PROCEEDINGS OF SCIENCE

Belle: Updated results on B -> Kpi/KK decays

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We report an improved measurements of direct *CP* violation in the decay $B^0 \to K^+\pi^-$ using 350 fb^{-1} of data and measurements of B meson decays to two kaons using 253 fb^{-1} of data. The measured *CP* violating asymmetries are $\mathscr{A}_{CP}(K^+\pi^-) = -0.113 \pm 0.022(\text{stat.}) \pm 0.008(\text{syst.})$, $\mathscr{A}_{CP}(K^+\pi^0) = 0.04 \pm 0.04(\text{stat.}) \pm 0.02(\text{syst.})$ and $\mathscr{A}_{CP}(\pi^+\pi^0) = 0.02 \pm 0.08(\text{stat.}) \pm 0.01(\text{syst.})$, where the latter correspond to the intervals $-0.03 < \mathscr{A}_{CP}(K^+\pi^0) < 0.11$ and $-0.12 < \mathscr{A}_{CP}(\pi^+\pi^0) < 0.15$ at 90% confidence level. We also find evidence for signals in $B^+ \to \overline{K}^0 K^+$ and $B^0 \to K^0\overline{K}^0$ with significances of 3.0σ and 3.5σ, respectively. (Charge-conjugate modes included) The corresponding branching fractions are measured to be $\mathscr{B}(B^+ \to \overline{K}^0 K^+) = (1.0 \pm 0.4 \pm 0.1) \times 10^{-6}$ and $\mathscr{B}(B^0 \to K^0\overline{K}^0) = (0.8 \pm 0.3 \pm 0.1) \times 10^{-6}$. No signal is observed in the decay $B^0 \to K^+K^-$ and we set an upper limit of 3.7×10^{-7} at 90% confidence level. These results are obtained from a data sample collected near the $\Upsilon(4S)$ resonance, with the Belle detector at the KEKB asymmetric energy e^+e^- collider.

PACS: 11.30.Er, 12.15.Hh, 13.25.Hw, 14.40.Nd

International Europhysics Conference on High Energy Physics
July 21st - 27th 2005
Lisboa, Portugal

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PoS(HEP2005)256

1. Introduction

In the Standard Model (SM) *CP* violation arises via the interference of at least two diagrams with comparable amplitudes but different *CP* conserving and violating phases. Mixing induced *CP* violation in the B sector has been established in $b \to c\bar{c}s$ transitions [1]. Direct *CP* violation is expected to be sizable in the B meson system [2]. The $B \to \overline{K}K$ modes are hadronic $b \to d$ transitions. Here we report results on $B \to K^0K$ decays, which are dominated by the loop-induced $b \to d\bar{s}s$ process (so-called $b \to d$ penguins). We also report a search for $B^0 \to K^+K^-$, which can arise only from annihilation diagrams, unless there are final-state interactions (FSI) [3].

The results are based on a sample of 386 million, for $\mathcal{A}_{CP}$ measurements and 275 million $B\overline{B}$ pairs, for $B \to KK$ measurements, collected with the Belle detector at the KEKB e^+e^- asymmetric-energy (3.5 on 8 GeV) collider [4] operating at the $\Upsilon(4S)$ resonance.

2. Analysis Flow

Charged tracks are required to come from the interaction point (IP) in the transverse plane. Charged kaons and pions are identified using the Belle PID system and positively identified electrons or muons are rejected. Candidate K^0 mesons are reconstructed through $K^0_S \to \pi^+\pi^-$.

Two variables are used to identify B candidates: the beam-constrained mass, $M_{\rm bc} \equiv \sqrt{E^{*2}_{\rm beam} - p^{*2}_B}$, and the energy difference, $\Delta E \equiv E^*_B - E^*_{\rm beam}$, where $E^*_{\rm beam}$ is the run dependent beam energy and E^*_B and p^*_B are the reconstructed energy and momentum of the B candidates in the center-of-mass (CM) frame, respectively.

The dominant background is from $e^+e^- \to q\bar{q}$ $(q = u,d,s,c)$ continuum events. Event topology and B flavor tagging information are used to distinguish between the $B\overline{B}$ events and the continuum backgrounds. A signal/background likelihood is formed, based on a GEANT-based [5] Monte Carlo (MC) simulation and sideband data, from the product of the probability density function (PDF) of the Fisher discriminant and the B flight direction. The continuum suppression is achieved by applying a requirement on a likelihood ratio together with the B flavor tagging information. [6] Background contributions from $\Upsilon(4S) \to B\overline{B}$ events are investigated using a large MC sample, which includes events from $b \to c$ transitions and charmless decays. Except for the $B^0 \to K^0\overline{K}^0$ mode, a small charmless three-body contribution is found at low ΔE values region.

3. Singal Extraction

The signal yields are extracted by applying unbinned two dimensional maximum likelihood (ML) fits to the $(M_{\rm bc}, \Delta E)$ distributions of the B and $\overline{B}$ samples. The yields and asymmetries for the signal and backgrounds are allowed to float in all modes. Since the $K^+\pi^0$ and $\pi^+\pi^0$ feed across are difficult to distinguish with ΔE and $M_{\rm bc}$, these two modes are fitted simultaneously with a fixed ratio based on the measured K-π identification efficiencies and fake rates. All the signal PDFs are obtained using MC simulations. Those of $B \to K^+\pi^-$ and $B \to KK$ are modeled by a product of a single Gaussian for $M_{\rm bc}$ and a double Gaussians for ΔE. For the modes with a π^0 meson in the final state, their PDFs are described by smoothed two-dimensional histograms. Discrepancies between the signal peak positions in data and MC are calibrated using $B^+ \to \overline{D}^0\pi^+$ decays.

Table 1: Fitted signal yields, $\mathscr{A}_{CP}$ results, and background asymmetries for individual modes.

Mode	Signal Yield	$\mathscr{A}_{CP}$	Bkg $\mathscr{A}_{CP}$
$K^{\mp}\pi^{\pm}$	3026 ± 63	$-0.113 \pm 0.022 \pm 0.008$	-0.001 ± 0.004
$K^{\mp}\pi^{0}$	1084 ± 45	$+0.04 \pm 0.04 \pm 0.02$	-0.02 ± 0.01
$\pi^{\mp}\pi^{0}$	454 ± 36	$+0.02 \pm 0.08 \pm 0.01$	-0.01 ± 0.01

The continuum background in ΔE is described by a product of first or second order polynomial and an Argus function [7] for $M_{\rm bc}$ distribution. A large MC sample is used to investigate the background from charmless B decays and a smoothed two-dimensional histogram is taken as the PDF. The functional forms of the PDFs are the same for the B and $\overline{B}$ samples.

4. Results

Table 1 and 2 summarizes the fit results for each mode. The second errors in the yields are the systematic errors from fitting, estimated from the deviations after varying each parameter of the signal PDFs by one standard deviation, and from modeling the three-body background, studied by excluding the low ΔE region (< -0.15 GeV) and repeating the fit. The final systematic errors are then obtained by quadratically summing the errors due to the reconstruction efficiency and the fitting systematics.

Table 2: Fitted signal yields, reconstruction efficiencies, product of efficiencies and sub-decay branching fractions ($\mathscr{B}_s$), branching fractions with upper limits at 90% confidence level and significances for individual modes.

Mode	Sig. Yield	Bkg. Yield	Eff.(%)	Eff.$\times\mathscr{B}_s$ (%)	$\mathscr{B}(10^{-6})$	Sig.
K^+K^-	$2.5^{+5.1}_{-4.1}$	1508.1 ± 39.9	15.5	15.5	0.06 ± 0.1 (< 0.37)	0.5
$\overline{K}^0K^+$	13.3 ± 5.6	893.5 ± 30.7	14.5	5.0	1.0 ± 0.4 (< 1.5)	3.0
$K^0\overline{K}^0$	15.6 ± 5.8	1136.6 ± 34.8	28.7	6.8	0.8 ± 0.3 (< 2.1)	3.5

5. Conclusion

With 275 million $B\overline{B}$ pairs, we find evidence of $B^+ \to \overline{K}^0K^+$ and $B^0 \to \overline{K}^0K^0$ with branching fractions $\mathscr{B}(B^+ \to \overline{K}^0K^+) = (1.0 \pm 0.4 \pm 0.1) \times 10^{-6}$ and $\mathscr{B}(B^0 \to K^0\overline{K}^0) = (0.8 \pm 0.3 \pm 0.1) \times 10^{-6}$. These are examples of $b \to d$ penguin dominated hadronic transitions. Our measurements are consistent with preliminary results reported by the BaBar collaboration [8]. They are also in general agreement with theoretical expectations [3, 9, 10, 11, 12]. No signal is observed in $B^0 \to K^+K^-$ and we set the upper limit of 3.7×10^{-7} at the 90% confidence level, using the Feldman-Cousins approach [13] taking into account both the statistical and systematic errors [14].

The partial rate asymmetry $\mathscr{A}_{CP}(K^+\pi^-)$ is found to be $-0.113 \pm 0.022 \pm 0.008$ with 386 million $B\overline{B}$ pairs. The significance including the effect of systematic uncertainty is 4.97σ. This result

supersedes our previous measurement [15] and remains consistent with the value reported by Babar, $\mathscr{A}_{CP}(K^+\pi^-) = -0.133 \pm 0.030 \pm 0.009$ [16]. The observed $\mathscr{A}_{CP}(K^+\pi^0)$ value is consistent with zero at the current level of statistical precision. The difference between the results for $\mathscr{A}_{CP}(K^+\pi^-)$ and $\mathscr{A}_{CP}(K^+\pi^0)$ persists; their central values differ by 3.1σ. This suggests a possible contribution from the electroweak penguin process or other mechanisms [17]. No evidence of direct *CP* violation is observed in the decay $B^+ \to \pi^+\pi^0$. We set 90% C.L. intervals: $-0.03 < \mathscr{A}_{CP}(K^+\pi^0) < 0.11$ and $-0.12 < \mathscr{A}_{CP}(\pi^+\pi^0) < 0.15$. All of the above results are preliminary.

We thank the KEKB group for the excellent operation of the accelerator, the KEK cryogenics group for the efficient operation of the solenoid, and the KEK computer group and the NII for valuable computing and Super-SINET network support. We acknowledge support from MEXT and JSPS (Japan); ARC and DEST (Australia); NSFC (contract No. 10175071, China); DST (India); the BK21 program of MOEHRD and the CHEP SRC program of KOSEF (Korea); KBN (contract No. 2P03B 01324, Poland); MIST (Russia); MHEST (Slovenia); SNSF (Switzerland); NSC and MOE (Taiwan); and DOE (USA).

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