-$	$\Lambda_c^+\bar{\Lambda}_c^-\bar{K}^0$
Tracking efficiency	9.9	10.0	11.4	11.4
B counting	1.1	1.1	1.1	1.1
MC sample size	0.8	1.6	2.4	1.5
PID efficiency	4.6	3.5	3.0	4.0
ΔE resolution	3.0	3.0	3.0	3.0
Intermediate BFs	3.4	6.9	0.8	0.1
$\Lambda_c^+ \to pK^-\pi^+$ Dalitz	2.9	1.8	1.8	3.6
$B \to \Lambda_c^+\bar{\Lambda}_c^-K$ Dalitz	6.9	⋯	⋯	4.2
$\Upsilon(4S)$ BF	3.0	3.0	3.0	3.0
Fit related	2.0	1.4	3.5	2.5
Total	14.5	13.7	13.4	14.3

To investigate whether the three-body mode $B^- \to \Lambda_c^+\bar{\Lambda}_c^-K^-$ contains intermediate resonances, we examine the Dalitz plot structure of candidates in the signal region ($m_{ES} > 5.27\ \mathrm{GeV}/c^2$), shown in Fig. 3. After taking into account the expected background (estimated from the m_{ES} sidebands), the $\Lambda_c^+K^-$ mass spectrum of the data is inconsistent with a phase-space distribution (χ^2 probability of 1.5×10^{-7}). Fitting the data with a single, nonrelativistic Breit-Wigner line shape convolved with a Gaussian function for experimental resolution, we obtain $m = 2931 \pm 3(\mathrm{stat}) \pm 5(\mathrm{syst})\ \mathrm{MeV}/c^2$ and $\Gamma = 36 \pm 7(\mathrm{stat}) \pm 11(\mathrm{syst})$ MeV. We do not see any such structure in the m_{ES} sideband region. This description is in good agreement with the data (χ^2 probability of 22%) and could be interpreted as a single Ξ_c^0 resonance with those parameters, though a more complicated explanation (e.g. two narrow resonances in close proximity) cannot be excluded. Because of the limited statistics, the helicity angle distribution does not distinguish between spin hypotheses.

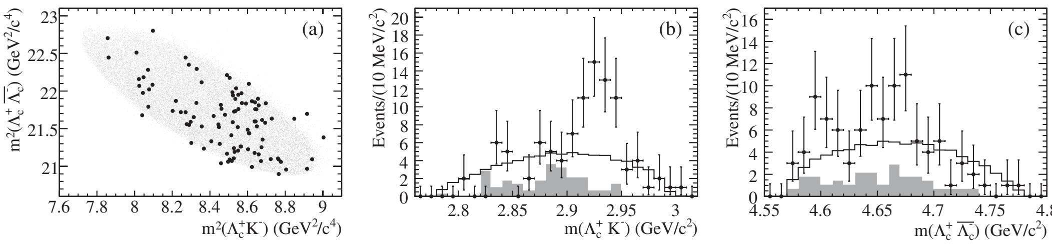

FIG. 3. Reconstructed $B^- \to \Lambda_c^+ \bar{\Lambda}_c^- K^-$ candidates in the signal region ($m_{ES} > 5.27$ GeV$/c^2$, $\Delta E < 22$ MeV), shown as (a) the Dalitz plot, (b) the $\Lambda_c^+ K^-$ invariant mass distribution, and (c) the $\Lambda_c^+ \bar{\Lambda}_c^-$ invariant mass distribution. Data from the signal region are shown as black points. Signal events from a phase-space simulation are shown as small gray points in (a) and as a histogram in (b) and (c). Data from the sideband region $5.20 < m_{ES} < 5.26$ GeV$/c^2$ are shown as a shaded histogram in (b) and (c), normalized according to the expected background yield in the signal region. The masses of the B-meson candidates are not constrained.

In summary, we have studied B-meson decays to charmed baryon pairs in four decay modes using a sample of 230×10^6 $\Upsilon(4S) \to B\bar{B}$ events. The measured branching fractions are consistent with the previous values within uncertainties [9,10]. The branching fraction of $B^- \to \Lambda_c^+ \bar{\Lambda}_c^- K^-$ is found to be comparable to the $\mathcal{O}(10^{-3})$ branching fraction predicted for two-body decays to a pair of charmed baryons. The data in the Dalitz plot and two-body mass projections are inconsistent with a phase-space distribution and suggest the presence of a Ξ_c^0 resonance in the decay.

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