ARTICLES

Study of flavor-tagged baryon production in B decay

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Using data collected on the $\Upsilon(4S)$ resonance and the nearby continuum by the CLEO-II detector, we have studied combinations of baryons with leptons produced in the process $\Upsilon(4S)\to B\bar{B}$, $B\to$lepton$+X$, $B\to$baryon$+X$. Our results do not support models which attribute the bulk of Λ_c production in B decay to the process $b\to cW^-, W^-\to\bar{c}s$. [S0556-2821(97)03701-6]

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I. INTRODUCTION

Among the challenges in heavy quark physics today is the resolution of the discrepancy between the measured B-meson semileptonic branching fraction and the number of charms generated per B-meson decay. In order to accommodate the experimental value for $\mathcal{B}(B\to l+X)$ of 10.4% [1,2], theoretical estimates of the semileptonic width result in the expectation that the number of charms per B decay be around 1.3 [3], while the measured number is 1.10 ± 0.06 [2]. Dunietz *et al.* [4] suggest that theory has, to date, underestimated the B-hadronic width by neglecting B-decay channels to baryonic final states, and that the existence of a substantial fraction of B decays to baryonic states might resolve the situation.

Figure 1 shows some of the possible mechanisms for baryon production in B decay.[1] In the simplest ''external spectator'' picture [Fig. 1(a)], the W^- decays into a light fermion-antifermion pair; baryon production occurs when two quark-antiquark pairs are created from the vacuum and bind with the charmed quark and the spectator quark to form a Λ_c^+ (cud) plus an antinucleon N at the lower vertex. (Higher excitations of the ground state baryons can also be formed. By ''Λ_c'' and ''Ξ_c'' in the figure, we implicitly include all such excitations. For example, Σ_c's could also be produced in this process. All Σ_c's decay strongly by pion emission to Λ_c.) In the case where one of the popped $q\bar{q}$ pairs is an $s\bar{s}$ pair, production of a Ξ_c results. Although external W emission with $W^-\to\bar{c}s$ can contribute to baryon production [Fig. 1(b)], it is expected to be severely phase space suppressed due to the large minimum hadronic mass ($\sim$5.2 GeV) of the final state. Past determinations of quantities such as the inclusive branching fraction $\mathcal{B}(\Lambda_c\to\Lambda+X)$ using B-decay data assumed that charmed baryons were exclusively produced as B-decay products through Fig. 1(a) [5–7].

In principle, ''internal'' W emission could also account for a substantial fraction of the Λ_c's and Ξ_c's produced in B decay, with either $W^-\to\bar{u}d$ [Fig. 1(c)] or $W^-\to\bar{c}s$ [Fig. 1(d)]. The usual color matching constraints, which suppress the internal spectator diagram in the mesonic sector, are less important in the baryonic case, owing to the color degrees of freedom of the popped $q\bar{q}$ pair [4]. The internal spectator diagrams may also be favored in baryon production since only one $q\bar{q}$ pair needs to be created from the vacuum, compared to two $q\bar{q}$ pairs needed to produce baryons via the external W-emission diagram.

In the model of Dunietz *et al.*, $\bar{B}$ decays to charmed baryons are nearly saturated by the internal W-emission transition $b\to c\bar{c}s$. This also leads to a soft Λ_c momentum spectrum in B decay, consistent with observation [8]. Inspection of Fig. 1(d) shows that the $b\to c\bar{c}s$ transition has a clean signature: when a B meson decays via this diagram a Λ_c^- is produced. On the other hand, when a $\bar{B}$ meson decays via one of the other diagrams in Fig. 1, a Λ_c^+ is produced. Figures 1(a) and 1(c) are therefore expected to be the dominant sources of Λ_c^+'s in B decay, and Fig. 1(d) is expected to produce Λ_c^-'s.

Although Λ_c's have previously been observed in $\Upsilon(4S)$ decays by both ARGUS and CLEO, Λ_c's from B's have not previously been separated from Λ_c's produced in B decay. In this paper we will make this separation. We can separate Λ_c's produced in B meson decay from those produced in B meson decay by tagging the flavor of the other B meson in the event. This can be achieved by requiring a high momentum lepton ($p_\ell>1.4$ GeV/c) to also be in the event. With this technique, a correction needs to be made to account for $B\bar{B}$ mixing [we assume $\Upsilon(4S)\to B^+B^-/\Upsilon(4S)\to B^0\bar{B}^0=1.0$ in making this correction]. The minimum p_ℓ requirement rejects events in which both the Λ_c and the lepton come from the same B, as in $B\to\Lambda_c N l\nu$ decays. It also rejects leptons produced by the two step process $b\to cX$, $c\to\ell X$ (cascade leptons). Hence, in $B\bar{B}$ events, $\Lambda_c^-\ell^+$ pairs tag the decay $B\to\Lambda_c^- X$, whereas $\Lambda_c^+\ell^+$ pairs tag the process $\bar{B}\to\Lambda_c^+ X$.

Experimentally, we thus measure the ratio of rates, R_{Λ_c}:

$$R_{\Lambda_c}=\frac{N_{\Lambda_c^-\ell^+}}{N_{\Lambda_c^+\ell^+}}=\frac{\mathcal{B}(\bar{B}\to\bar{\Lambda}_c^- X)\mathcal{B}(B\to X\ell^+\nu_\ell)}{\mathcal{B}(\bar{B}\to\Lambda_c^+ X)\mathcal{B}(B\to X\ell^+\nu_\ell)}.$$

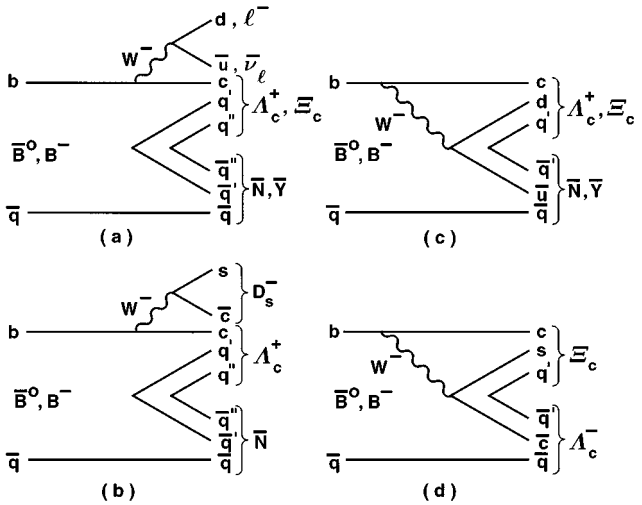

FIG. 1. External (top, left) and internal (top, right) $W\to\bar{u}d$ graphs representing $\bar{B}\to\Lambda_c X$ decays. Also shown are the corresponding plots for the case $W\to\bar{c}s$ (bottom, left and bottom, right, respectively). In the figure, ''Λ_c'' implicitly includes contributions from Σ_c's, N denotes nucleons, and Y denotes hyperons. It is expected that limited phase space severely suppresses Fig. 1(b).

[1]Charge conjugate modes are implicit.

In this ratio many important experimental systematics cancel. Provided that the only significant sources of charmed baryons in B decay are those in Figs. 1(a), 1(c), and 1(d), the ratio R_{Λ_c} is a measure of the fraction of charmed baryons produced via $b\to c\bar{c}s$ relative to the fraction produced via $b\to c\bar{u}d$ [9].

In this paper, we have attempted to separate Λ_c^+ from $\bar{\Lambda}_c^-$ production in B decay. Using a data sample of events containing both a high momentum lepton and a baryon, we have thereby measured the fraction of charmed baryons produced through $b\to c\bar{c}s$ in B-meson decay from the sign correlation between the lepton and the baryon.

In a similar study, we have used a high momentum lepton tag to separate the processes $B\to\Lambda X$ and $B\to\bar{\Lambda}X$. The result of this study is expressed as a measurement of the ratio R_Λ, defined analogously to the ratio R_{Λ_c}. Inspection of Fig. 1 shows that, in B decay, Λ's can only be produced as decay products of the B, via the processes $\Lambda_c\to\Lambda X$ and $\Xi_c\to\Lambda X$. On the other hand, $\bar{\Lambda}$'s can be produced directly in B decay, [Figs. 1(a) and 1(b)], or they can be produced in the decay of the $\bar{\Lambda}_c^-$ [Fig. 1(d)]. Therefore, in B decay, we expect Λ's to be produced in association with Ξ_c's. A nonzero value of R_Λ thereby provides support for our preliminary observation of Ξ_c production in B meson decay [10]. Notice that in the case of Λ-lepton pairs, our ability to draw firm, quantitative conclusions on the mechanism responsible for charmed baryon decay is compromised by unknowns such as the inclusive rates for $\Xi_c\to\Lambda X$ and $\Lambda_c\to\Lambda X$, the unknown $s\bar{s}$ popping fraction in B-decay, and the extent to which background processes such as $B\to D\Lambda\Lambda X$, in which the W produces baryons in its decay, might contaminate the Λ-lepton pairs we observe.

II. DATA SAMPLE AND CANDIDATE SELECTION

The CLEO-II detector is discussed in detail elsewhere [11]. This analysis involves mainly the central tracking system, consisting of two precision vertex chambers and a cylindrical wire drift chamber, all inside a 1.5 T axial magnetic field. Outside the drift chamber is a time-of-flight (TOF) system, which is used, in conjunction with specific ionization measurements in the drift chamber, for particle identification. Beyond the TOF is the CsI electromagnetic calorimeter, followed by the magnet solenoid, iron hadron absorber, and drift planes for muon detection. The integrated luminosities of the $\Upsilon(4S)$ resonance and continuum data used for this analysis total 2036 pb^{-1} and 967 pb^{-1}, respectively, corresponding to $(2.19\pm0.04)\times10^6$ produced $B\bar{B}$ pairs.

We reconstruct Λ_c candidates in the four decay modes $\Lambda_c\to pK\pi^-$, $\Lambda_c\to pK_S^0$ $\Lambda_c\to\Lambda\pi$, and $\Lambda_c\to\Sigma^0\pi(\Sigma^0\to\Lambda\gamma)$, using methods similar to previous studies of Λ_c production in B decay [12]. The Λ candidates are reconstructed in the decay mode $\Lambda\to p\pi$, by requiring the $p\pi$ to form a detached vertex. K_S^0 candidates are similarly reconstructed by searching for detached vertices consistent with $K_S^0\to\pi^+\pi^-$. After subtracting contributions using scaled off-resonance data, we obtain a total sample of 3154 ± 160 $\Lambda_c^\pm$ candidates from $B\bar{B}$ decays.

Candidate Λ_c's are also restricted to have momenta less than 2.3 GeV/c, corresponding to the maximum allowed Λ_c momentum for $B\to\Lambda_c X$. Leptons used as flavor tags are required to have momenta in the range $1.4<p_\ell<2.4$ GeV/c, where the minimum momentum cut is needed to suppress the backgrounds discussed above and where the maximum momentum is the end point for leptons produced via $b\to\bar{c}\ell^+\nu$. The lepton identification criteria are described in Refs. [11,13]. Lepton candidates are restricted to the angular region $|\cos\theta_\ell|\leq0.71$ for electrons and $|\cos\theta_\ell|\leq0.61$ for muons, where θ_ℓ is the polar angle with respect to the beam axis. Muon candidates are required to penetrate at least five nuclear absorption lengths into the iron hadron absorber. Electron identification relies on E/p measurements, derived from the calorimeter and drift chamber, as well as on specific ionization measurements. The requirement of $\ln(P_e/P_{\ell})\geq3.0$ is imposed, where P_e (P_{ℓ}) is the probability that a given charged track is an electron (not an electron).

A. Experimental study of Λ_c-lepton pairs

Each Λ_c candidate, selected as described above, is then paired with each lepton candidate in the event. Figures 2(a) and 2(b) show the Λ_c invariant mass distributions for $\bar{\Lambda}_c^-\ell^+$ and $\Lambda_c^+\ell^+$ pairs, respectively. The distributions from resonance data are shown as points, whereas the distributions from scaled continuum data are displayed as shaded histograms.

To determine Λ_c yields, we fit mass distributions to a Gaussian signal, with width fixed according to Monte Carlo simulations, plus a smooth, low-order polynomial background. We observe 50 ± 15 $\bar{\Lambda}_c^-\ell^+$ and 143 ± 15 $\Lambda_c^+\ell^+$ pairs in the resonance data, and 7 ± 7 $\bar{\Lambda}_c^-\ell^+$ and 2 ± 6 $\Lambda_c^+\ell^+$ pairs in the scaled continuum data. After continuum

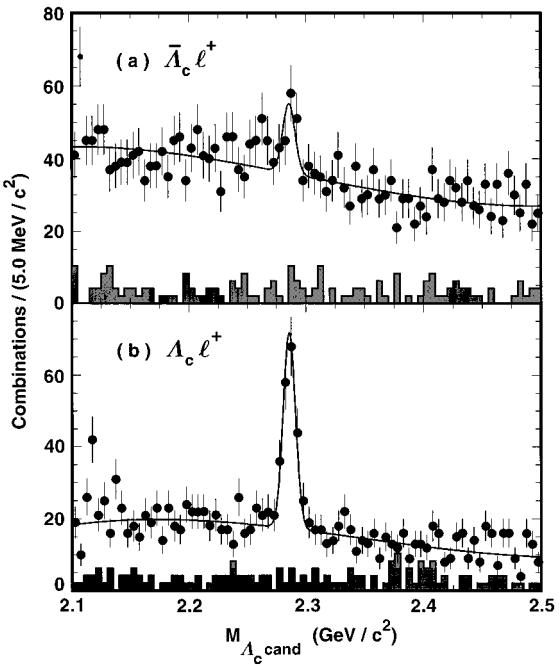

FIG. 2. The Λ_c invariant mass distributions from resonance data (shown as points) and scaled continuum (shaded histograms) for the case of (a) $\bar{\Lambda}_c^-\ell^+$, and (b) $\Lambda_c^+\ell^+$.

TABLE I. Summary of observed baryon-lepton pair events, and corrections. ''Lepton backgrounds'' includes contributions from both fake leptons as well as from secondary leptons produced by $b\to cX, c\to s l^+\nu_l$. Lepton tags are required to have $p_{\ell}>1.4$ GeV; for the Λ-lepton study, we require all Λ candidates to have a measured momentum in excess of 200 MeV/c (see text).

Pair	$B\overline{B}$ raw yield	Mean $\Lambda_{(c)}$ momentum $\langle p\rangle$ (GeV/c)	Lepton backgrounds	$R_{\Lambda_{(c)}}$ ratio (efficiency corrected)	$R_{\Lambda_{(c)}}$ ratio (efficiency + mixing corrected)
$\overline{\Lambda}_c^-\ell^+$	43 ± 16	0.67 ± 0.10	-7 ± 3		
$\Lambda_c^+\ell^+$	141 ± 16	0.87 ± 0.07	-3 ± 2	0.26 ± 0.12	$0.19\pm0.13\pm0.04$
$\overline{\Lambda}\ell^+$	436 ± 50	0.67 ± 0.04	-16 ± 3		
$\Lambda\ell^+$	992 ± 54	0.84 ± 0.03	-18 ± 3	0.52 ± 0.08	$0.43\pm0.09\pm0.07$

subtraction, we obtain 43 ± 16 $\overline{\Lambda}_c^-\ell^+$ and 141 ± 16 $\Lambda_c^+\ell^+$ pairs. The largest sources of backgrounds in our high momentum lepton sample are hadrons faking leptons, cascade leptons, and leptons from charmonium decay. After subtracting these backgrounds, we arrive at 36 ± 16 $\overline{\Lambda}_c^-\ell^+$ and 137 ± 16 $\Lambda_c^+\ell^+$ pairs. The Λ_c efficiency is flat as a function of momentum, so the ratio of $\overline{\Lambda}_c^-\ell^+$ pairs to $\Lambda_c^+\ell^+$ pairs is directly determined to be 0.26 ± 0.12. Correcting for the effect of $B^0\overline{B}^0$ mixing [14], we obtain a final value $R_{\Lambda_c}=0.19\pm0.13\pm0.04$. The signal, background and mixing corrections are summarized in Table I.

The systematic error includes contributions from uncertainties in the fitting procedure used to extract the number of $\overline{\Lambda}_c^-\ell^+$ and $\Lambda_c^+\ell^+$ pairs and from the uncertainty in the mixing probability. Each of these sources contributes a relative systematic uncertainty of roughly 10%.[2]

As a check that the Λ_c and the lepton are daughters of different B's, we have examined the distribution of $\cos\theta_{\Lambda_c\ell}$, defined as the cosine of the angle between the Λ_c candidate and the lepton in the laboratory. Since the B and the $\overline{B}$ are produced almost at rest in the laboratory frame, and since they both decay isotropically, there should be no angular correlation between the decay products of different B's. To check this, the Λ_c yield was extracted in four bins of $\cos\theta_{\Lambda_c\ell}$ and the distribution of $dN/d(\cos\theta_{\Lambda_c\ell})$ was plotted. Fitting these distributions to flat lines gives confidence levels of 62% and 68%, respectively, for $\Lambda_c^+\ell^-$ and the $\overline{\Lambda}_c^-\ell^-$, consistent with expectation. The flatness of this distribution thus supports our presumption that there is very little background to our observed pairs from processes such as $B\to\Lambda_c N\ell\nu_\ell$. Given the 1.4 GeV minimum momentum cut that we have applied on the lepton tag, we would expect such decays to result in the Λ_c and the lepton being opposite one another. Our data do not show evidence for such peaking.

This value of R_{Λ_c} is a measure of the production rate of charmed baryons in B decay from $b\to c\overline{c}s$ relative to $b\to c\overline{u}d$ processes. Based on the R_{Λ_c} value of $19\pm13\%$, we conclude that the internal spectator $b\to c\overline{c}s$ process is not the dominant source of charmed baryons produced in decays of bottom mesons.

[2]We have implicitly assumed that $\Gamma(\overline{B}^0\to\Lambda_c^\pm X)=\Gamma(B^+\to\Lambda_c^\pm X)$.

B. Experimental study of lambda-lepton pairs

As discussed above, correlations between Λ's and high-momentum leptons also give information on baryon production in B decays. In particular, a nonzero measured rate for $\overline{\Lambda}\ell^+$ thus provides some evidence for Ξ_c production in B decay. Leptons are selected in the same fashion as for the $\Lambda_c\ell$ pair study described previously. Additionally, to suppress continuum contributions, a cut on the event topology has been made to preferentially select spherical events, as expected for threshold production of $B\overline{B}$ pairs, rather than jetty continuum $q\overline{q}$ events. Since our efficiency for Λ reconstruction drops rapidly for Λ momenta below 0.2 GeV/c (due to the small decay length of the Λ), we require $p_\Lambda>0.2$ GeV/c. All numbers quoted for Λ-lepton pairs, including R_Λ, are for $p_\Lambda>0.2$ GeV/c.

Figure 3 shows the $p\pi$ invariant mass spectrum for $\overline{\Lambda}\ell^+$ or $\Lambda\ell^+$ combinations. As before, yields are extracted by fitting the invariant mass spectrum to Monte Carlo-derived Gaussian signal shapes plus smooth polynomial backgrounds. The yields and background estimates for the $\Lambda\ell$ study are displayed in Table I. Unlike the Λ_c case, how-

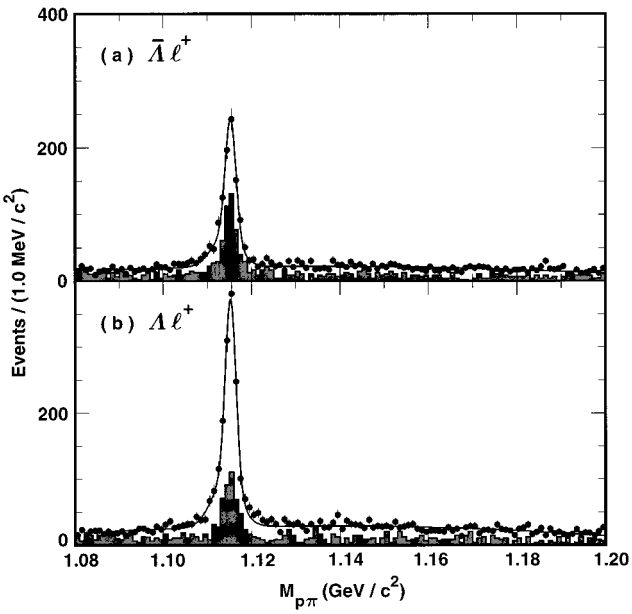

FIG. 3. The $p\pi$ invariant mass distributions from resonance data (shown as points) and scaled continuum (shaded histograms) for the case of (a) $\overline{\Lambda}\ell^+$ and (b) $\Lambda\ell^+$.

ever, there is a momentum-dependent efficiency correction which must be applied to our observed Λ-lepton pair sample to determine the final value of R_Λ. Since the $B\to\Lambda X$ momentum spectrum is softer than the $B\to\Lambda X$ momentum spectrum, the efficiency for finding $\Lambda\ell^+$ events is $\approx 85\%$ of that of $\Lambda\ell^+$ events.

As presented in Table I, the corrected ratio of R_Λ is measured to be $0.43\pm0.09\pm0.07$ (for $p_\Lambda>0.2$ GeV). The systematic error shown in R_Λ includes uncertainties in yields from fitting the Λ signal (10% relative error), in the cuts used in event selection (7% relative error), and in the mixing parameter (10% relative error). As a check that the Λ and lepton are daughters of different B's, we have examined the angular distribution between the Λ and lepton in both the $\Lambda\ell^+$ and $\Lambda\ell^+$ samples. Both distributions are consistent with being flat (at the 34% and the 79% confidence level, respectively), as expected if the Λ and lepton originate from opposite B's.

In the case of Λ-lepton pairs, we see approximately the same ℓ^+ to $\Lambda\ell^+$ ratio as observed for Λ_c's. Qualitatively, the smallness of R_Λ again suggests that $B\to\Xi_c\bar{\Lambda}_c^-$ processes are not a dominant source of charmed baryons in B decay. However, the large $\Lambda\ell$ rate provides confirmation, albeit indirect, of the observation of Ξ_c production in B decay [10].

C. Baryon momentum spectra

We have studied both the Λ and the Λ_c momentum spectra in our lepton-tagged samples. If the bulk of $\bar{\Lambda}_c^-$'s produced in B decay are produced via $b\to c\bar{c}s$, then the mass recoiling against the Λ_c^- should be larger than that recoiling against the Λ_c^+. Therefore the inclusive momentum spectrum of the $\bar{\Lambda}_c^-$ from the decay $B\to\bar{\Lambda}_c^-X$ should be softer than that of the Λ_c from the decay $B\to\Lambda_c^+X$.

Using our lepton-tagged sample, we have measured the mean Λ_c momentum in our $\Lambda_c^+\ell^+$ events to be 0.87 ± 0.07 GeV/c, compared with 0.67 ± 0.10 GeV/c for our $\bar{\Lambda}_c^-\ell^+$ sample. Similarly, we measure the mean Λ momentum in our continuum-subtracted event sample for $\Lambda\ell^+$ events to 0.84 ± 0.03, compared with 0.67 ± 0.04 for $\bar{\Lambda}\ell^+$ events [15]. These results are consistent with the interpretation that different processes are producing Λ_c^+'s vs $\bar{\Lambda}_c^-$'s in B-meson decay, with a larger mass object recoiling against the $\bar{\Lambda}_c^-$ than against the Λ_c^+. However, they do not establish this interpretation on their own.

III. SUMMARY

By examining events containing both a high momentum lepton as well as a baryon, we have made the first separation of the two processes $B\to\Lambda_c^+X$ and $B\to\bar{\Lambda}_c^-X$. Previously only the sum of these two processes had been measured. We have also made the first separation of the processes $B\to\Lambda X$ and $B\to\bar{\Lambda}X$. Our results are summarized in the ratios $R_{\Lambda_c}=0.19\pm0.13\pm0.04$ and $R_\Lambda=0.43\pm0.09\pm0.07$, respectively. The small value of R_{Λ_c} shows that the internal spectator process $b\to c\bar{c}s$ is not the dominant contribution to charmed baryon production in the decay of B mesons. On the other hand, the nonzero value of R_Λ provides an important consistency check for our preliminary observations of $\mathcal{B}(B\to\Xi_c^+X)\sim 1.5\pm0.7\%$ and $\mathcal{B}(B\to\Xi_c^0X)\sim 2.4\pm1.3\%$ (statistical errors only) from full reconstruction of Ξ_c's in B decay [10].

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[14] This is a nontrivial correction, and must properly take into account the quantum coherence of a $B^0\bar{B}^0$ system produced on the $\Upsilon(4S)$ resonance, as pointed out by L. Okun, V. Zakharov,

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$$\chi_d=\frac{N(B^0B^0)+N(\overline{B^0B^0})}{N(B^0B^0)+N(\overline{B^0B^0})+N(B^0\overline{B^0})}$$

and was measured [CLEO Collaboration, J. Bartelt *et al.*, Phys. Rev. Lett. **71**, 1680 (1993). We use the result based on the tagged sample of B^0 events and have combined all statistical and systematic sources of error in quadrature] to be $\chi_d=0.149\pm0.032$. Assuming that the $\Upsilon(4S)$ resonance decays to charged and neutral $B\overline{B}$ pairs in equal amounts, we get for the probability b of a mixed event in any $B\overline{B}$ decay to be

$$b=\frac{N(B^0B^0)+N(\overline{B^0B^0})}{N_{B\overline{B}}}=\tfrac{1}{2}\chi_d=0.075\pm0.016,$$

where $N_{B\overline{B}}$ stands for the total number of $B\overline{B}$ pairs produced. The observed numbers of Λ_c-lepton correlations are then given by

$$N_{\overline{\Lambda_c}^-l^+}=\tfrac{1}{2}N_{B\overline{B}}\epsilon_l\epsilon_{\Lambda_c}\mathcal{B}(B\to Xl^+\nu)[(1-b)\mathcal{B}(\overline{B}\to\overline{\Lambda_c}^-X)+b\mathcal{B}(B\to\overline{\Lambda_c}^-X)]$$

and

$$N_{\Lambda_c^+l^+}=\tfrac{1}{2}N_{B\overline{B}}\epsilon_l\epsilon_{\Lambda_c}\mathcal{B}(B\to Xl^+\nu)[(1-b)\mathcal{B}(\overline{B}\to\Lambda_c^+X)+b\mathcal{B}(B\to\Lambda_c^+X)],$$

where ϵ_l and ϵ_{Λ_c} stand for the total lepton and Λ_c reconstruction efficiencies, respectively. We have assumed here that $\Gamma(\overline{B^0}\to\Lambda_c^{\pm}X)=\Gamma(B^-\to\Lambda_c^{\pm}X)$. Making use of the equivalences $\mathcal{B}(\overline{B}\to\overline{\Lambda_c}^-X)=\mathcal{B}(B\to\Lambda_c^+X)$ and $\mathcal{B}(B\to\overline{\Lambda_c}^-X)=\mathcal{B}(\overline{B}\to\Lambda_c^+X)$, the observed ratio $R^{\rm obs}_{\Lambda_c}$ can be expressed as:

$$R^{\rm obs}_{\Lambda_c}=\frac{N_{\overline{\Lambda_c}^-l^+}}{N_{\Lambda_c^+l^+}}=\frac{(1-b)\mathcal{B}(B\to\Lambda_c^+X)+b\mathcal{B}(\overline{B}\to\Lambda_c^+X)}{(1-b)\mathcal{B}(\overline{B}\to\Lambda_c^+X)+b\mathcal{B}(B\to\Lambda_c^+X)}.$$

Introducing the ratio:

$$r_{\Lambda_c}=\frac{\mathcal{B}(\overline{B}\to\overline{\Lambda_c}^-X)}{\mathcal{B}(\overline{B}\to\overline{\Lambda_c}^-X)+\mathcal{B}(\overline{B}\to\Lambda_c^+X)},$$

we find for the observed ratio of Λ_c-lepton correlations:

$$R^{\rm obs}_{\Lambda_c}=\frac{(1-b)r_{\Lambda_c}+b(1-r_{\Lambda_c})}{(1-b)(1-r_{\Lambda_c})+br_{\Lambda_c}}.$$

Solving this equation for r_{Λ_c}, we find:

$$r_{\Lambda_c}=\frac{R^{\rm obs}_{\Lambda_c}(1-b)-b}{(1+R^{\rm obs}_{\Lambda_c})(1-2b)}.$$

Using $R^{\rm obs}_{\Lambda_c}=0.26\pm0.12$, we arrive at $r_{\Lambda_c}=0.157\pm0.089\pm0.026$. The quantity r_{Λ_c} is related to the sought after ratio R_{Λ_c} via:

$$R_{\Lambda_c}=\frac{\mathcal{B}(\overline{B}\to\overline{\Lambda_c}^-X)}{\mathcal{B}(\overline{B}\to\Lambda_c^+X)}=\frac{r_{\Lambda_c}}{1-r_{\Lambda_c}}=(19\pm13\pm4)\%.$$

[15] As these mean momenta are extracted using only the continuum-subtracted samples, there is no mixing correction that has been performed. Applying a mixing correction would have the effect of accentuating, rather than mitigating the difference between the measured mean momenta.