NEW RESULTS ON BARYON PRODUCTION IN B MESON DECAYS FROM THE CLEO II DETECTOR

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ABSTRACT

The CLEO II collaboration has made preliminary studies exploring baryon production in B meson decay using a data sample containing over two million events where $e^+e^- \to \Upsilon(4S) \to B\bar{B}$. Baryon-lepton correlation data imply that external W-emission does not saturate charmed baryon production in B meson decay. Further, these data and the observation of Ξ_c production indicate a contribution from $b \to cW^-$, $W^- \to \bar{c}s$. Finally, we measure $B(\bar{B}^0 \to \Lambda_c^+ \bar{p}\pi^+\pi^-) = (0.187 \pm 0.059 \pm 0.056 \pm 0.045)\%$.

1. Introduction

The B meson has been previously observed to decay into charmed baryons, specifically the Λ_c[1] and Σ_c.[2] This is the only meson system observed to decay into these baryons and little is understood about the mechanism. The simplest picture is the "external spectator", shown in Fig. 1(a) below. From such a picture one would expect a semileptonic contribution of about 10%, as is the case in decays to charmed mesons. Strange charmed baryons would result only from $s\bar{s}$ quark popping from the vacuum. The "internal spectator" of Fig. 1(b) would not result in semileptonic decays.

One puzzling feature of the previous data is the softness of the momentum spectrum of the charmed baryons from B decay. Figure 2 shows the spectrum for Λ_c's and the spectrum for Σ_c's is similarly soft. In Fig. 1, the W^- is shown as going to $\bar{u}d$, but it may also go to $\bar{c}s$ (and to Cabibbo suppressed combinations, which we ignore here). It has been suggested recently that the soft momentum spectrum could be explained if this $b \to c\bar{c}s$ transition dominates the B to baryons decay width.[3]

Here we present preliminary data bearing on the B to baryons mechanism using a high statistics sample taken with the CLEO II detector.[4] These results have been presented in more detail elsewhere.[5] Data were taken at the energy of the $\Upsilon(4S)$ resonance (2036 pb^{-1}) and just below that energy (967 pb^{-1}). This latter data sample is referred to as the "continuum" and is used to subtract non-$B\bar{B}$ contributions from the on-resonance data. There are $(2.19 \pm 0.04) \times 10^6$ $B\bar{B}$ pairs produced via $\Upsilon(4S)$ decay in our dataset.

Fig. 1. Graphs for (a) "external spectator" and (b) "internal spectator" decays of the B meson into charmed baryons. Θ_c represents a non-strange charmed baryon, Ξ_c a strange charmed baryon.

Fig. 2. Measured Λ_c momentum spectrum from B Decays compared to the shape expected from (a) $B \to \Xi_c \bar{\Lambda}_c$, $B \to \Xi_{c'} \bar{\Sigma}_c$, (b) $B \to \Lambda_c \bar{N}(m\pi)$ for $m = 0...4$.

2. Baryon-Lepton correlations

We observe 3154±160 Λ_c's coming from B decay in our dataset using four different Λ_c decay modes: $pK^-\pi^+$, $\Lambda\pi^+$, $p\bar{K}^0$, and $\Sigma^0\pi^+$. A high momentum lepton ($p > 1.4$ GeV/c) can be used to tag the flavor of the *other* B meson in the event, shedding light on the production mechanism for the charmed baryon. Electrons are identified using dE/dx measurements in the drift chamber and measurements of energy deposited in the electromagnetic calorimeter. Muons are identified using muon chambers to detect charged particles which penetrate the magnet iron.

2.1. Λ_c-Lepton correlations

If we observe a Λ_c^+ coming from a b quark decay (hence from a $\bar{B}^0$ or B^- meson), then it must contain the c quark from $b \to cW^-$. If instead we observe a Λ_c^-, that must arise from the $\bar{c}$ antiquark from $W^- \to \bar{c}s$. The high momentum lepton coming from the other B meson in the event would be positively charged ($\bar{b} \to \bar{c}W^+; W^+ \to l^+\nu$). Thus like-sign Λ_c-lepton correlations point to the $b \to c\bar{u}d$ mechanism, and opposite sign to $b \to c\bar{c}s$. The data yield 141 ± 16 like-sign combinations and 43 ± 16 opposite-sign combinations. We now remove backgrounds from misidentified leptons, and secondary leptons (that is, those produced via the decay chain $b \to cX, c \to sW^+, W^+ \to l^+\nu$). A correction is applied for the effect of $B^0\bar{B}^0$ mixing and we obtain 148 ± 19 like-sign events and 29 ± 19 opposite-sign events. These numbers would indicate that in B decays to charmed baryons the ratio of events produced via the $b \to c\bar{c}s$ mechanism to those from $b \to c\bar{u}d$ is $(20 \pm 13 \pm 4)\%$. The former mechanism does not dominate, but does contribute.

2.2. Search for Semileptonic B Decays with Λ_c

We now try to determine the semileptonic contribution to charmed baryon production in B meson decay. This contribution must come from an external spectator process. The lepton coming from the same B as the charmed baryon will be softer than the lepton we used previously to tag the flavor of the other B in the event. At most 2% of these leptons would pass our cut of $p > 1.4$ GeV/c. We use three techniques to try to observe the semileptonic contribution.

First we look for events with a Λ, a soft lepton which could come from the same B, and a hard lepton which could come from the opposite B. We observe only four such events and find that backgrounds from continuum processes, fake leptons, and secondary leptons can account for this number. We obtain an upper limit* of: $\frac{B \to \Lambda_c \bar{N} X l\nu}{B \to \Lambda_c X} < 5.7\%$.

Next we take our fully reconstructed Λ_c's and match them with a soft electron. We observe 95±20 events where the Λ_c and electron have opposite charges (as expected when they come from the same B in a semileptonic decay) and 74 ± 16 events with the same charge. After subtracting backgrounds and correcting for $B^0\bar{B}^0$ mixing we have a signal excess of 35 ± 26 events in the opposite charge channel, and find that the backgrounds account for all of the events in the same charge channel (as they should). This yields an upper limit of: $\frac{B \to \Lambda_c \bar{N} l\nu}{B \to \Lambda_c X} < 6\%$.

*Upper limits in this paper are at the 90% confidence level.

Third, a search was made for the exclusive decay $B \to \Lambda_c \bar{p} l^- \nu$ using a missing mass technique to account for the undetected neutrino. We obtained an upper limit on this decay of: $\frac{B\to\Lambda_c \bar{p} l^- \nu}{B \to \Lambda_c X} < 10\%$.

3. Ξ_c Production in B Decays

We observe here for the first time, Ξ_c's from B meson decay. Figure 3 shows the continuum subtracted signals of 71.2 ± 21.1 events for the Ξ_c^+ and 51.8 ± 18.7 events for the Ξ_c^0. Using reasonable estimates of the Ξ_c branching ratios, we get $B(B \to \Xi_c^+ X) = (1.5 \pm 0.7)\%$ and $B(B \to \Xi_c^0 X) = (2.4 \pm 1.3)\%$. These can be compared to $B(B \to \Lambda_c^+ X) = (6.3 \pm 2.4)\%$; so the sum of the Ξ_c yields is roughly half the Λ_c yield. The momentum spectrum of the Ξ_c's is soft, as one would expect for the $b \to c\bar{c}s$ mechanism. However, we do see a small number of events above $p = 1.2$ GeV$/c$, which is the kinematic limit for a Ξ_c from $B \to \Xi_c \bar{\Lambda}_c X$. This suggests that some Ξ_c's are produced from $b \to c\bar{u}d$ with $s\bar{s}$ popping.

Fig. 3. Signals observed after continuum subtraction for $B \to \Xi_c^+ X, \Xi_c^+ \to \Xi^- \pi^+ \pi^+$ and $B \to \Xi_c^0 X, \Xi_c^0 \to \Xi^- \pi^+$.

4. Exclusive B Decays with a Λ_c

Now we try to fully reconstruct some previously unobserved B meson decays. Instead of an invariant mass, a beam constrained mass is used since the energy of the B meson must equal E_{beam}. We plot $M_B = \sqrt{E_{beam}^2 - (\Sigma \vec{p})^2}$ and select events where $|\Sigma E - E_{beam}| < 25$ MeV. The Monte Carlo predicts the width in $|\Sigma E - E_{beam}|$ to be 12 to 16 MeV depending upon the signal being considered. Nine different decay channels were studied and a signal of 15.0 ± 4.7 events, shown in Fig. 4, was seen in the $\bar{B}^0 \to \Lambda_c^+ \bar{p} \pi^- \pi^+$ channel. No events are seen in the continuum, the energy sidebands or the Λ_c sidebands. We obtain a branching fraction $B(\bar{B}^0 \to \Lambda_c^+ \bar{p} \pi^+ \pi^-) = (0.187 \pm 0.059 \pm 0.056 \pm 0.045)\%$, where the third error reflects the uncertainty in the Λ_c branching fractions used. No statistically significant signals were seen in the other eight channels and the resulting upper limits are tabulated below.

Fig. 4. Beam constrained mass distribution for $\bar{B}^0 \to \Lambda_c^+ \bar{p} \pi^+ \pi^-$.

5. Conclusions

We have explored the production of charmed baryons in B meson decay with a high statistics data sample. Baryon-lepton correlation data imply that external W-emission does not saturate charmed baryon production in B meson decay. The observation of Ξ_c production indicates a contribution from $b \to cW^-$, $W^- \to \bar{c}s$ and the correlations data indicate this contribution is $(20 \pm 13 \pm 4)\%$ of $b \to cW^-$, $W^- \to \bar{u}d$. Finally, we have observed the first fully recontructed B meson decays involving charmed baryons.

References

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