PHYSICAL REVIEW D **68**, 011103(R) (2003)

Improved measurement of the partial-rate *CP* asymmetry in $B^+ \to K^0 \pi^+$ and $B^- \to \overline{K}^0 \pi^-$ decays

Y. Unno,[3] K. Suzuki,[9] K. Abe,[9] K. Abe,[44] T. Abe,[45] I. Adachi,[9] H. Aihara,[46] M. Akatsu,[23] Y. Asano,[51] T. Aso,[50] V. Aulchenko,[2] T. Aushev,[13] S. Bahinipati,[5] A. M. Bakich,[41] Y. Ban,[34] S. Banerjee,[42] A. Bay,[19] I. Bedny,[2] P. K. Behera,[52] I. Bizjak,[14] A. Bondar,[2] A. Bozek,[28] M. Bračko,[21,14] J. Brodzicka,[28] T. E. Browder,[8] B. C. K. Casey,[8] P. Chang,[27] Y. Chao,[27] K.-F. Chen,[27] B. G. Cheon,[40] R. Chistov,[13] S.-K. Choi,[7] Y. Choi,[40] Y. K. Choi,[40] M. Danilov,[13] L. Y. Dong,[11] J. Dragic,[22] A. Drutskoy,[13] S. Eidelman,[2] V. Eiges,[13] Y. Enari,[23] F. Fang,[8] N. Gabyshev,[9] A. Garmash,[2,9] T. Gershon,[9] B. Golob,[20,14] R. Guo,[25] J. Haba,[9] F. Handa,[45] H. Hayashii,[24] M. Hazumi,[9] L. Hinz,[19] T. Hokuue,[23] Y. Hoshi,[44] W.-S. Hou,[27] H.-C. Huang,[27] T. Iijima,[23] K. Inami,[23] A. Ishikawa,[23] R. Itoh,[9] H. Iwasaki,[9] Y. Iwasaki,[9] H. K. Jang,[39] J. H. Kang,[55] J. S. Kang,[16] P. Kapusta,[28] S. U. Kataoka,[24] N. Katayama,[9] H. Kawai,[3] H. Kawai,[46] N. Kawamura,[1] T. Kawasaki,[30] H. Kichimi,[9] D. W. Kim,[40] H. J. Kim,[55] Hyunwoo Kim,[16] J. H. Kim,[40] S. K. Kim,[39] K. Kinoshita,[5] S. Kobayashi,[37] S. Korpar,[21,14] P. Križan,[20,14] P. Krokovny,[2] R. Kulasiri,[5] S. Kumar,[33] A. Kuzmin,[2] Y.-J. Kwon,[55] J. S. Lange,[6,36] G. Leder,[12] S. H. Lee,[39] J. Li,[38] A. Limosani,[22] S.-W. Lin,[27] D. Liventsev,[13] J. MacNaughton,[12] F. Mandl,[12] D. Marlow,[35] H. Matsumoto,[30] T. Matsumoto,[48] A. Matyja,[28] W. Mitaroff,[12] H. Miyake,[32] H. Miyata,[30] T. Mori,[4] A. Murakami,[37] T. Nagamine,[45] Y. Nagasaka,[10] T. Nakadaira,[46] E. Nakano,[31] M. Nakao,[9] H. Nakazawa,[9] J. W. Nam,[40] Z. Natkaniec,[28] S. Nishida,[17] O. Nitoh,[49] T. Nozaki,[9] S. Ogawa,[43] T. Ohshima,[23] T. Okabe,[23] S. Okuno,[15] S. L. Olsen,[8] W. Ostrowicz,[28] H. Ozaki,[9] P. Pakhlov,[13] H. Palka,[28] C. W. Park,[16] H. Park,[18] K. S. Park,[40] L. S. Peak,[41] J.-P. Perroud,[19] L. E. Piilonen,[53] N. Root,[2] H. Sagawa,[9] S. Saitoh,[9] Y. Sakai,[9] M. Satapathy,[52] A. Satpathy,[9,5] O. Schneider,[19] A. J. Schwartz,[5] T. Seki,[48] S. Semenov,[13] K. Senyo,[23] M. E. Sevior,[22] T. Shibata,[30] J. B. Singh,[33] N. Soni,[33] S. Stanič,[9,*] M. Starič,[14] A. Sugi,[23] K. Sumisawa,[9] T. Sumiyoshi,[48] S. Suzuki,[54] S. K. Swain,[8] T. Takahashi,[31] F. Takasaki,[9] J. Tanaka,[46] M. Tanaka,[9] G. N. Taylor,[22] Y. Teramoto,[31] T. Tomura,[46] K. Trabelsi,[8] T. Tsuboyama,[9] T. Tsukamoto,[9] S. Uehara,[9] K. Ueno,[27] S. Uno,[9] G. Varner,[8] K. E. Varvell,[41] C. H. Wang,[26] J. G. Wang,[53] M.-Z. Wang,[27] M. Watanabe,[30] Y. Watanabe,[47] E. Won,[16] B. D. Yabsley,[53] Y. Yamada,[9] A. Yamaguchi,[45] H. Yamamoto,[45] Y. Yamashita,[29] M. Yamauchi,[9] H. Yanai,[30] Heyoung Yang,[39] C. C. Zhang,[11] J. Zhang,[51] Z. P. Zhang,[38] Y. Zheng,[8] D. Žontar,[20,14] and D. Zürcher[19]

(Belle Collaboration)

[1]*Aomori University, Aomori*
[2]*Budker Institute of Nuclear Physics, Novosibirsk*
[3]*Chiba University, Chiba*
[4]*Chuo University, Tokyo*
[5]*University of Cincinnati, Cincinnati, Ohio 45221*
[6]*University of Frankfurt, Frankfurt*
[7]*Gyeongsang National University, Chinju*
[8]*University of Hawaii, Honolulu, Hawaii 96822*
[9]*High Energy Accelerator Research Organization (KEK), Tsukuba*
[10]*Hiroshima Institute of Technology, Hiroshima*
[11]*Institute of High Energy Physics, Chinese Academy of Sciences, Beijing*
[12]*Institute of High Energy Physics, Vienna*
[13]*Institute for Theoretical and Experimental Physics, Moscow*
[14]*J. Stefan Institute, Ljubljana*
[15]*Kanagawa University, Yokohama*
[16]*Korea University, Seoul*
[17]*Kyoto University, Kyoto*
[18]*Kyungpook National University, Taegu*
[19]*Institut de Physique des Hautes Énergies, Université de Lausanne, Lausanne*
[20]*University of Ljubljana, Ljubljana*
[21]*University of Maribor, Maribor*
[22]*University of Melbourne, Victoria*
[23]*Nagoya University, Nagoya*
[24]*Nara Women's University, Nara*
[25]*National Kaohsiung Normal University, Kaohsiung*
[26]*National Lien-Ho Institute of Technology, Miao Li*
[27]*Department of Physics, National Taiwan University, Taipei*
[28]*H. Niewodniczanski Institute of Nuclear Physics, Krakow*
[29]*Nihon Dental College, Niigata*
[30]*Niigata University, Niigata*
[31]*Osaka City University, Osaka*
[32]*Osaka University, Osaka*
[33]*Panjab University, Chandigarh*

0556-2821/2003/68(1)/011103(6)/$20.00

[34]*Peking University, Beijing*
[35]*Princeton University, Princeton, New Jersey 08545*
[36]*RIKEN BNL Research Center, Upton, New York 11973*
[37]*Saga University, Saga*
[38]*University of Science and Technology of China, Hefei*
[39]*Seoul National University, Seoul*
[40]*Sungkyunkwan University, Suwon*
[41]*University of Sydney, Sydney, New South Wales*
[42]*Tata Institute of Fundamental Research, Bombay*
[43]*Toho University, Funabashi*
[44]*Tohoku Gakuin University, Tagajo*
[45]*Tohoku University, Sendai*
[46]*Department of Physics, University of Tokyo, Tokyo*
[47]*Tokyo Institute of Technology, Tokyo*
[48]*Tokyo Metropolitan University, Tokyo*
[49]*Tokyo University of Agriculture and Technology, Tokyo*
[50]*Toyama National College of Maritime Technology, Toyama*
[51]*University of Tsukuba, Tsukuba*
[52]*Utkal University, Bhubaneswer*
[53]*Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061*
[54]*Yokkaichi University, Yokkaichi*
[55]*Yonsei University, Seoul*

(Received 24 April 2003; published 31 July 2003)

We report an improved measurement of the partial-rate *CP* asymmetry in $B^\pm \to \overset{(-)}{K}{}^0 \pi^\pm$ decays. The analysis is based on a data sample of 85×10^6 $B\bar{B}$ pairs collected at the $\Upsilon(4S)$ resonance with the Belle detector at the KEKB e^+e^- storage ring. We measure $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0\pi^\pm) = 0.07^{+0.09}_{-0.08}{}^{+0.01}_{-0.03}$, where the first and second errors are statistical and systematic, respectively; the corresponding 90% confidence-level interval is $-0.10 < \mathcal{A}_{CP}(\overset{(-)}{K}{}^0\pi^\pm) < 0.22$.

DOI: 10.1103/PhysRevD.68.011103 PACS number(s): 11.30.Er, 12.15.Hh, 13.25.Hw, 14.40.Nd

In the Kobayashi-Maskawa (KM) model [1], *CP* violation arises from a complex phase in the quark-mixing matrix of the weak interaction. This idea is strongly supported by the observation of mixing-induced *CP* violation at the *B* factories [2]. Direct *CP* violation (DCPV) is also expected in the KM scheme and has been observed in the *K* meson system [3]. However, DCPV has not yet been observed in the *B* meson system.

Charmless hadronic *B* decays can provide opportunities to observe DCPV [4–8]. Many of these decays include contributions from both $b\to u$ tree and $b\to s$ penguin diagrams and the interference between these two processes can produce a partial-rate *CP* asymmetry:

$$\mathcal{A}_{CP} = \frac{\Gamma(\bar{B}\to\bar{f}) - \Gamma(B\to f)}{\Gamma(\bar{B}\to\bar{f}) + \Gamma(B\to f)} = \frac{2|A_T||A_P|\sin\delta\sin\phi}{|A_T|^2+|A_P|^2+2|A_T||A_P|\cos\delta\cos\phi}.$$

Here, $\Gamma(B\to f)$ denotes the partial width of either a B_d^0 or B^+ meson decaying into a flavor-specific final state f and $\Gamma(\bar{B}\to\bar{f})$ represents that of the charge conjugate decay; A_T and A_P represent the tree and penguin amplitudes; and δ and ϕ stand for the *CP*-conserving and *CP*-violating relative phases, respectively, between A_T and A_P. In order to have a sizable $\mathcal{A}_{CP}$, both phase differences have to be nonzero, i.e., $\delta\neq 0$ and $\phi\neq 0$, and the tree and penguin amplitudes should be of comparable size ($|A_T|\sim|A_P|$).

The decay $B^\pm \to \overset{(-)}{K}{}^0 \pi^\pm$ is almost a pure $b\to s$ penguin process and, thus, no sizable asymmetry is expected in the context of the standard model (SM) [9,10]. However, our previously published result, based on an analysis of a 29 fb^{-1} data sample, was $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0\pi^\pm) = 0.46\pm 0.15\pm 0.02$ [6]. An asymmetry of this magnitude cannot be explained in the SM, even with the inclusion of the interference of the basic penguin amplitude with a large $B^\pm \to (K^\pm\pi^0)_{\rm tree} \to \overset{(-)}{K}{}^0\pi^\pm$ rescattering process [11], and would be an indication of a new physics contribution in the penguin loop [12]. It is important to verify whether the central value persists with improved precision.

In this paper, we report an updated measurement of the partial-rate *CP* asymmetry in $B^\pm \to \overset{(-)}{K}{}^0 \pi^\pm$ decays based on a 78 fb^{-1} data sample collected at the $\Upsilon(4S)$ resonance, corresponding to $(85.0\pm 0.5)\times 10^6$ $B\bar{B}$ pairs, with the Belle detector [13] at the KEKB e^+e^- storage ring [14]. This is approximately three times as much data as the sample that

*On leave from Nova Gorica Polytechnic, Nova Gorica.

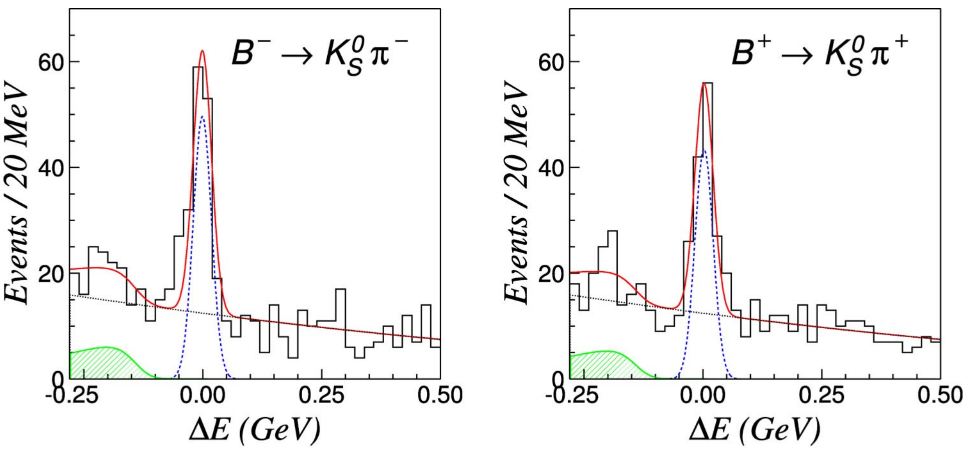

FIG. 1. The ΔE distributions for the $B^\pm \to K_S^0 \pi^\pm$ candidates divided into B^- (left) and B^+ (right) samples. The fit results are shown as the solid, dashed and dotted curves for the total, signal and $q\bar{q}$ background, respectively; the hatched area indicates the contribution from other charmless B decays.

was used for the previous measurement and significantly improves the statistical precision. Throughout this paper, the partial-rate *CP* asymmetry $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0\pi^\pm)$ is defined as

$$\mathcal{A}_{CP}(\overset{(-)}{K}{}^0\pi^\pm) \equiv \frac{N(K_S^0\pi^-) - N(K_S^0\pi^+)}{N(K_S^0\pi^-) + N(K_S^0\pi^+)},$$

where $N(K_S^0\pi^-)$ denotes the yield of $B^- \to K_S^0\pi^-$ decay and $N(K_S^0\pi^+)$ represents that of the charge conjugate mode.

The Belle detector is a large-solid-angle spectrometer that consists of a three-layer silicon vertex detector, a 50-layer central drift chamber (CDC), an array of threshold Čerenkov counters with silica aerogel radiators (ACC), time-of-flight scintillation counters, and an electromagnetic calorimeter comprised of CsI(TI) crystals (ECL) located inside a superconducting solenoid coil that provides a 1.5 T magnetic field. An iron flux-return located outside of the coil is instrumented to detect K_L^0 mesons and to identify muons (KLM). A detailed description of the Belle detector can be found elsewhere [13].

The analysis procedure is the same as described in Ref. [6]. Candidate $B^\pm$ mesons are reconstructed using high momentum $\pi^\pm$ and K_S^0 mesons. For candidate $\pi^\pm$ mesons, charged tracks are required to originate from the interaction region based on their impact parameters. Candidate K_S^0 mesons are reconstructed using pairs of oppositely charged tracks that have an invariant mass $m_{\pi\pi}$ in the range $480 < m_{\pi\pi} < 516\ \mathrm{MeV}/c^2$. A candidate must have a displaced vertex and flight direction consistent with a K_S^0 originating from the interaction region.

In Belle, high momentum $\pi^\pm$ and $K^\pm$ mesons are distinguished by their associated Čerenkov light yield $N_{\mathrm{p.e.}}$ in the ACC and the ionization energy loss dE/dx in the CDC. These quantities are used to form a particle identification (PID) likelihood ratio $\mathcal{R}_\pi = \mathcal{L}_\pi/(\mathcal{L}_\pi + \mathcal{L}_K)$, where $\mathcal{L}_\pi$ denotes the product of the individual likelihoods of $N_{\mathrm{p.e.}}$ and dE/dx for $\pi^\pm$ mesons; $\mathcal{L}_K$ is the product for $K^\pm$ mesons. For the $\mathcal{R}_\pi$ requirement used in this analysis, $\pi^\pm$ mesons are identified with an efficiency of 91% and there is a 10% $K^\pm$ misidentification rate. The efficiency and fake rate are estimated by comparing the $\overset{(-)}{D}{}^0$ yields in a sample of $D^{*\pm}$-tagged $\overset{(-)}{D}{}^0 \to K^\mp \pi^\pm$ decays before and after the application of the high momentum PID requirements. A similar likelihood ratio that also includes the energy deposit in the ECL is used to identify electrons; positively identified electrons are rejected.

Signal candidates are identified using the beam-energy constrained mass $m_{bc} = \sqrt{E_{\mathrm{beam}}^{*2} - p_B^{*2}}$ and the energy difference $\Delta E = E_B^* - E_{\mathrm{beam}}^*$, where $E_{\mathrm{beam}}^* = 5.29$ GeV and p_B^* and E_B^* are the momentum and energy of the reconstructed B meson in the e^+e^- center-of-mass frame.

The dominant background comes from the $e^+e^- \to q\bar{q}(q = u,d,s,c)$ continuum process; backgrounds from $b \to c$ decays are negligible because the momenta of the decay products are smaller than those of the signal K_S^0 and $\pi^\pm$. We discriminate the signal from the $q\bar{q}$ background by the event topology. This is quantified by the Super-Fox-Wolfram (SFW) variable [6,15], which is formed from modified Fox-Wolfram moments that are combined using a Fisher discriminant [16] into a single variable. The angle of the B-meson's flight direction with respect to the beam axis (θ_B) provides additional discrimination. A likelihood ratio $\mathcal{R}_s = \mathcal{L}_s/(\mathcal{L}_s + \mathcal{L}_{q\bar{q}})$ is calculated, where $\mathcal{L}_s$ ($\mathcal{L}_{q\bar{q}}$) denotes the product of the individual SFW and θ_B likelihoods for signal ($q\bar{q}$ background). The probability density functions (PDFs) are derived from GEANT-based Monte Carlo (MC) simulations [17] for the signal and m_{bc} sideband ($5.2 < m_{bc} < 5.26\ \mathrm{GeV}/c^2$) data for the $q\bar{q}$ background. We make a requirement on $\mathcal{R}_s$

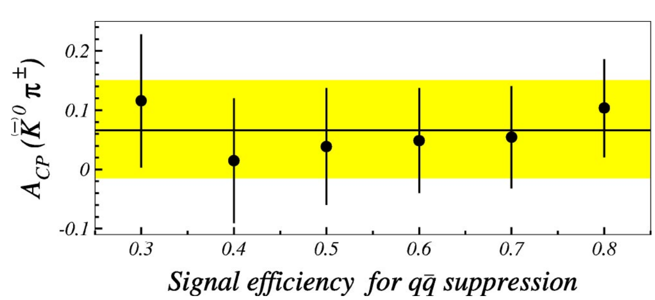

FIG. 2. $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0\pi^\pm)$ as a function of the signal efficiency of the $q\bar{q}$ suppression ($\mathcal{R}_s$) selection. The horizontal line and hatched area indicate the $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0\pi^\pm)$ value and its statistical error for the $\mathcal{R}_s$ requirement used in the actual measurement. Note that the statistical errors for the different data points are strongly correlated.

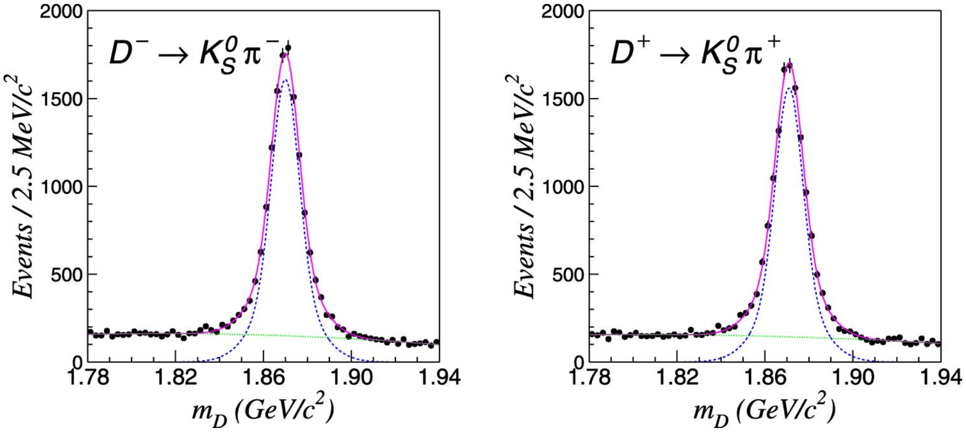

FIG. 3. The mass spectra for the $D^\pm \to K_S^0\pi^\pm$ candidates separated into D^- (left) and D^+ (right) samples, where the kinematic requirements and daughter particle reconstruction are the same as used for the $B^\pm \to K_S^0\pi^\pm$ signal. The fit results are shown as the solid, dashed and dotted curves for the total, $D^\pm \to K_S^0\pi^\pm$ and combinatorial background, respectively.

that eliminates 88% of the $q\bar{q}$ background while retaining 73% of the signal.

Signal yields are extracted from the ΔE distributions of events in the m_{bc} signal region ($5.271 < m_{bc} < 5.287$ GeV/c^2), separately for the $K_S^0\pi^+$ and $K_S^0\pi^-$ final states. The signal reconstruction efficiency [18] is estimated to be 12% based on the MC. The ΔE distributions are fitted using a binned maximum likelihood fit with three components: the signal, $q\bar{q}$ background, and other charmless B decays, as shown in Fig. 1. The signal PDF is modeled with a Gaussian distribution taken from the signal MC and calibrated using a $B^\pm \to \overset{(-)}{D}{}^0(\to K^\pm\pi^\mp)\pi^\pm$ sample where a similar reconstruction procedure is applied. For the $q\bar{q}$ background, the PDF is modeled with a second-order polynomial with a shape that is determined from the m_{bc} sideband data. For other charmless B decays, the PDF is taken from a smoothed histogram of a large MC sample. (The enhancement in the lower ΔE region is due to charmless B decay modes involving an additional unreconstructed π meson.) Except for the signal peak positions, the same PDF shape parameters are used for both B^+ and B^- samples. The signal peak positions are determined separately for the B^+ and B^- samples since a small systematic difference between the two samples is observed. (This is discussed below.) In the fit procedure, all of the PDF shape parameters are fixed and all the normalizations are free parameters. The signal yields are found to be $N(K_S^0\pi^+) = 104.4^{+13.2}_{-12.5}$ and $N(K_S^0\pi^-) = 119.1^{+13.8}_{-13.1}$, and the partial-rate CP asymmetry is determined to be $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0\pi^\pm) = 0.07^{+0.09}_{-0.08}$.

TABLE I. Summary of the detector-based bias tests. For tests other than those with the $D^\pm \to K_S^0\pi^\pm$ sample, $\mathcal{A}_{CP}$ values determined without the high momentum PID ($\mathcal{R}_\pi$) and $q\bar{q}$ suppression ($\mathcal{R}_s$) requirements are also listed.

Samples		$\mathcal{A}_{CP}$ (%)
$D^\pm \to K_S^0\pi^\pm$		2.0 ± 0.8
$B^\pm \to \overset{(-)}{D}{}^0(\to K^\pm\pi^\mp)\pi^\pm$		0.6 ± 1.7
	$w/o\mathcal{R}_\pi$	0.0 ± 1.5
	$w/o\mathcal{R}_s$	0.0 ± 1.4
$B^\pm \to K_S^0\pi^\pm m_{bc}$ sideband data		0.9 ± 1.3
	$w/o\mathcal{R}_\pi$	0.5 ± 0.9
	$w/o\mathcal{R}_s$	0.5 ± 0.4

The stability of $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0\pi^\pm)$ as a function of the selection requirements is tested by varying the $q\bar{q}$ suppression requirement. As shown in Fig. 2, the value of $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0\pi^\pm)$ is stable when this requirement is changed.

Detector-based biases in $K_S^0\pi^\pm$ reconstruction are investigated using a sample of inclusive, high momentum continuum $D^\pm \to K_S^0\pi^\pm$ decays, where the daughter particles are required to satisfy the same kinematic requirements and reconstruction criteria, including the PID requirement, as used for the signal. Separate fits to the D^+ and D^- mass distributions, shown in Fig. 3, indicate that the signal ΔE resolutions for the B^+ and B^- samples are consistent, but there is a 1.0 ± 0.1 MeV/c^2 difference in the mass peak positions. This difference in the peak positions is caused by a below 0.1% difference between the momentum measurement for high momentum negative and positive tracks that is attributed to a residual detector misalignment. After accounting for this difference in peak positions, $\mathcal{A}_{CP}(D^\pm \to K_S^0\pi^\pm)$ is determined and listed in Table I. Here the sign convention in the definition of $\mathcal{A}_{CP}(D^\pm \to K_S^0\pi^\pm)$ follows that of $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0\pi^\pm)$. The observed (2.0 ± 0.8)% asymmetry is treated as a possible bias, and -2.8% is assigned as a systematic error in the $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0\pi^\pm)$ measurement.

Possible biases in the B reconstruction are examined using a sample of $B^\pm \to \overset{(-)}{D}{}^0(\to K^\pm\pi^\mp)\pi^\pm$ decays where the entire reconstruction procedure, except for the K_S^0 reconstruction, is applied. Fits to the ΔE distributions are shown in Fig. 4 for the B^+ and B^- samples separately. It confirms that the resolutions are consistent between the two samples. Due to the same effect that was found for the $D^\pm \to K_S^0\pi^\pm$ sample, however, a 3.2 ± 0.5 MeV difference in peak positions is observed. The MC study shows that the 1.0 MeV/c^2 $D^\pm$ mass shift comes from the high momentum measurement bias for positive and negative tracks, and we find that amount of this shift corresponds to 3.2 MeV shift in ΔE by the same MC study.

After accounting for the difference in ΔE peak positions, $\mathcal{A}_{CP}(B^\pm \to \overset{(-)}{D}{}^0\pi^\pm)$ is determined and listed in Table I. The absence of an asymmetry indicates there is no bias. Biases in

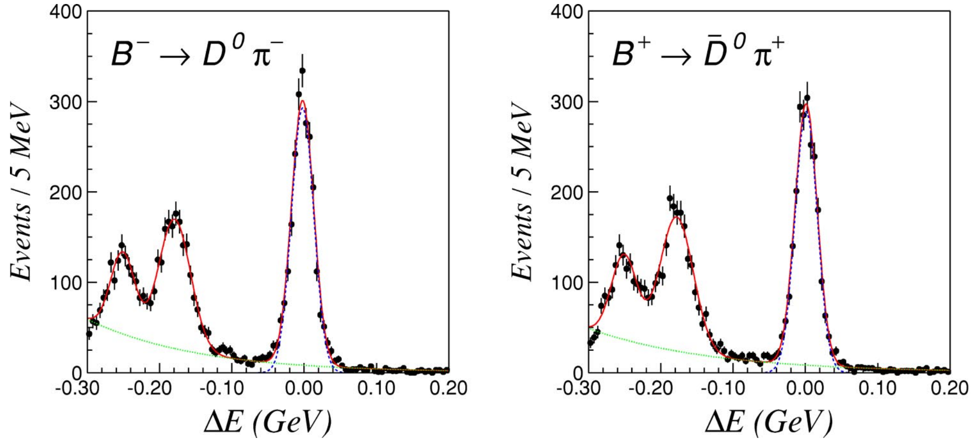

FIG. 4. The ΔE distributions for $B^\pm \to \overset{(-)}{D}{}^0(\to K^\pm \pi^\mp)\pi^\pm$ candidates separately for the B^- (left) and B^+ (right) samples after application of the entire reconstruction procedure other than that for the K_S^0. The fit results are shown as the solid, dashed and dotted curves for the total, $B^\pm \to \overset{(-)}{D}{}^0(\to K^\pm \pi^\mp)\pi^\pm$ and combinatorial background, respectively. The enhancement in the lower ΔE region contains backgrounds from $B \to D^* \pi^\pm$ and $D^0 \rho$. The ΔE resolutions obtained are 15.2 ± 0.3 and 15.3 ± 0.3 MeV for the B^+ and B^- samples, respectively.

the high momentum PID and $q\bar{q}$ suppression are also examined by removing each of them in the $\mathcal{A}_{CP}(B^\pm \to \overset{(-)}{D}{}^0 \pi^\pm)$ measurement. The results are given in Table I. No biases are observed.

Possible asymmetries in the detector response and reconstruction for the $q\bar{q}$ background are checked using events in the m_{bc} sideband region. The application of the entire reconstruction procedure confirms that the ΔE shapes of the B^+ and B^- samples are consistent, and no bias is observed, as indicated in Table I. The absence of $\mathcal{R}_\pi$- and $\mathcal{R}_s$-related biases are confirmed in the same manner as for the $B^\pm \to \overset{(-)}{D}{}^0(\to K^\pm \pi^\mp)\pi^\pm$ sample.

In order to study the sensitivity to the signal and $q\bar{q}$ background PDF shapes, each shape parameter is independently varied by its 1σ error. In addition, the signal shape parameters are also estimated from the actual $B^\pm \to K_S^0 \pi^\pm$ samples by allowing them to be free parameters in the fits. The uncertainty in the contribution from other charmless B decays is estimated from the change in the asymmetry by fitting the region of $\Delta E > -0.1$ GeV without those decays. The resulting relative changes in asymmetries are added in quadrature giving the fitting systematics of $+0.014$ and -0.006.

Because of the difference between the results presented here and the sizable asymmetry in our previous measurement, the asymmetries of different data sub-samples are examined. Figure 5 shows $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0 \pi^\pm)$ for each data sub-sample together with $\mathcal{A}_{CP}(D^\pm \to K_S^0 \pi^\pm)$ as a reference. The variation of $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0 \pi^\pm)$ is independent of that in $\mathcal{A}_{CP}(D^\pm \to K_S^0 \pi^\pm)$ and is consistent with statistical fluctuations. This conclusion is also supported by a least square fit of the variation to the hypothesis of the $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0 \pi^\pm)$ for whole data sample that gives $\chi^2/n = 12.1/7 = 1.7$, where n stands for the number of degree of freedom.

The total systematic error in the $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0 \pi^\pm)$ is evaluated from the quadratic sum of the $K_S^0 \pi^\pm$ reconstruction bias and ΔE fitting systematics. Finally, the asymmetry

$$\mathcal{A}_{CP}(\overset{(-)}{K}{}^0 \pi^\pm) = 0.07^{+0.09}_{-0.08}{}^{+0.01}_{-0.03}$$

is obtained and a 90% confidence level interval

$$-0.10 < \mathcal{A}_{CP}(\overset{(-)}{K}{}^0 \pi^\pm) < 0.22,$$

is set, where Gaussian statistics are assumed and the systematic error is added linearly.

In conclusion, we have measured the partial-rate *CP* asymmetry in $B^\pm \to \overset{(-)}{K}{}^0 \pi^\pm$ with 85×10^6 $B\bar{B}$ pairs collected on the $\Upsilon(4S)$ resonance at the Belle experiment. The resulting $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0 \pi^\pm) = 0.07^{+0.09}_{-0.08}{}^{+0.01}_{-0.03}$ is consistent with zero at the current level of statistical precision. The 90% confidence level interval $-0.10 < \mathcal{A}_{CP}(\overset{(-)}{K}{}^0 \pi^\pm) < 0.22$ is set, which is consistent with other measurements [7,8]. This result has a statistical precision below 10% and supersedes our previous measurement [6]. We do not observe a significant partial-rate *CP* asymmetry in $B^\pm \to \overset{(-)}{K}{}^0 \pi^\pm$ and attribute the sizable $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0 \pi^\pm)$ found previously in a much smaller data sample to a statistical fluctuation.

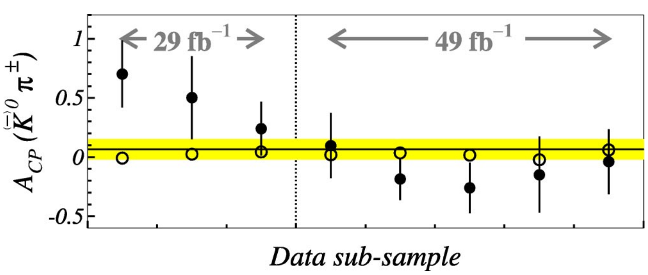

FIG. 5. $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0 \pi^\pm)$ in each data sub-sample. The horizontal line and hatched area show the central value and the 1σ statistical error of the $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0 \pi^\pm)$ result reported here. The solid points with the statistical error bars represent the $\mathcal{A}_{CP}(\overset{(-)}{K}{}^0 \pi^\pm)$ result obtained for each data sub-sample; the open points show $\mathcal{A}_{CP}(D^\pm \to K_S^0 \pi^\pm)$. The sum of the three leftmost points corresponds to the 29 fb^{-1} data sample used in our previous measurement.

We are grateful to Y. Okada for useful discussions and comments. We wish to thank the KEKB accelerator group for the excellent operation of the KEKB accelerator. We acknowledge support from the Ministry of Education, Culture, Sports, Science, and Technology of Japan and the Japan Society for the Promotion of Science; the Australian Research Council and the Australian Department of Industry, Science and Resources; the National Science Foundation of China under contract No. 10175071; the Department of Science and Technology of India; the BK21 program of the Ministry of Education of Korea and the CHEP SRC program of the Korea Science and Engineering Foundation; the Polish State Committee for Scientific Research under contract No. 2P03B 17017; the Ministry of Science and Technology of the Russian Federation; the Ministry of Education, Science and Sport of the Republic of Slovenia; the National Science Council and the Ministry of Education of Taiwan; and the U.S. Department of Energy.

[1] M. Kobayashi and T. Maskawa, Prog. Theor. Phys. **49**, 652 (1973).

[2] Belle Collaboration, K. Abe *et al.*, Phys. Rev. Lett. **87**, 091802 (2001); Phys. Rev. D **66**, 071102(R) (2002); BABAR Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **87**, 091801 (2001); **89**, 201802 (2002).

[3] KTeV Collaboration, A. Alavi-Harati *et al.*, Phys. Rev. Lett. **83**, 22 (1999); NA48 Collaboration, J. R. Batley *et al.*, Phys. Lett. B **544**, 97 (2002).

[4] See for a recent review, R. Fleischer, hep-ph/0210323.

[5] Belle Collaboration, K. Abe *et al.*, Phys. Rev. D **64**, 071101(R) (2001); Phys. Rev. Lett. **89**, 071801 (2002); Phys. Rev. D **68**, 012001 (2003).

[6] Belle Collaboration, B. C. K. Casey *et al.*, Phys. Rev. D **66**, 092002 (2002).

[7] CLEO Collaboration, S. Chen *et al.*, Phys. Rev. Lett. **85**, 525 (2000).

[8] BABAR Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **87**, 151802 (2001); Phys. Rev. D **65**, 051502(R) (2002); Phys. Rev. Lett. **89**, 281802 (2002); **91**, 021801 (2003).

[9] See, for example, M. Beneke *et al.*, Nucl. Phys. **B606**, 245 (2001).

[10] See, for example, A. I. Sanda and K. Ukai, Prog. Theor. Phys. **107**, 421 (2002); Y.-Y. Keum and A. I. Sanda, hep-ph/0209014.

[11] See, for example, A. J. Buras, R. Fleischer, and T. Mannel, Nucl. Phys. **B533**, 3 (1998); W. S. Hou and K. C. Yang, Phys. Rev. Lett. **84**, 4806 (2000).

[12] See, for example, X. G. He, W. S. Hou, and K. C. Yang, Phys. Rev. Lett. **81**, 5738 (1998); R. Fleischer and T. Mannel, hep-ph/9706261.

[13] Belle Collaboration, A. Abashian *et al.*, Nucl. Instrum. Methods Phys. Res. A **479**, 117 (2002).

[14] S. Kurokawa and E. Kikutani, Nucl. Instrum. Methods Phys. Res. A **499**, 1 (2003).

[15] G. C. Fox and S. Wolfram, Phys. Rev. Lett. **41**, 1581 (1978).

[16] R. A. Fisher, Ann. Eugenics **7**, 179 (1936).

[17] R. Brun *et al.*, GEANT 3.21, CERN Report No. DD/EE/84-1, 1987.

[18] The signal reconstruction efficiency includes branching fractions of $K^0 \to K_S^0$ and $K_S^0 \to \pi^+\pi^-$.