BARYONIC B DECAYS

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We summarize recent results of baryonic B decays from Belle and BaBar. The results from Belle are based on 140 fb$^{-1}$ and results from BaBar are based on 81 fb$^{-1}$ of data collected at the Υ(4S) resonance at KEKB or PEP-II respectively. We report the results of two- and three-body baryonic B decays as well as searches for pentaquarks. The three-body baryonic B decays display an enhancement in the low mass region, which is not in agreement with general phase space expectations.

1 Introduction

Baryonic B decays are a unique feature of B meson decays and have already been well established through previous measurements\cite{1,2,3,4}. Three-body baryonic B decays were found to have a larger branching fraction than two-body decays.

Three-body baryonic B decays display the common feature of a peaking behaviour toward the baryon-antibaryon pair mass threshold. This feature has also been observed in baryonic J/$\Psi$ decays\cite{5}, indicating it may be a universal feature of these decays. Possible explanations include intermediate (gluonic) resonant states or non-perturbative QCD effects of the quark fragmentation process\cite{6,7,8,9}. Angular distributions are used to discriminate between the different decay mechanisms.

2 The analyses

2.1 Event Selection

We use a data sample of $152 \times 10^6$ $B\bar{B}$ pairs, corresponding to an integrated luminosity of 140 fb$^{-1}$, collected by the Belle detector at the KEKB\cite{10} asymmetric energy $e^+e^-$ collider. The detector is described in detail elsewhere\cite{11}.
We select events through the following decay channels: \( \Lambda_c^+ \rightarrow pK^−\pi^+, p\bar{K}^0, \Lambda\pi^+, p\bar{K}^−\pi^+\pi^− \) and \( \Lambda \rightarrow p\pi^- \) and \( K^0_S \rightarrow \pi^+\pi^-\). 

All primary charged tracks are required to satisfy track quality criteria based on the track impact parameters relative to the interaction point (IP). To identify charged tracks, the proton \( (L_p) \), kaon \( (L_K) \) and pion \( (L_{\pi}) \) likelihoods are determined from information obtained by the hadron identification system. A track is identified as a proton if \( L_p/(L_p + L_{\pi}) > 0.6 \) and \( L_p/(L_p + L_K) > 0.6 \) (0.01), or as a kaon if \( L_K/(L_K + L_{\pi}) > 0.6 \) (0.2), or as a pion if \( L_{\pi}/(L_K + L_{\pi}) > 0.6 \) (0.05).

We require the mass of the \( \Lambda \) candidates to be consistent with the nominal \( \Lambda \) baryon mass, 1.111 (1.113) GeV < \( \mbox{M}_{\Lambda\pi^-} \) < 1.121 (1.118) GeV. The values inside (without) brackets apply to the \( B \rightarrow \Lambda_c^+\bar{p}\pi^- \) (all other) analyses.

Continuum background, the major background contribution for all decays, is suppressed in the \( \bar{B}^{-} \rightarrow \Lambda_c^+\bar{p}\pi^- \) decay by imposing requirements on the angle between the thrust axis of the \( B \) candidate tracks and that of other tracks, as well as on the ratio of the second to the zeroth Fox-Wolfram moment \(^{12} \). For all other decays, we form a Fisher discriminant \(^{13} \) that combines seven event shape variables. Probability density functions (PDF) for the Fisher discriminant and the cosine of the angle between the \( B \) flight direction and the beam direction in the \( \Upsilon(4S) \) rest frame are combined to form the signal (background) likelihood \( L_s \) (\( L_b \)). We then optimize the selection of the likelihood ratio \( R = L_f/(L_f + L_i) \) for each mode. For more details of the selection and background suppression refer to \(^{14-17} \).

### 2.2 Charmless B decays

We perform an unbinned likelihood fit that maximizes the likelihood function,

\[
L = \frac{e^{-(N_s+N_b)}}{N!} \prod_{i=1}^{N} \left[ N_s P_s(M_{bc1}, \Delta E_i) + N_b P_b(M_{bc1}, \Delta E_i) \right],
\]

to estimate the signal yield in 5.20 GeV/\( c^2 \) < \( M_{bc} \) < 5.29 GeV/\( c^2 \) and \( -0.1 \) GeV < \( \Delta E \) < 0.2 GeV for \( B \rightarrow p\bar{p}K \) and \( B^0 \rightarrow p\Lambda\pi^- \), \( -0.15 \) GeV < \( \Delta E \) < 0.3 for \( B^+ \rightarrow \Lambda\Lambda K^+ \) and \( -0.2 \) GeV < \( \Delta E \) < 0.5 for \( B^+ \rightarrow p\Lambda\gamma \); here \( P_s \) (\( P_b \)) denotes the signal (background) PDF, \( N \) is the number of events in the fit, and \( N_s \) and \( N_b \) are fit parameters representing the number of signal and background events, respectively.

The differential branching fractions as a function of the baryon pair mass are shown in Figure \( \text{FIGURE} \) after applying a charmonium veto for the \( B \rightarrow p\bar{p}K \) modes. A clear enhancement at threshold in disagreement with phase space expectations can be seen. The width of the peaking behaviour depends on the signal mode. The \( \Delta E \) distributions (with \( M_{bc} > 5.27 \) GeV) for the

\*Charge conjugate modes are implicitly included throughout this paper.
The fit yield is 50 resonance, fragmentation or final state interactions. as seen in Figure 3 (c) cannot conclusively determine whether the enhancement arises from a pair shows a low mass enhancement. This can be parameterized with a Breit-Wigner peak and intermediate states are given in Table 1. As in the previous analyses, the baryon-antibaryon $c\Sigma^{++}(2520)$ for a pentaquark signal. We also perform a search for $\Theta^-$ from a $u$ for a detailed description of this analysis please read 15. The upper limits are given in Table 1.

We perform a Dalitz plots analysis to investigate of the three-body charmed $B^+ \to \Lambda^+_c \bar{p} + \gamma$ with baryon-antibaryon mass less than 2.85 GeV/$c^2$. The solid, dotted and dashed lines represent the combined fit results, fitted signal and fitted background, respectively.

The final systematic errors are listed in Table 1

系统的错误是误差；对于详细的描述，该过程请参考14,15,16。The final systematic errors are listed in Table 1

2.3 $B^- \to \Lambda^+_c \bar{p} + \pi^-$

We perform a Dalitz plots analysis to investigate of the three-body charmed $B^- \to \Lambda^+_c \bar{p} + \pi^-$ decay. The distributions for $\Delta E$, the mass of the $\Lambda^+_c + \pi^-$ pair, the mass of the $\Lambda^+_c + \bar{p}$ pair and its helicity distribution are displayed in Figure 3. The intermediate states of $\Sigma_c(2455)^0$ and $\Sigma_c(2520)^0$ can clearly be identified in Figure 3(b). The branching fractions of these two-body intermediate states are given in Table 1. As in the previous analyses, the baryon-antibaryon pair shows a low mass enhancement. This can be parameterized with a Breit-Wigner peak and feed downs. The fit gives a mass of $(3.35^{+0.01}_{-0.02})$ GeV/$c^2$ and a full width of $(0.07^{+0.04}_{-0.03})$ GeV/$c^2$. The fit yield is $50 \pm 10$ events with a statistical significance of 5.6. The angular distribution as seen in Figure 3(c) cannot conclusively determine whether the enhancement arises from a resonance, fragmentation or final state interactions.

The angle $\theta_p$ is defined as the angle between the proton direction and the meson direction in the baryon-antibaryon pair rest frame. We find an asymmetry in the angular distributions, which indicates that the fragmentation picture is favored. Antiprotons are emitted along the $K^+$ direction most of the time, which can be explained by a parent $\bar{b} \to \bar{s}$ penguin transition followed by $\bar{s}u$ fragmentation into the final state. The energetic $\bar{s}$ quark picks up the $u$ quark from a $\bar{u}u$ pair in vacuum and the remaining $\bar{u}$ quark then drags a $\bar{u}d$ diquark out of vacuum.

Two-body charmless baryonic $B$ decays were investigated, but no signal events were seen. For a detailed description of this analysis please refer to 14,15,16. The upper limits are listed in Table 1.
Table 1: Branching fractions of the baryonic $B$ decays. We list the decay modes, the significances, the branching fractions and the experiment that performed the analysis.

| Mode                     | Significance | Branching fraction $[10^{-6}]$ | Experiment |
|--------------------------|--------------|-------------------------------|------------|
| $B(B^+ \rightarrow \Lambda \Lambda K^+)$ | 7.4          | $2.91^{+0.39}_{-0.70} \pm 0.38$ | Belle      |
| $B(B^+ \rightarrow \Lambda \Lambda \pi^+)$ | -            | $< 2.8$                       | Belle      |
| $B(B^+ \rightarrow ppK^+)$ | $> 10$       | $5.30^{+0.43}_{-0.30} \pm 0.58$ | Belle      |
| $B(B^+ \rightarrow ppK^+)$ | $> 10$       | $6.74^{+0.92}_{-0.57} \pm 0.53$ | BaBar      |
| $B(B^+ \rightarrow p\Lambda \pi^−)$ | 6.2          | $3.27^{+0.23}_{-0.30} \pm 0.39$ | Belle      |
| $B(\Sigma_c(2455)\bar{p})$ | 8.6          | $2.16^{+0.35}_{-0.53} \pm 0.20$ | Belle      |
| $B(B^+ \rightarrow \Lambda\bar{p}n)$ | 18.1         | $201 \pm 15 \pm 20 \pm 52$     | Belle      |
| $B(\Lambda^+_c \bar{p}n)$ | 6.2          | $38.7^{+11.5}_{-7.2} \pm 4.3 \pm 10.1$ | Belle      |
| $B(\Sigma_c(2455)\bar{p})$ | 8.4          | $36.7^{+13.4}_{-6.6} \pm 3.6 \pm 9.5$ | Belle      |
| $B(B \rightarrow \theta^+\Lambda)/B(\theta^+\pi^0\Lambda)$ | -            | $< 0.41/0.49/0.69$           | Belle      |
| $B(B \rightarrow \theta^+\Lambda)/B(\theta^+\pi^0\Lambda)$ | -            | $< 0.23$                     | Belle      |
| $B(B \rightarrow \theta^+\pi^0\Lambda)/B(\theta^+\pi^0\Lambda)$ | -            | $< 0.091/0.15-0.40$          | Belle / BaBar |

3 Summary

We have observed three-body charmless baryonic $B$ decays and charmed baryonic two- and three-body decays. All three-body decays display an enhancement at threshold in the baryon-antibaryon mass. The fragmentation picture seems to be favored to explain this behaviour. The results are listed in Table 1.

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