PROCEEDINGS OF SCIENCE

$b \to s$ Hadronic Decays at Belle

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We report measurements of charmless hadronic B^0 decays into the $\pi^+\pi^-K^+\pi^-$ final state from Belle. This study includes the first observation of $B^0 \to \rho^0 K^+\pi^-$, which is measured to have the branching fraction $\mathscr{B}[B^0 \to \rho^0 K^+\pi^-;\ M_{K\pi} \in (0.75, 1.20)\ \mathrm{GeV}/c^2] = [2.8 \pm 0.5(\mathrm{stat}) \pm 0.5(\mathrm{syst})] \times 10^{-6}$ and the first evidence of the decays $B^0 \to f_0(980)K^+\pi^-$ and $B^0 \to \pi^+\pi^-K^{*0}$ with significances of 3.5σ and 4.5σ, respectively. For the two-body decays $B^0 \to \rho^0 K^{*0}$ and $B^0 \to f_0(980)K^{*0}$, the significances are 2.7σ and 2.5σ, respectively, and the upper limits on the branching fractions are 3.4×10^{-6} and 2.2×10^{-6} at 90% confidence level. These measurements are obtained from a data sample of 657 million $B\bar{B}$ pair events collected with the Belle detector at the KEKB asymmetric-energy e^+e^- collider.

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1. Introduction

In the Standard Model (SM), charmless hadronic B decays occur mainly via two processes (i) $b \to s$ penguin and (ii) $b \to u$ tree decay. These charmless hadronic B decays therefore give us plenty of information. Search for new physics effect, for example, can be done by studying loop processes because $b \to s$ quark transitions are very sensitive to physics beyond SM. In addition, measuring the branching fraction ($\mathscr{B}$) and angular correlations could advance the phonomenological test and/or development of the theoretical models.

In particular, the measurements of the longitudinal polarization fraction ($f_{\rm L}$) in rare B decays to vector-vector (VV) state, such as $B \to \phi K^*$ [1 – 3], have revealed an unexpectedly large fraction of transverse polarization. This implies that non-factorizable contributions to the decays amplitude play a significant role. Therefore, further information about these effects can be obtained with $\mathscr{B}$ and $f_{\rm L}$ in the decay $B^0 \to \rho^0 K^{*0}$, this occuring mostly via the $b \to s$ penguin process [1 – 5].

The results are based on a sample of 657 million $B\bar{B}$ pair events, collected with the Belle [6] detector at the KEKB [7] asymmetric-energy e^+e^- collider (3.5 on 8 GeV) operating at the $\Upsilon(4S)$.

2. Measurements of $B^0 \to \rho^0 K^{*0}$ and $B^0 \to \pi^+\pi^- K^+\pi^-$

We reconstruct the signal B candidates using the kinematic variables such as the beam-energy constrained mass, $M_{\rm bc} \equiv \sqrt{E^2_{\rm beam} - p^2_B}$; the energy difference, $\Delta E \equiv E_B - E_{\rm beam}$; the invariant masses of $\pi\pi$ and $K\pi$ ($M_{\pi\pi}$ and $M_{K\pi}$), where $E_{\rm beam}$ is the beam energy and E_B and p_B are the reconstructed energy and momentum, respectively, of B candidates in the center-of-mass frame.

The dominant background arises from the continuum process. The continuum suppression is achieved by applying a requirement on a likelihood ratio, based on a GEANT-based [8] Monte Carlo (MC) simulation and sideband data, together with the B flavour tagging information [9]. Background contribution from $b \to c$ events is investigated using a large MC sample. We veto the decays $B \to D^{*\pm}X$, $B \to D^{\pm}X$ and $B \to D^0 X$ by applying the invariant mass cuts.

After the optimization of selection cuts, events that remain in the fitting regions of the observables $M_{\rm bc}$, ΔE, $M_{\pi\pi}$ and $M_{K\pi}$ are used for the yield extraction. This process is done by performing the four-dimensional unbinned maximum likelihood fit (4D fit).

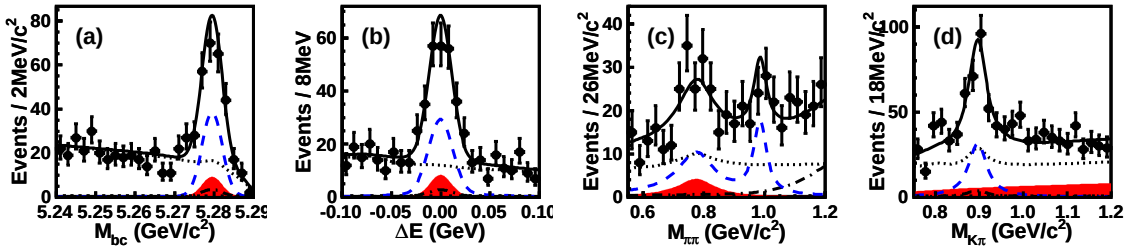

Figure 1: Projection of the 4D fit results onto (a) $M_{\rm bc}$, (b) ΔE, (c) $M_{\pi\pi}$, (d) $M_{K\pi}$, with the other variables required to satisfy (except for the variable plotted) $M_{\rm bc} \in (5.27, 5.29)$ GeV/c^2, $\Delta E \in (-0.045, 0.045)$ GeV, $M_{\pi\pi} \in (0.62, 1.04)$ GeV/c^2 and $M_{K\pi} \in (0.84, 0.94)$ GeV/c^2. The curves are for the $\rho^0 K^+\pi^-$ (solid-shaded), the sum of $\rho^0 K^{*0}$ and $f_0(980)K^{*0}$ (dashed), $f_2(1270)K^{*0}$ and the sum of feed-down modes (dot-dashed), the sum of the backgrounds (dotted), and the total (solid).

Table 1: The signal yield Y and its statistical uncertainty, corrected MC efficiency ε (assuming $f_L = 0.5$ for $B^0 \to \rho^0 K^{*0}$), significance $\mathscr{S}$ including the systematic uncertainties, measured branching fraction $\mathscr{B}$ and the upper limit (UL) at the 90% confidence level $\mathscr{B}_{\rm UL}$. For non-resonant decay components, ε, $\mathscr{B}$ and $\mathscr{B}_{\rm UL}$ are obtained for $M_{K\pi} \in (0.75, 1.20)$ GeV/c^2 and $M_{\pi\pi} \in (0.55, 1.20)$ GeV/c^2 assuming phase space distributions. For the branching fraction, the first (second) uncertainty is statistical (systematic).

Mode	Y (events)	ε (%)	$\mathscr{S}$ (σ)	$\mathscr{B}$ (10^{-6})	$\mathscr{B}_{\rm UL}$ (10^{-6})
$B^0 \to \rho^0 K^{*0}$	$77.6^{+28.6}_{-27.9}$	5.73	2.7	$2.1^{+0.8+0.9}_{-0.7-0.5}$	< 3.4
$B^0 \to f_0(980) K^{*0}$	$51.2^{+20.4}_{-19.3}$	5.56	2.5	$1.4^{+0.6+0.6}_{-0.5-0.4}$	< 2.2
$B^0 \to \rho^0 K^+ \pi^-$	$207.8^{+39.8}_{-39.2}$	11.15	5.0	$2.8 \pm 0.5 \pm 0.5$	-
$B^0 \to f_0(980) K^+ \pi^-$	$106.9^{+31.6}_{-29.9}$	11.43	3.5	$1.4 \pm 0.4^{+0.3}_{-0.4}$	< 2.1
$B^0 \to \pi^+ \pi^- K^{*0}$	$200.7^{+46.7}_{-44.9}$	6.74	4.5	$4.5^{+1.1+0.9}_{-1.0-1.6}$	-
$B^0 \to \pi^+ \pi^- K^+ \pi^-$	$-5.4^{+54.9}_{-44.9}$	6.84	0.0	$-0.1^{+1.2+1.4}_{-1.1-0.8}$	< 2.1

The fit projections are shown in Figure 1, and the results are summarized in Table 1. The fit yields the first observation for $B^0 \to \rho^0 K^+ \pi^-$ with a significance of 5.0σ (including systematic uncertainty). We also find evidence for $B^0 \to f_0(980) K^+ \pi^-$ with a significance of 3.5σ, and evidence for $B^0 \to \pi^+ \pi^- K^{*0}$ with a significance of 4.5σ. For $B^0 \to \rho^0 K^{*0}$ and $B^0 \to f_0(980) K^{*0}$, we observe excesses of events with significances of 2.7σ and 2.5σ, respectively. Our results for these two-body decays are approximately 2σ and 1σ lower, respectively, than in the previous measurement [4]. We have also searched for the fully non-resonant four-body decays $B^0 \to \pi^+ \pi^- K^+ \pi^-$ and calculated a 90% confidence level upper limit on its partial branching fraction. Our results [10] for the non-resonant modes are the first and can advance our understanding of the polarization puzzle in ρK^* decays.

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