PRAMANA — journal of physics © Indian Academy of Sciences Vol. 67, No. 5 November 2006 pp. 763–772

CP-violations in B decays

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Abstract. Recent results on CP-violation measurements in B decays from energy-asymmetric B-factory experiments are reported. Thanks to large accumulated data samples, CP-violations in B decays in mixing-decay interference and direct CP-violation are now firmly established. The measurements of three angles of the unitarity triangle from CP-violations of B decays are quite consistent with the Standard Model expectations. These results strongly support the validity of the Kobayashi–Maskawa prescription of CP-violation.

Keywords. CP-violation; B decays; flavor physics.

PACS Nos 11.30.Er; 12.15.Hh; 13.25.Hw

1. Introduction

Violations of CP symmetry have been one of the most interesting phenomena in physics, not only in elementary particle physics but also in cosmology or astrophysics. It is one of the key elements that are required to explain a matter dominance of the present universe: baryon number violation, existence of non-equilibrium, and CP-violation. A CP-violation was first observed in the decay of neutral K mesons in 1964 [1]. In 1973, Kobayashi and Maskawa (KM) proposed a model [2] that attributed CP-violation to an irreducible complex phase in the weak-interaction quark mixing (CKM) matrix. The KM idea required (or predicted) three generations of quarks and was remarkable when only three quarks (u, d, and s) were known at that time. The subsequent discoveries of the c, b, and t quarks and that the CP asymmetry of K mesons can be well explained by the KM model were strong supports of validity of the KM model though alternative models still exist.

The CKM matrix is a 3×3 unitary matrix which relates the weak eigenstates and mass eigenstates of (d, s, b) quarks and is given with the Wolfenstein parametrization [3] as

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}. \tag{1}$$

The unitarity condition, $V_{ud}\,V_{ub}^{*}+V_{cd}\,V_{cb}^{*}+V_{td}\,V_{tb}^{*}=0$, forms the so-called unitarity triangle and its three angles (notations of β, α, γ instead of ϕ_1, ϕ_2, ϕ_3 are also used) are defined as

$$\phi_1 = \arg\left(-\frac{V_{cd}V_{cb}^{*}}{V_{td}V_{tb}^{*}}\right), \quad \phi_2 = \arg\left(-\frac{V_{td}V_{tb}^{*}}{V_{ud}V_{ub}^{*}}\right),$$
$$\phi_3 = \arg\left(-\frac{V_{ud}V_{ub}^{*}}{V_{cd}V_{cb}^{*}}\right). \tag{2}$$

There are three types of CP-violations in particle decays.

- *Direct CP-violation in mixing*: Magnitudes of decay amplitudes for a particle to a certain final state and its charge conjugate are different. A CP asymmetry is given by

$$A_{\rm CP} = \frac{\Gamma(\bar{P}\to\bar{f}) - \Gamma(P\to f)}{\Gamma(\bar{P}\to\bar{f}) + \Gamma(P\to f)}. \tag{3}$$

- *CP-violation in mixing*: When a mixing occurs between neutral particle and its anti-particle, such as K^0 and B^0 system, mass eigenstates are expressed as

$$|P_1\rangle = p|P^0\rangle + q|\bar{P}^0\rangle, \quad |P_2\rangle = p|P^0\rangle - q|\bar{P}^0\rangle. \tag{4}$$

  A CP-violation in the mixing ($|q/p| \neq 1$) introduces a difference in transition rates between $P^0 \to \bar{P}^0$ and $\bar{P}^0 \to P^0$.
- *CP-violation in mixing due to interference between mixing and decay amplitudes*: In 1980, Sanda, Carter and Bigi [4] predicted that a large CP-violation could be possible in certain B decays from the KM model in contrast to small CP-violation, $\mathcal{O}(10^{-3})$, in K mesons. More details are described in §3.

2. Accelerators and detectors

The B-factory accelerators, PEP-II [5] in USA and KEKB [6] in Japan, have remarkably improved their performance since their first operations in late 1998. The experiments, Belle [7] and BaBar [8], started physics data taking in 1999. Both accelerators achieved peak luminosities exceeding 10^{34} cm^{-2} s^{-1}.

Thanks to the excellent performance of the two accelerators, BaBar and Belle have accumulated integrated luminosity of ~310 fb^{-1} and ~530 fb^{-1} by this workshop, respectively. Among them, up to 232 and 386 million $B\bar{B}$ pairs from $\Upsilon(4S)$ resonance are used for the analyses reported here.

3. ϕ_1 measurements

The Standard Model (SM) predicts CP asymmetries in the time-dependent rates for B^0 and $\bar{B}^0$ decays to a common CP eigenstate $f_{\rm CP}$ [4]. In the decay chain

$\Upsilon(4S) \to B^0\bar{B}^0 \to f_{\rm CP} f_{\rm tag}$, where one of the B mesons decays at time $t_{\rm CP}$ to a final-state $f_{\rm CP}$ and the other decays at time $t_{\rm tag}$ to a final-state $f_{\rm tag}$ that distinguishes between B^0 and $\bar{B}^0$, a time-dependent CP asymmetry is given by

$$A_{\rm CP}(\Delta t) = \mathcal{S}\sin(\Delta m \Delta t) + \mathcal{A}\cos(\Delta m \Delta t), \tag{5}$$

where

$$\mathcal{S} = \frac{2\,\Im\lambda_{\rm f}}{1+|\lambda_{\rm f}|^2}, \quad \mathcal{A} = \frac{|\lambda_{\rm f}|^2-1}{|\lambda_{\rm f}|^2+1}, \quad \lambda_{\rm f} = \frac{q}{p}\frac{\bar{A}_{\rm f}}{A_{\rm f}}. \tag{6}$$

Note that BaBar uses a notation $C = -\mathcal{A}$. Here τ_{B^0} is the B^0 lifetime, Δm is the mass difference between the two B^0 mass eigenstates, $\Delta t = t_{\rm CP} - t_{\rm tag}$. A $b \to c\bar{c}s$ decay to a CP eigenstate ($B^0 \to$ charmonium $K^0_{S,L}$) is the theoretically cleanest example providing $\mathcal{S} = -\xi_{\rm f}\sin 2\phi_1$ where $\xi_{\rm f} = +1(-1)$ corresponds to CP-even (-odd) final states. In this case, a dominant part of the $b \to sc\bar{c}$ penguin amplitudes has the same CKM phase as the $b \to c\bar{c}s$ tree amplitude and the effect of the penguin contributions with different weak phase than the tree amplitude is less than $\sim$1%.

The measurement requires the reconstruction of $B^0 \to f_{\rm CP}$ decays, the determination of the b-flavor of the accompanying B-decay ($f_{\rm tag}$), a measurement of Δt, and a fit of the expected Δt distribution to the measured distribution using a maximum-likelihood method.

$B^0 \to ({\rm charmonium} + K^0_S)$ decays (charge conjugate modes are implied throughout this report unless otherwise mentioned) are identified using the energy difference $\Delta E \equiv E_B^{\rm cms} - E_{\rm beam}^{\rm cms}$ and the beam-energy constrained mass $M_{\rm bc} \equiv \sqrt{(E_{\rm beam}^{\rm cms})^2 - (p_B^{\rm cms})^2}$, where $E_{\rm beam}^{\rm cms}$ is the cms beam energy, and $E_B^{\rm cms}$ and $p_B^{\rm cms}$ are the cms energy and momentum of the B candidate. Candidate $B^0 \to J/\psi K^0_L$ decays are selected by requiring hit patterns in the electromagnetic calorimeter and/or the K^0_L detector that are consistent with the presence of a shower induced by a neutral hadron. The kinematic quantity is calculated with the $B^0 \to J/\psi K_L$ two-body decay hypothesis. Signal and background distributions are extracted from the fit.

Belle has updated $\sin 2\phi_1$ measurement using $B^0 \to J/\psi K^0_S$ and $J/\psi K^0_L$ decay modes (i.e. experimentally cleanest sample) with 386 million $B\bar{B}$ pairs [9]. The result is $\sin 2\phi_1 = 0.652 \pm 0.039({\rm stat.}) \pm 0.020({\rm sys.})$. The world average combined with BaBar result [10] is $\sin 2\phi_1 = 0.69 \pm 0.03$ ($\mathcal{A} = 0.03 \pm 0.04$) [11] which is consistent with the SM expectation from other measurements. This serves as a firm reference point for the SM.

3.1 $b \to s$ *Penguin modes*

Decays such as $B^0 \to \phi K^0, \eta' K^0$ etc. are considered to be dominated by $b \to s$ penguin amplitudes. To a good approximation, the SM predicts $\mathcal{S} = -\xi_{\rm f}\sin 2\phi_1$ and $\mathcal{A} = 0$ for $b \to s\bar{q}q$ transitions. If new physics contributes to the $b \to s$ loop diagrams and has a different weak phase, it would give rise to $\mathcal{A} \neq 0$ and/or $\mathcal{S} \neq -\xi_{\rm f}\sin 2\phi_1$. Measurements of various decay modes of this category have been intensively performed by both Belle and BaBar. Belle has updated these measurements with 386

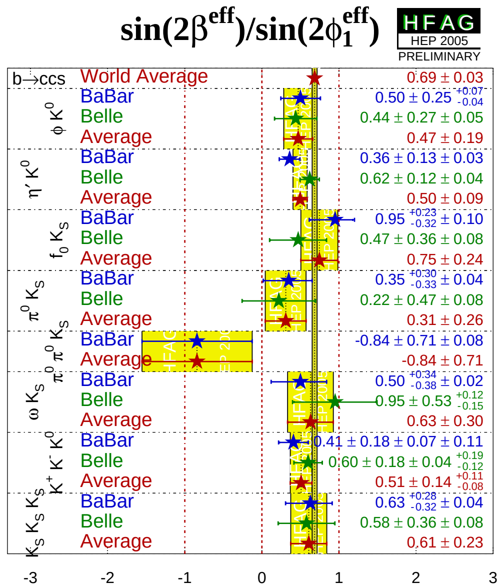

Figure 1. Summary of $-\xi_f \mathcal{S}$ for $b \to s$ penguin modes.

million $B\bar{B}$ pairs [9]. The decay modes to K_L^0 as well as K_S^0 are now included for $B^0 \to \phi K^0$ and $\eta' K^0$ decays. The results are summarized in figure 1 [11]. The $\mathcal{S}$ of individual modes are all consistent with that of the SM expectation ($b \to c\bar{c}s$ mode) within $1 \sim 2\sigma$. A naive average value $\mathcal{S} = 0.5 \pm 0.09$ deviates by 2.6σ from the SM. Still more data are needed to be conclusive on whether these are due to new physics effects or statistical effects.

4. ϕ_2 measurement

ϕ_2 is an angle between $V_{ub}^* V_{ud}$ and $V_{tb}^* V_{td}$ and can be measured by a time-dependent CP asymmetry analysis using B^0 decays to CP eigenstates through a $b \to u$ tree diagram. In this case, decay amplitude contains $V_{ub}^* V_{ud}$ and CP asymmetry due to interference with $B^0 - \bar{B}^0$ mixing amplitude that contains $V_{tb}^* V_{td}$ provides $\sin 2\phi_2$ in the same way as CP asymmetry of $B^0 \to J/\psi K^0$ decay ($V_{cb}^* V_{cs}$) provides $\sin 2\phi_1$.

Unfortunately, in contrast to $B^0 \to J/\psi K^0$ decay case, the contribution of $b \to d$ penguin amplitude could be comparable to that of $b \to u$ tree. Because these amplitudes have different weak phases, $\mathcal{S}$ is no more $\sin 2\phi_2$ and is expressed as

$$\mathcal{S} = \sqrt{1 - \mathcal{A}^2} \sin(2\phi_2 + 2\theta). \tag{7}$$

The value of θ can be extracted using the isospin relations of $B^0 \to \pi^+\pi^-$, $B^0 \to \pi^0\pi^0$, and $B^+ \to \pi^+\pi^0$ decays [12]. A non-zero $\mathcal{A}$ is a manifestation of the direct CP-violation due to an interference of $b \to u$ tree and $b \to d$ penguin amplitudes.

4.1 $B^0 \to \pi^+\pi^-$

The BaBar and Belle experiments have measured CP asymmetry parameters, $\mathcal{S}_{\pi\pi}$, $\mathcal{A}_{\pi\pi}$, using 232 million and 275 million $B\bar{B}$ pairs, respectively. The results are

BaBar [13]: $\mathcal{S} = -0.30 \pm 0.17(\text{stat.}) \pm 0.03(\text{sys.})$,
$\mathcal{A} = +0.09 \pm 0.15(\text{stat.}) \pm 0.04(\text{sys.})$,
Belle [14]: $\mathcal{S} = -0.67 \pm 0.16(\text{stat.}) \pm 0.06(\text{sys.})$,
$\mathcal{A} = +0.56 \pm 0.12(\text{stat.}) \pm 0.06(\text{sys.})$,
Average [11]: $\mathcal{S} = -0.50 \pm 0.12(\text{tot.})$, $\mathcal{A} = +0.37 \pm 0.10(\text{tot.})$.

The Belle result shows the evidence for direct CP-violation, while BaBar result does not show significant direct CP-violation. The difference between two experiments is $\sim 2.3\sigma$. It is interesting to note that the average $\mathcal{A}$ value is consistent with the expectation $-3A_{\text{CP}}(B^0 \to K^+\pi^-)$ [15].

The isospin analysis is performed [16] using the above results and the current world averages of $\mathcal{B}(B^+ \to \pi^+\pi^0)$, $\mathcal{B}(B^0 \to \pi^+\pi^-)$, $\mathcal{B}(B^0 \to \pi^0\pi^0)$, and $\mathcal{A}(B^+ \to \pi^0\pi^0)$ [11]. Because of unexpectedly large $\mathcal{B}(B^0 \to \pi^0\pi^0)$ and large experimental error of its measurement, only loose constraint on ϕ_2 can be obtained.

4.2 $B^0 \to \rho^+\rho^-$

A decay mode $B^0 \to \rho^+\rho^-$ contains two vector mesons in the final state which in general is not a pure CP eigenstate, and ρ meson is a wide resonance which would suffer from interference effects with other resonances and a non-resonant component. Therefore, it was thought that analysis of this decay mode would be complicated and might not be useful for ϕ_2 measurement. However, recently the longitudinal polarization fractions (f_{L}) in $B^+ \to \rho^+\rho^0$ and $B^0 \to \rho^+\rho^-$ decays were found to be close to 100% [17] which implies that the final state is almost pure CP even state. Furthermore, the branching fraction of $B^0 \to \rho^0\rho^0$ [18] is found to be much smaller than those of $B^0 \to \rho^+\rho^-$ and $B^+ \to \rho^+\rho^0$ [11], which indicates that the effect of penguin diagram (θ) is small enough.

The BaBar and Belle experiments have measured CP asymmetry parameters, for $B^0 \to \rho^+\rho^-$ with 232 million and 275 million $B\bar{B}$ pairs, respectively. The results are

BaBar [19]: $\mathcal{S} = -0.33 \pm 0.24(\text{stat.})^{+0.08}_{-0.14}(\text{sys.})$,
$\mathcal{A} = +0.03 \pm 0.18(\text{stat.}) \pm 0.09(\text{sys.})$,
Belle [20]: $\mathcal{S} = +0.09 \pm 0.42(\text{stat.}) \pm 0.08(\text{sys.})$,
$\mathcal{A} = 0.00 \pm 0.30(\text{stat.})^{+0.10}_{-0.09}(\text{sys.})$.

In both analyses, f_{L} is assumed to be 100% and the possible effect of CP odd component is included in the systematic error. f_{L} is also measured with these samples and found to be $0.987 \pm 0.014(\text{stat.})^{+0.020}_{-0.028}(\text{sys.})$ (BaBar) and $0.951^{+0.033}_{-0.039}(\text{stat.})^{+0.029}_{-0.031}(\text{sys.})$ (Belle), respectively. These confirm that f_{L} is close to 100%.

The isospin analysis similar to $B \to \pi\pi$ is performed using the above results ($\mathcal{S}$, $\mathcal{A}$ and f_{L}) and the current world averages of $\mathcal{B}(B^+ \to \rho^+\rho^0)$, $\mathcal{B}(B^0 \to \rho^+\rho^-)$, and the central value of $\mathcal{B}(B^0 \to \rho^0\rho^0)$ corresponding to the upper limit [11].

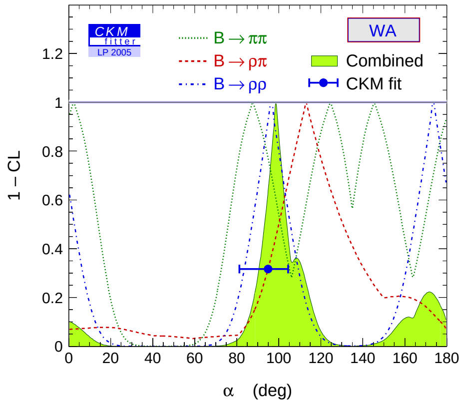

Figure 2. Summary of confidence level as a function of ϕ_2 obtained from $B^0 \to \pi^+\pi^-\pi^0$ decay, $B \to \pi\pi$ isospin analysis, $B \to \rho\rho$ isospin analysis, and all three decay modes combined.

Selecting the solution closest to the global fit constraint [16] to the unitarity triangle, $\phi_2 = 96^\circ \pm 13^\circ$ is obtained.

4.3 $B^0 \to \rho^+\pi^-$

A final state of $B^0 \to \rho^+\pi^-$ decay is not a CP eigenstate, but this decay proceeds via the same quark level diagram as $B^0 \to \pi^+\pi^-$ and both B^0 and $\bar{B}^0$ can decay to $\rho^+\pi^-$. Consequently, mixing-induced CP-violations can occur in four decay amplitudes, $B^0 \to \rho^\pm\pi^\mp$ and $\bar{B}^0 \to \rho^\pm\pi^\mp$. The measurements of CP-violation parameters for these decays, where they are treated as quasi-two-body decays, have been made both by BaBar [21] and Belle [22]. However, an isospin analysis is rather complicated and no significant constraint on ϕ_2 has been obtained [16].

BaBar has performed a time-dependent Dalitz plot analysis to $B^0 \to \pi^+\pi^-\pi^0$ decays [23]. This method allows to extract ϕ_2 without multi-fold ambiguity utilizing the different behavior of time evolution in Dalitz plane due to interference of $\rho^+\pi^-$, $\rho^-\pi^+$, and $\rho^0\pi^0$ amplitudes [24]. They use 'square Dalitz plot' parameters (m' and θ') rather than the usual squared masses of two particles. The constraint on ϕ_2 obtained from the fit is $\phi_2 = [113^{+27}_{-17}(\text{stat.}) \pm 6(\text{sys.})]^\circ$. Although the constraint is still moderate, no multi-fold ambiguity is seen as expected.

Figure 2 shows the constraint with all the above-mentioned three decay modes combined [16], which gives $\phi_2 = [99^{+12}_{-17}]^\circ$ and is consistent with that of the global fit constraint which is also shown in the plot.

5. ϕ_3 measurement

ϕ_3 is an angle between $V^*_{ub}V_{ud}$ and $V^*_{cb}V_{cd}$ and cannot be measured using a mixing-induced CP-violation in B^0 decays in a simple manner as was done for the other

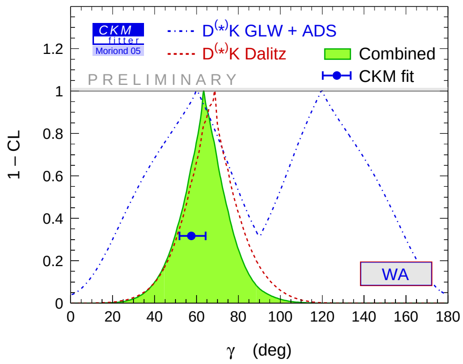

Figure 3. Confidence level as a function of ϕ_3.

two angles. Naturally, decay modes that are useful to measure ϕ_3 should involve an interference between an amplitude with V_{ub} and that with any CKM element other than V_{td}. Also, some trick is required to get rid of the effect of the strong phase in CP-violation. One of the promising decay modes is B decays to a neutral D meson and a kaon. If both D^0 and $\bar{D}^0$ decay to a common final state ($f_{\rm com}$), an amplitude of $B^- \to D^0K^- \to f_{\rm com}K^-$ (via $b \to c\bar{u}s$ diagram) and that of $B^- \to \bar{D}^0K^- \to f_{\rm com}K^-$ (via $b \to u\bar{c}s$ diagram) have an interference, resulting in a CP-violation which is related to ϕ_3. Several types of $f_{\rm com}$ are considered to be useful:

- $f_{\rm com} = D_{\rm CP}$ (*GWL method*) [25]: This method uses D^0 decays to CP eigenstates, such as $\pi^+\pi^-$, K^+K^- for CP even, and $K_S^0\pi^0$, $K_S^0\phi$ for CP odd states. There are four observables (ratio to favored D^0 decay and charge asymmetry for each of CP even and odd mode) and it allows to determine three unknowns including ϕ_3 up to an 8-fold ambiguity.
- $f_{\rm com} = D_{\rm DCSD}$ (*ADS method*) [26]: This method uses double Cabibbo suppressed decay (DCSD) of D^0 such as $D^0 \to K^+\pi^-$ so that $B^- \to D^0K^- \to K^+\pi^-K^-$ interferes with Cabibbo-favored decay of $\bar{D}^0$ in $B^- \to \bar{D}^0K^- \to K^+\pi^-K^-$. There are two observables (a ratio to Cabibbo-favored mode and a charge asymmetry) for three unknowns and ϕ_3 cannot be determined from a single measurement. However, combining results from several different decay modes, one can uniquely determine ϕ_3.
- $f_{\rm com} = K_S^0\pi^+\pi^-$ (*Dalitz method*) [27]: This method uses non-flavor-specific three-body D^0 decays. A simultaneous fit to Dalitz distributions of $K_S^0\pi^+\pi^-$ for B^+ and B^- decays is performed with three unknowns including ϕ_3. More details are described below.

The GWL and ADS methods are theoretically clean and many measurements have been made, whose summary can be seen in ref. [11], but only loose constraint on ϕ_3 can be obtained with current accuracy of measurements as shown in figure 3.

The Dalitz method was first tried by the Belle with 152 million $B\bar{B}$ pairs [28] and turned out to be the most promising with currently available data sample. The Belle has updated the results for $B^+ \to DK^+$ and $B^+ \to D^*[D\pi^0]K^+$ with an additional mode $B^+ \to DK^{*+}$ using 275 million $B\bar{B}$ pairs [29]. BaBar also obtained the results for $B^+ \to DK^+$, $B^+ \to D^*[D\pi^0]K^+$ and $B^+ \to D^*[D\gamma]K^+$ decay modes with 227 million $B\bar{B}$ pairs [30].

The decay amplitude in Dalitz plane is given for B^+ as

$$M_+ = f(m_+^2, m_-^2) + r\mathrm{e}^{i\phi_3+i\delta} f(m_-^2, m_+^2), \tag{8}$$

and the corresponding amplitude for B^- decay is given as

$$M_- = f(m_-^2, m_+^2) + r\mathrm{e}^{-i\phi_3+i\delta} f(m_+^2, m_-^2), \tag{9}$$

where r and δ are ratio of magnitudes and strong phase difference of two amplitudes $b \to c\bar{u}s$ and $b \to u\bar{c}s$, respectively, $m_+^2(m_-^2)$ is the squared invariant mass of $K_S^0\pi^+(K_S^0\pi^-)$, and $f(m_+^2, m_-^2)$ is the complex amplitude of $\bar{D}^0 \to K_S^0\pi^+\pi^-$ decay. $f(m_+^2, m_-^2)$ is determined as a sum of intermediate quasi-two-body decays using D^0 from $D^{*+} \to D^0\pi^+$ whose flavor is tagged by a charge of a soft pion. Unbinned maximum likelihood fits are performed including the effects of background, efficiency, and resolutions. Figure 3 shows the constraints on ϕ_3 with all available results combined [16]. The obtained result is $\phi_3 = [63^{+15}_{-13}]^\circ$ and consistent with that from the global fit.

6. Direct CP-violation

As mentioned in §4.2, the first evidence of the direct CP-violation was reported by Belle in the $B^0 \to \pi^+\pi^-$ decay. In the summer of 2004, BaBar and Belle reported its evidence [31] in $B^0 \to K^+\pi^-$ decay using 227 million and 275 million $B\bar{B}$ pairs, respectively. In the summer of 2005, Belle updated this measurement using 386 million $B\bar{B}$ pairs and obtained $A_{\rm CP} = -0.113 \pm 0.021 \pm 0.008$ with $\sim 5\sigma$ significance [32]. The world average is $A_{\rm CP} = -0.115 \pm 0.018$ [11] with a significance of 6.4σ, which establishes the direct CP-violation in B decays.

Direct CP-violations have been intensively searched for in many other B decay modes, but no evidence has been found so far, except for that described below. Belle has performed a Dalitz plot analysis for $B^+ \to K^+\pi^+\pi^-$ three-body decays including CP-violation effect [33]. In this analysis, not only the difference of magnitudes contributes but also that of phases of amplitudes of intermediate two-body decays contribute to a direct CP-violation. For the $B^+ \to \rho^0 K^+$ mode, they find $A_{\rm CP} = 0.30 \pm 0.11(\text{stat.}) \pm 0.02(\text{sys.})^{+0.11}_{-0.04}(\text{model})$ with a significance of 3.9σ. It should be noted that this is the first evidence of CP-violation in charged particle decays (i.e. CP-violations observed so far are all in neutral particles for both K and B). BaBar has also made a similar analysis and obtained $A_{\rm CP} = 0.34 \pm 0.13(\text{stat.}) \pm 0.06(\text{sys.})^{+0.15}_{-0.20}(\text{model})$ [34] where the central value is quite similar but significance is less than 3σ.

7. Summary

Thanks to the excellent performance of the KEKB and PEP-II accelerators, measurements of CP-violations with large accumulated data samples have now established the large CP-violation in B decays in mixing-decay interference and direct

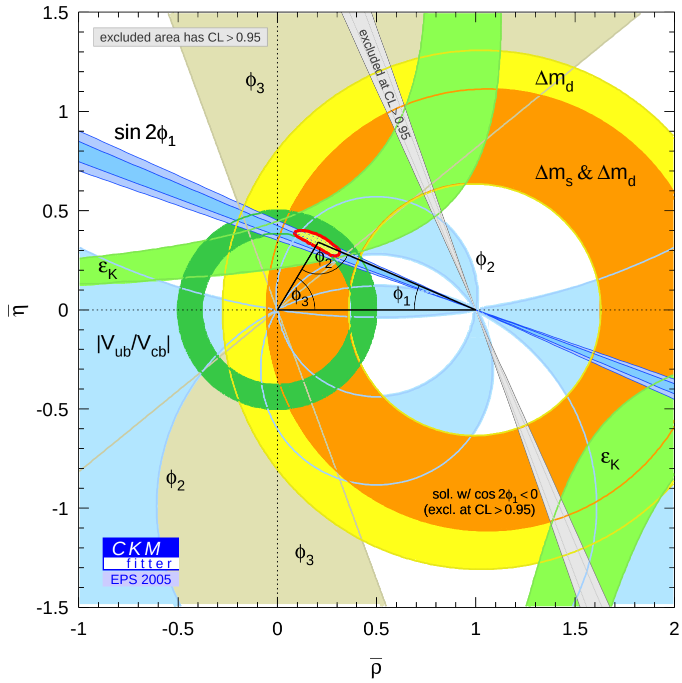

Figure 4. Constraints of the unitarity triangle from various measurements and global fit result.

CP-violation. The measurements of three angles of the unitarity triangle from CP-violations of B decays are quite consistent with the SM expectations as shown in figure 4. These results strongly support the validity of the KM prescription of CP-violation, although a CP-violation in the $B^0 - \bar{B}^0$ mixing, which is expected to be equal to or less than $\mathcal{O}(10^{-3})$ and well below current experimental sensitivity [35], is not yet established.

Further precision measurements of CP-violation, especially with decays dominated by loop diagram such as $b \to s$ penguin are of great interest to search for the effect of new physics beyond the SM with more data sample in future.

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