Belle: Charmless hadronic B meson decays with Belle

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Recent results of charmless B decays from Belle are reported. These include the two-body decays of ηh, ωh, and $\eta' h$, and ηhh three-body decay, where h stands for kaon or pion. The charge asymmetries of high statistics modes are also reported. This study is based on a 357 fb^{-1} data sample, consisting of 386 million $B\bar{B}$ pairs, collected by the Belle detector at the KEKB asymmetric energy e^+e^- (3.5 on 8 GeV) collider.

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1. Introduction

Charmless hadronic B decays provide a rich ground to study the dynamics of B meson and CP violation phenomenon. In the Standard Model, direct CP violation can arise in particle decays from the interference of two or more amplitudes with both strong phases and weak phases being different. Many charmless hadronic B meson decays contain both tree and penguin amplitudes and provide a good sample for direct CP violation searches. Since the B^- meson contains a b quark, we adopt the convention that the direct CP asymmetry in a $B \to f$ decay is defined as

$$A_{CP} = \frac{\Gamma(B^- \to f^-) - \Gamma(B^+ \to f^+)}{\Gamma(B^- \to f^-) + \Gamma(B^+ \to f^+)}.$$

It has been suggested that the direct CP violation could be large in $B^- \to \eta \pi^-$ [1], and $B^- \to \eta K^-$ decays [1]. Previous measurements do not have enough statistics to determine this effect. The $B \to \eta' X_s$ decay is still an unsolved puzzle for many theorists. It provides the largest branching fractions among the charmless hadronic decays of B mesons. The observed branching fractions of $B \to \eta' K$ [2] are larger than the expectation from generalized factorization approach. It is speculated that SU(3)-singlet couplings unique to η' meson or new physics contribute to the amplitude. The two-body B decays with a vector meson ω and a pseudoscalar particle h [3] proceed through $b \to s$ penguin diagrams and spectator $b \to u$ diagrams. Theoretical expectations from QCD factorization approaches suggest that the branching fractions of charged B decays are $\sim (3-8)10^{-6}$ and the ωK^- branching fraction is smaller than the $\omega \pi^-$. The decay $B^0 \to \omega \pi^0$ is color suppressed while the neutral B decays to ωK is expected to have slightly smaller branching fraction than the charged B decays.

We present a study of the above two-body decays, namely ηh, ωh, and $\eta' h$ of B mesons, where h stands for kaon or pion. It is based on a 357 fb^{-1} data sample, consisting of 386 million $B\bar{B}$ pairs, collected by the Belle [5] detector at the KEKB asymmetric energy e^+e^- (3.5 on 8 GeV) collider.

There are interests for $B^0 \to a_0^- h^+$ and the observation of these decay modes will provide information both on B meson decays to scalar mesons and on the nature of the a_0^- meson. We also use the same data sample to study the three-body decays, $B^0 \to \eta h^+ h^-$ [4], which contains the intermediate decay process of $B^0 \to a_0^- h^+$.

2. Analysis procedure

The challenge of observing rare B decay processes is to fish out a few signal events from background events. Since the center-of-mass energy is set to match the $\Upsilon(4S)$ resonance and $\Upsilon(4S)$ decays into a $B\bar{B}$ pair, we can use the following two kinematic variables to identify the reconstructed B meson candidates: the beam-energy constraint mass, $M_{bc} = \sqrt{E_{beam}^2 - p_B^2}$, and the energy difference, $\Delta E = E_B - E_{beam}$, where E_{beam}, p_B and E_B are the beam energy, the momentum and energy of the reconstructed B meson in the rest frame of $\Upsilon(4S)$, respectively. The resolution of M_{bc} is about 3 MeV/c^2 which is due to the spread of the beam energy. Typically, the resolution of ΔE is

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[1]Throughout this report, inclusion of charge conjugate mode is always implied unless otherwise stated.

about 10 MeV for final states with charged particles only. It has a wider spread and a low energy tail in the ΔE spectrum for modes with $\pi^0(\gamma)$. The signal shape and its efficiency is determined by GEANT [6] based Monte Carlo (MC) simulation.

The generic B decay is mainly via the $b \to c$ transition which normally has more final state particles than those of the rare decay modes reported here, thus the background from generic B decays is much less than that from the continuum process. Similar B decay processes close to the target mode should be checked carefully one by one because they might feed into the signal region. One important feature is a 50 MeV shift in the ΔE spectrum due to $\pi - K$ misidentification. For the continuum events, they have quite different event topology (more back-to-back or jet-like) than that of $B\bar{B}$ events (more spherical) in the $\Upsilon(4S)$ frame. We can select some shape variables to form a Fisher discriminant in order to reject the continuum background. After the optimization of selection cuts, events in the candidate $M_{bc} - \Delta E$ region are used for yield determination. This is done by un-binned likelihood fit. If there is no evidence of signal events, one can use the fit results to estimate the expected background, and compare this with the observed number of events in the signal region in order to set the upper limit on the yield at the 90% confidence level [7].

3. Results

The results of this study are summarized in Table 1. A typical plot for checking the A_{CP} of $B^- \to \eta K^-$ is shown in Fig. 1. We are looking forward to exciting news from B factories with more data in the near future.

Table 1: Measured branching fractions ($\mathcal{B}$), the 90% confidence level upper limits (UL) on the branching fractions and A_{CP}'s for different B decays modes. Note that the branching fractions related to a_0^- are the products of branching fractions for B decays and $a_0^- \to \eta \pi^-$.

Mode	$\mathcal{B}_r(\times 10^{-6})$	UL$(\times 10^{-6})$	A_{CP}
ηK^-	$2.2 \pm 0.4 \pm 0.1$	–	$-0.55 \pm 0.19 \pm 0.04$
$\eta \pi^-$	$3.9 \pm 0.5 \pm 0.2$	–	$-0.10 \pm 0.11 \pm 0.02$
ηK^0	$0.9 \pm 0.6 \pm 0.1$	< 1.9	–
$\eta' K^-$	$68.6 \pm 2.1 \pm 3.6$	–	$0.029 \pm 0.028 \pm 0.02$
$\eta' \pi^-$	$1.73^{+0.69}_{-0.63} \pm 0.12$	–	$0.15^{+0.39+0.02}_{-0.38-0.06}$
$\eta' K^0$	$56.6^{+3.6+3.3}_{-3.5-3.2}$	–	–
ωK^-	$8.1 \pm 0.6 \pm 0.5$	–	$0.05 \pm 0.08 \pm 0.01$
$\omega \pi^-$	$7.0 \pm 0.6 \pm 0.5$	–	$-0.03 \pm 0.09 \pm 0.02$
ωK^0	$3.9 \pm 0.7 \pm 0.4$	–	–
$\omega \pi^0$	$0.8^{+0.5}_{-0.4} \pm 0.1$	< 1.5	–
$\eta K^+ \pi^-$	$31.7 \pm 1.9^{+2.2}_{-2.6}$	–	–
$\eta \pi^+ \pi^-$	$6.2^{+1.8+0.8}_{-1.6-0.6}$	< 12	–
$a_0^- K^+$	–	< 1.6	–
$a_0^- \pi^+$	–	< 2.8	–

Acknowledgments

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References

[1] For a detailed description about theoretical predictions and experimental findings, see K. Abe *et al.* (Belle Collaboration), BELLE-CONF-0525, hep-ex/0508030 and references therein.

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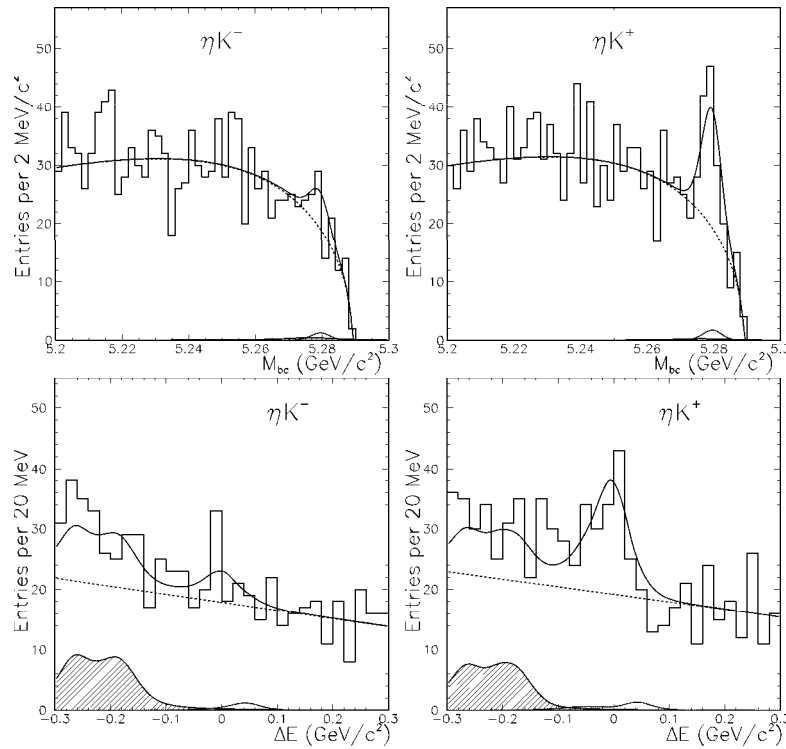[7] J. Conrad *et al.*, Phys. Rev. D **67**, 012002 (2003).

Figure 1: M_{bc} and ΔE projections for (left) $B^- \to \eta K^-$ and (right) $B^+ \to \eta K^+$ with the $\eta_{\gamma\gamma}$ and $\eta_{3\pi}$ modes combined. Open histograms are data, solid curves are the fit functions, dashed lines show the continuum contributions and shaded areas are the contributions from charmless B decays. The small bumps near $M_{bc} = 5.28$ GeV/c^2 and $\Delta E = 0.05$ GeV are the backgrounds from $B^{\pm} \to \eta \pi^{\pm}$ due to $\pi - K$ misidentification.