B DECAYS TO STATES WITH BARYON PAIRS

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Abstract

The production mechanisms for the processes, $B \to$ baryon pairs $+ X$ have been studied. There is evidence that the dominant mechanism may be internal W emission and that the process, $b \to c\overline{u}d$, occurs more frequently than the process, $b \to c\overline{c}s$. The first observation of B decays to an exclusive Λ_c^+ channel is also presented.

1. Introduction

The decays of B mesons to inclusive Λ_c^+ channels have previously been observed by ARGUS[1] and by CLEO 1.5 [2], the latter measuring $BR(B \to \Lambda_c^+ X)$ to be $(6.4 \pm 0.8 \pm 0.8)\%$. Both groups observed the recoil spectrum of the Λ_c to be soft, implying that the X system was heavy.

The mechanism for B decays to Λ_c^+ final states is not understood. These decays could proceed through an external W process, as shown in Fig. 1(a) for b quark decay. This would require two quark pairs to be popped between the original quarks. The presence of such a process would also imply a corresponding semileptonic decay of the order of 10%, as observed in B decays to final states with charmed mesons.

These decays may also proceed through an internal W process, shown in Fig. 1(b) for b quark decay. Such processes are not expected to be colour suppressed to the same extent as B decays to meson final states via an internal W process. Only one quark pair is popped between the original quarks, the most likely possibilities being $u\overline{u}$, $d\overline{d}$ or $s\overline{s}$, (the latter occurs at a rate $\approx 1/3$ of either of the first two). With the coupling, $W^- \to \overline{u}d$, the only c quark will be on the top line, as seen in Fig. 1(b), which may produce a Λ_c^+ . (The contribution from Cabibbo suppressed processes such as, $W^- \to \overline{u}s$ is not considered here). In contrast the coupling, $W^- \to \overline{c}s$, yields an s quark at the top and a $\overline{c}$ quark at the bottom. This may produce a Ξ_c^+ or Ξ_c^0 at the top, possibly with a $\overline{\Lambda_c}^-$ at the bottom of the diagram. Were this the case, the relatively larger masses of the Ξ_c states provide a natural explanation for the softness of the Λ_c recoil spectrum, as has recently been proposed[3].

The flavour of the parent B meson may be tagged by observing the sign of the high momentum lepton when the opposite B meson, B^+ or B^0, decays semileptonically, i.e. $\overline{b} \to \overline{c}W^+$, $W^+ \to l^+\nu_l$. Thus like sign $\Lambda_c l$ correlations, indicate the presence of the $b \to c\overline{u}d$ process, while the opposite sign correlations indicate the presence of the $b \to c\overline{c}s$ process.

2. Experimental Details

These preliminary results are based on data collected with the CLEO II detector[4] and have been reported more fully elsewhere[5]. The data sample consists of 2.036 fb^{-1}, taken on the $\Upsilon(4S)$ resonance, and 0.967 fb^{-1} on the continuum just below the $\Upsilon(4S)$ resonance, corresponding to $(2.19 \pm 0.04) \times 10^6$ B pairs.

The $\Lambda_c^{+\dagger}$ is reconstructed in the following decay

† References to data for a particular channel or final state always imply the inclusion of data for the charge conjugate system.

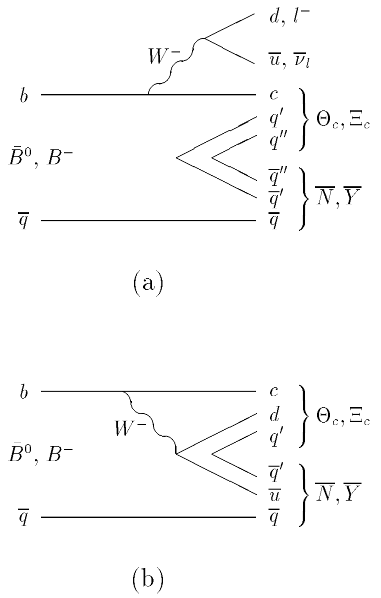

Figure 1. Quark diagrams for $B \to$ baryon pairs $+\ X$ via (a) external and (b) internal W emission. Θ_c and and Ξ_c are charmed non-strange and strange baryons respectively.

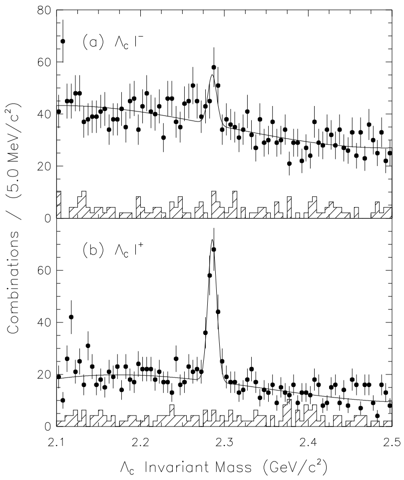

Figure 2. (a). The Λ_c invariant mass in GeV/c^2 for (a) opposite sign ($\Lambda_c^+\ l^-$) correlations and (b) like sign ($\Lambda_c^+\ l^+$) correlations. The shaded histograms are for continuum data.

channels: $pK^-\pi^+$, $p\overline{K^0}$, $\Lambda\pi^+$ and $\Sigma^0\pi^+$. The number of Λ_c^+ events was obtained by fitting the mass spectra for each channel for the on resonance data and subtracting the corresponding spectra for the scaled continuum data. This yielded a sample of 3154 ± 160 Λ_c candidates from B decays.

The momenta of the tagging leptons were required to satisfy, $1.4 < p_l < 2.4$ GeV/c, thus ensuring a pure sample of primary leptons from B decays. Details of the lepton selection criteria are given elsewhere[5].

3. $\Lambda_c\ l$ Sign Correlations

The data for the like and opposite sign $\Lambda_c\ l$ correlations are shown in Fig. 2, with the unshaded (shaded) histogram being the $\Upsilon(4S)$ (continuum) data. The fits yielded 141 ± 16 like sign and 43 ± 16 opposite sign correlations. These numbers were corrected for contamination by secondary leptons (from $c \to sl\nu$ decays), hadron fakes, and finally for $B^0\overline{B}^0$ mixing. The corrected values were 148 ± 16 like sign events and 29 ± 19 opposite sign events. It was checked that these numbers are consistent with those expected from the initial sample of 3154 Λ_c events. In addition the lepton momentum spectra for these events were found to be consistent with those expected of primary leptons from B decays. Likewise the angular distribution between the lepton and Λ_c directions was flat, as expected.

These results, then, indicate that, for internal W processes,

$$\frac{b \to c\bar{c}s}{b \to c\bar{u}d} = \frac{N(\Lambda_c^+\ l^-)}{N(\Lambda_c^+\ l+)} = (20 \pm 13 \pm 4)\%.$$

Thus, in B decays to Λ_c final states, the process $b \to c\bar{u}d$ dominates, but the process $b \to c\bar{c}s$ is significant.

4. Search for External W Processes in $B \to \Lambda_c\ +\ X$

The contribution of external W production for B decays to Λ_c states was investigated in two ways. Both methods exploited the fact that semileptonic B decays to Λ_c final states are a signature of an external W process. In addition these decays are characterized by a relatively soft signal lepton, which has opposite sign to that of the lepton used to tag the flavour of the other B meson. For this purpose, the signal lepton was required to satisfy, $p_{l_{sig}} < 1.4$ GeV/c; only a small fraction of the signal leptons would fail to pass this cut.

In the first method, a search was made for $\Lambda_c^+ l_{sig}^-$ correlations. The wrong sign $\Lambda_c^+ l_{sig}^+$ signal contained 74 ± 16 events, which was consistent with zero after making background corrections, as expected. The right sign combinations contained 95 ± 20 events, which yielded a signal of 35 ± 26 events after background corrections were applied. This produced an upper limit‡

‡ All limits presented here are for a 90% confidence level.

of, $\frac{BR(\overline{B}\to\Lambda_c^+\overline{N}l^-\overline{\nu}_l)}{BR(\overline{B}\to\Lambda_c^+X)} < 6\%$.

Secondly, employing a missing mass technique to discrminate in favour of the undetected neutrino, a search was made for the decay, $\overline{B} \to \Lambda_c^+\overline{p}l^-\overline{\nu}_l$. This yielded an upper limit, $\frac{BR(\overline{B}\to\Lambda_c^+\overline{p}l^-\overline{\nu}_l)}{BR(\overline{B}\to\Lambda_c^+X)} < 6\%$.

Both searches gave upper limits of about 6% for semileptonic decays of B mesons to Λ_c^+ states, relative to decays to all Λ_c^+ states. The corresponding value for B decays to D final states is about 12%. This suggests that external W processes are more significant, for B decays, to meson final states than to baryon final states.

5. Search for Ξ_c Final States in B Decays

A search was made for B decays to Ξ_c^+ and Ξ_c^0 final states, where $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ and $\Xi_c^0 \to \Xi^-\pi^+$. Signals were seen in both continuum events and in $\Upsilon(4S)$ events. After continuum subtraction, signals of 71.2 ± 21.1 Ξ_c^+ and 51.8 ± 18.7 Ξ_c^0 events were obtained for the $\Upsilon(4S)$ data. With reasonable assumptions for the Ξ_c branching ratios, these data yield the values: $BR(\overline{B} \to \Xi_c^+X) = (1.5 \pm 0.7)\%$ and $BR(\overline{B} \to \Xi_c^0X) = (2.4 \pm 1.3)\%$. The sum of these Ξ_c yields is roughly half that of the yield for Λ_c^+ noted above.

The observation of B decays to Ξ_c final states indicates the presence of internal $b \to c\overline{c}s$ processes accompanied by $u\overline{u}$ or $d\overline{d}$ popping. The kinematic limit for the Ξ_c momentum is then ≈ 1.2 GeV/c. There are a few events above this limit, suggesting the presence of a small component of the $b \to c\overline{u}d$ process, accompanied by $s\overline{s}$ popping.

6. Search for Exclusive B Decays to Λ_c^+

Attempts were made to reconstruct fully the decays $\overline{B} \to \Lambda_c^+\overline{p}\,(n)\pi$, where $n = 0, .., 4$ charged pions or where $n = 0, .., 3$ charged pions accompanied by one π^0. Since genuine B mesons will have an energy equal to the beam energy, the beam constrained mass of the B candidates, $M_B = \sqrt{E_{beam}^2 - (\Sigma\vec{p})^2}$, was used. Monte Carlo sudies indicated that the one sigma resolution of the energy difference, $\Delta E = |\Sigma E - E_{beam}|$, varied between 10 and 12 MeV, depending on the final state being considered. These candidates were therefore required to satisfy, $|\Sigma E - E_{beam}| < 25$ MeV. A signal of 15.0 ± 4.7 events was seen in the $\overline{B}^0 \to \Lambda_c^+\overline{p}\pi^-\pi^+$ decay channel. No signal was seen in either the energy sidebands, the Λ_c sidebands or the continuum events. The data are shown in Fig. 3. This yields a branching ratio, $BR(\overline{B} \to \Lambda_c^+\overline{p}\pi^-\pi^+) = (0.187\pm0.059\pm0.056\pm0.045)\%$, the third error resulting from the uncertainty in the Λ_c braching fraction.

In all other individual channels investigated, no significant signal was seen.

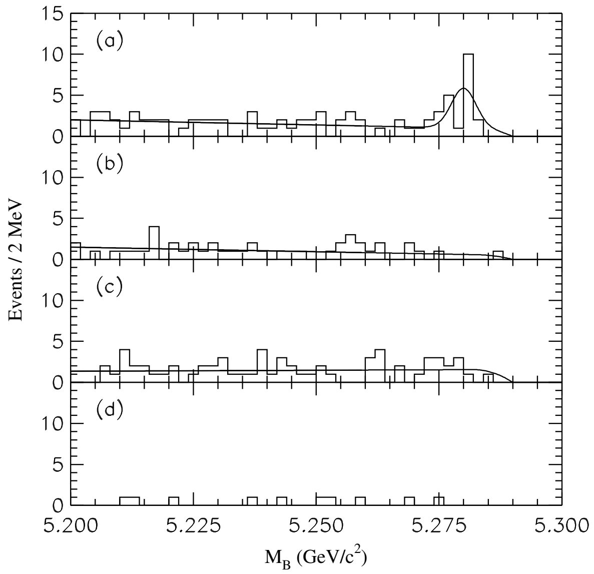

Figure 3. (a). The $\Lambda_c^+\overline{p}\pi^+\pi^-$ invariant mass in GeV/c^2 for $\Upsilon(4S)$ events. The same distribution for (b) the ΔE sidebands , (c) the Λ_c^+ sidebands and (d) the continuum.

7. Conclusions

The decay of B mesons to Λ_c final states was studied using Λ_c lepton sign correlations. Limits of about 6% were set on the contribution of external W processes. The internal processes proceeded mainly through the $b \to c\overline{u}d$ process, with the $b \to c\overline{c}s$ process contributing $(20 \pm 13 \pm 4)\%$. Decays of B mesons to Ξ_c final states proceeded mainly through a $b \to c\overline{c}s$ process, with some evidence for a contribution from the $b \to c\overline{u}d$ process. Finally a signal was observed for fully reconstructed events in the decay, $\overline{B} \to \Lambda_c^+\overline{p}\pi^-\pi^+$, with a measured braching ratio of $(0.187 \pm 0.059 \pm 0.056 \pm 0.045)\%$.

References

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