

CKM-UT Angles: Mixing and CP violation at the B Factories

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We review the experimental status of the angles of the Unitarity Triangle of the CKM matrix, as measured by the *BABAR* and Belle experiments.

1. Introduction

The B Factories have demonstrated since the beginning of this decade that CP violation in the B meson system is consistent with the Standard Model (SM) description in terms of the complex phase in the three-by-three Cabibbo-Kobayashi-Maskawa (CKM) matrix [1]. With one single phase, the SM predicts clear patterns for quark mixing and CP violations, to be satisfied by all processes. The unitarity relation $V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$ among the first and third columns of the CKM matrix is represented in the complex plane by a Unitarity Triangle (UT) with angles $\alpha = \arg[-V_{td}V_{tb}^*/V_{ud}V_{ub}^*]$, $\beta = \arg[-V_{cd}V_{cb}^*/V_{td}V_{tb}^*]$, $\gamma = \arg[-V_{ud}V_{ub}^*/V_{cd}V_{cb}^*]$. Physics beyond the SM could in general change the picture; for this reason it is very important to make many independent measurements to possibly find inconsistencies of the SM. In the evolution of $B^0\bar{B}^0$ pairs, we reconstruct the decay of one meson to final f at proper time t_f , and identify (tag) its flavor using information from the other B meson in the event, decaying at time t_{tag} . The time-dependent CP asymmetry of B^0 (\bar{B}^0) mesons decaying to final state f can be defined as $A_{CP}(\Delta t) \equiv (N_f - \bar{N}_f)/(N_f + \bar{N}_f) = S_f \sin(\Delta m_d \Delta t) - C_f \cos(\Delta m_d \Delta t)$. Here $\Delta t \equiv t_f - t_{\text{tag}}$, and Δm_d is the mass difference of the B meson mass eigenstates.¹ The sine term re-

sults from the interference between direct decay and decay after a $B^0 - \bar{B}^0$ oscillation. A non-zero cosine term arises from the interference between decay amplitudes with different weak and strong phases (direct CP violation) or from CP violation in $B^0 - \bar{B}^0$ mixing (the latter is predicted to be small in the SM and has not been observed to date).

The results discussed in the present paper were obtained by the *BABAR* [2] and Belle [3] experiments, respectively located at the PEP-II and KEKB e^+e^- asymmetric-energy B factories. Here pairs of $B\bar{B}$ mesons are produced almost at rest in the decay of the $\Upsilon(4S)$ resonance. The separation between their decay vertices is increased in the laboratory frame due to the boost given by the asymmetric-energy beams. The *BABAR* experiment has concluded the data taking, collecting a total of 531 fb^{-1} , of which 433 fb^{-1} on the $\Upsilon(4S)$ peak, corresponding to about $470 \times 10^6 B\bar{B}$ pairs. Belle have logged about 850 fb^{-1} (730 fb^{-1} on the $\Upsilon(4S)$ resonance) as of June 2008. The results discussed in the present report refer to about $383 \times 10^6 B\bar{B}$ pairs (*BABAR*) and about $535 \times 10^6 B\bar{B}$ pairs (Belle) unless otherwise noted.

2. Measurements of β

2.1. $\sin 2\beta$ from $b \rightarrow c\bar{c}s$

The B -Factory paradigm of CP violation measurements is $\sin 2\beta$ from $b \rightarrow c\bar{c}s$ decays. Being dominated by a single decay amplitude, in the SM with very good accuracy $C_f = 0$ and

¹Some authors, including the Belle collaboration, use the symbols ϕ_2, ϕ_1, ϕ_3 for the angles α, β, γ , and $A_f = -C_f$ for the parameter describing direct CP violation. In the present article we will follow the $\alpha, \beta, \gamma, C_f$ nomenclature.

$S_f = -\eta_f \sin 2\beta$ for these decays, with η_f the CP eigenvalue of the final state. The latest measurement from *BABAR* [4], $\sin 2\beta = 0.714 \pm 0.032 \pm 0.018$, $C = 0.049 \pm 0.022 \pm 0.017$ ² includes modes with $\eta_f = -1$ ($B^0 \rightarrow J/\psi K_S^0$, $\psi(2S)K_S^0$, $\eta_c K_S^0$, $\chi_{c1} K_S^0$), with $\eta_f = +1$ ($B^0 \rightarrow J/\psi K_L^0$), and $B^0 \rightarrow J/\psi K^{*0}(\pi^0 K_S^0)$, which has no definite CP parity. Belle's latest published measurement [5] concentrates on $B^0 \rightarrow J/\psi K^0$: $\sin 2\beta = 0.650 \pm 0.029 \pm 0.018$, $C = 0.018 \pm 0.021 \pm 0.014$. Belle have recently published an updated measurement in the $\psi(2S)K_S^0$ channel [6], based on $657 \times 10^6 B\bar{B}$ pairs. The results, $\sin 2\beta = 0.72 \pm 0.09 \pm 0.03$ and $C = 0.019 \pm 0.020 \pm 0.015$, are in good agreement with the $B^0 \rightarrow J/\psi K^0$ measurement.

2.2. $b \rightarrow c\bar{c}d$ decays

This class of decays includes both $B^0 \rightarrow J/\psi \pi^0$, whose expected main contribution is a color-suppressed internal spectator tree diagram, and $B^0 \rightarrow D^{(*)+}D^{(*)-}$, dominated by a color-allowed tree diagram. In either case the weak phase of the involved CKM matrix elements is the same as in $b \rightarrow c\bar{c}s$ decays, and the SM would predict $C = 0$ and $S = \sin 2\beta$ in the absence of penguin-mediated contributions. The new *BABAR* measurement of the CP -even $B^0 \rightarrow J/\psi \pi^0$ channel based on the full dataset of $466 \times 10^6 B\bar{B}$ pairs [7] ($S = -1.23 \pm 0.21 \pm 0.04$, $C = -0.20 \pm 0.19 \pm 0.03$), constitutes a 4-sigma evidence for CP violation in this channel. The Δt distribution for B^0 and \bar{B}^0 tagged events is shown in Fig. 1. The branching fraction of $B^0 \rightarrow J/\psi \pi^0$ is relevant for constraining possible penguin contributions to the $SU(3)$ -related channel $J/\psi K^0$ [8], and is measured to be $\mathcal{B}(B^0 \rightarrow J/\psi \pi^0) = (1.69 \pm 0.14 \pm 0.07) \times 10^{-5}$. The recent update from Belle [9] of the time-dependent measurement of $B^0 \rightarrow J/\psi \pi^0$ ($S = -0.65 \pm 0.21 \pm 0.05$, $C = -0.08 \pm 0.16 \pm 0.05$), is quite consistent with *BABAR*'s result.

The $B^0 \rightarrow D^{*+}D^{*-}$ channel is a Vector-Vector (VV) final state, which can have $L = 0, 1, 2$ angular momentum and therefore both even and odd CP components. It is therefore necessary to measure the CP -odd fraction R_\perp , and to take

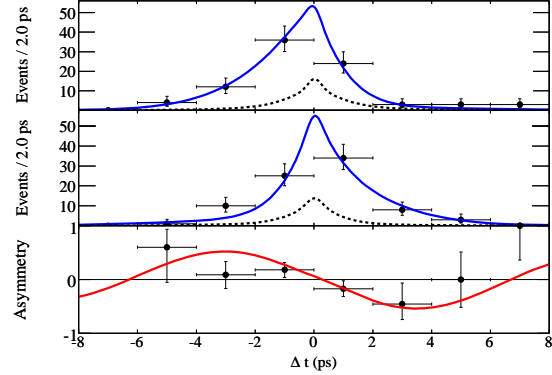


Figure 1. $B^0 \rightarrow J/\psi \pi^0$: Δt distribution for a sample of signal-enriched events tagged as B^0 (top) and \bar{B}^0 (middle). The bottom plot shows the Δt asymmetry $(N_{B^0} - N_{\bar{B}^0}) / (N_{B^0} + N_{\bar{B}^0})$. The solid curves represent the fitted distributions; the dashed line the background contribution.

into account the dilution due to the admixture. Belle presented a preliminary update [10] of $R_\perp = 0.116 \pm 0.042 \pm 0.004$, and of the CP -even asymmetry measurement: $S = -0.93 \pm 0.24 \pm 0.15$, $C = -0.16 \pm 0.13 \pm 0.02$. The latest published *BABAR* measurement [11] found a consistent value of $R_\perp = 0.143 \pm 0.034 \pm 0.008$, as well as of the CP parameters: $S = -0.66 \pm 0.19 \pm 0.04$, $C = -0.02 \pm 0.11 \pm 0.02$. Belle claim [12] 3.2 sigma evidence of direct CP violation in $B^0 \rightarrow D^+ D^-$: $S = -1.13 \pm 0.37 \pm 0.09$, $C = +0.91 \pm 0.23 \pm 0.06$. This is unexpected in the SM and not supported by *BABAR*'s measurement [13], which both in the $D^+ D^-$ and in $D^{*\pm} D^\mp$ channels finds CP asymmetries consistent with the SM prediction of tree dominance [14] and therefore with the result in $b \rightarrow c\bar{c}s$. Since however some new physics models could cause sizable corrections [15], it is important to keep reducing experimental uncertainties.

2.3. $b \rightarrow q\bar{q}s$ decays

The interest of $b \rightarrow q\bar{q}s$ decays has been pointed out for a long time. The quark transition $b \rightarrow s$ is forbidden in the SM at the tree level, and proceeds dominantly through a penguin

²Here and in the following, unless otherwise noted, the first error is statistical and the second one systematic. They are combined if only one error is given.

diagram with CKM coefficients proportional to $V_{tb}V_{ts}^*$ and therefore with the same weak phase as in $B^0 \rightarrow J/\psi K_s^0$ decays. Since the tree amplitude is missing, small effects such as those expected from additional diagrams due to heavy particles circulating in the loop are in principle more easily detectable. For this reason these decays are especially sensitive probes of new physics. We show in Fig. 2 a compilation prepared by the HFAG group [16] of available measurement of $b \rightarrow s$ transitions. No recent measurements are available at the time of the Capri 2008 Workshop, however this is a field of central interest, where improved experimental precision will hopefully help clarifying the nature of the small downward shift of $\sin 2\beta_{eff}$ observed in most of the $b \rightarrow s$ channels respect to the charmonium reference value.

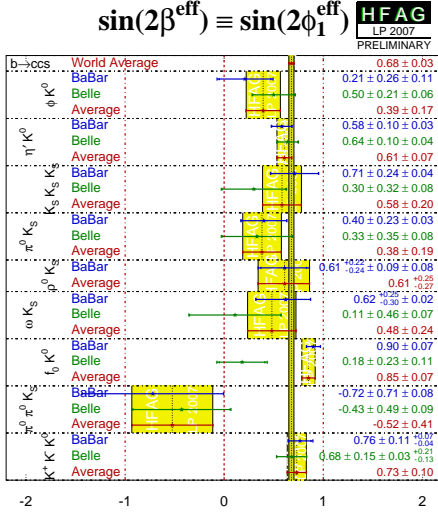


Figure 2. Summary of effective $\sin 2\beta$ measurements in $b \rightarrow s$ decay modes, compared to the world average $\sin 2\beta$ value in $b \rightarrow c\bar{c}s$.

3. Measurements of α

The angle α is measured with a time-dependent analysis of charmless decays of neutral B mesons, $B^0 \rightarrow h^+h^-$, with $h = \pi, \rho, a_1$. Due to the interplay of tree and penguin diagrams in these channels, the experiments are actually sensitive to an effective parameter α_{eff} . As shown in [17], one can in principle determine the shift $\alpha - \alpha_{eff}$

induced by the penguin amplitudes using the isospin-related decays $B^0 \rightarrow h^+h^-$, $B^0 \rightarrow h^0h^0$ and $B^\pm \rightarrow h^0h^\pm$. The procedure of measuring the so-called "isospin triangles" requires however rather large datasets, and leaves with up to eight-fold ambiguities. A relation less stringent, but more accessible with the current data sample since it does not require to tag the flavor of the decaying B also holds [18]: $\sin^2(\alpha - \alpha_{eff}) \leq \mathcal{B}(B^0 \rightarrow h^0h^0)/\mathcal{B}(B^\pm \rightarrow h^0h^\pm)$, which is particularly useful for small values of the numerator.

3.1. α from $B \rightarrow \pi\pi$

This is the "classic" channel to measure α , with a well-established evidence for indirect CP violation by both B -Factory experiments, which still show instead a poor (2.1 sigma) agreement on the $C_{\pi\pi}$ parameter. Both BABAR [19] and Belle [20] perform an isospin analysis to extract α , using all the available information (S_{+-} , C_{+-} , C_{00} , \mathcal{B}_{+-} , \mathcal{B}_{+0} , \mathcal{B}_{00}), shown in Fig. 3. One of the allowed solutions ($\alpha = (96_{-6}^{+11})^\circ$ for BABAR, ($\alpha = 97 \pm 11)^\circ$ for Belle) is consistent with the indirect determination of α in the SM.

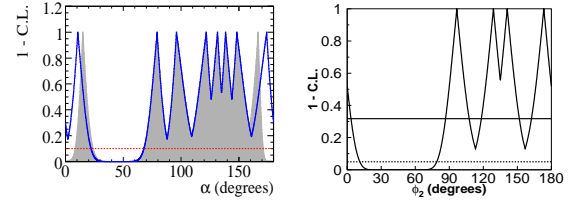


Figure 3. Constraints on the angle α in $B \rightarrow \pi\pi$ from BABAR (left) and Belle (right).

3.2. α from $B \rightarrow \rho\rho$

The decay channel $B^0 \rightarrow \rho^+\rho^-$ has the same quark content as $\pi^+\pi^-$ and can also be used to measure α . There are non-trivial experimental complications due to the presence of two neutral pions in the final state, with just weak mass constraints from the wide intermediate resonances. Moreover, $\rho^+\rho^-$ is a VV state and necessitates in principle a complete angular analysis to disentangle the effect of the three possible helicity

states. On the other hand, the branching fraction is about five times larger than $\mathcal{B}(B^0 \rightarrow \pi^+\pi^-)$, and the state is found to be almost purely longitudinally polarized, so that a per-event transversity analysis can be avoided and only the longitudinal CP parameters need to be determined. There is good agreement between CP violation measurement in $\rho^+\rho^-$ from *BABAR* [21] and *Belle* [22]. The HFAG average for the longitudinal components is $C_{\rho^+\rho^-} = -0.06 \pm 0.13$, $S_{\rho^+\rho^-} = -0.05 \pm 0.17$. *BABAR* [23] presented a preliminary first time-dependent measurement in the $B^0 \rightarrow \rho^0\rho^0$ channel. With $85 \pm 28 \pm 17$ signal events in a sample of $427 \times 10^6 B\bar{B}$ events, *BABAR* measure $\mathcal{B}_{\rho^0\rho^0} = (0.84 \pm 0.29 \pm 0.17) \times 10^{-6}$, $f_L = 0.70 \pm 0.14 \pm 0.05$, $S_L = 0.5 \pm 0.9 \pm 0.2$, $C_L = 0.4 \pm 0.9 \pm 0.2$. Consistently, *Belle* [24] set the upper limit $\mathcal{B}_{\rho^0\rho^0} < 1.0 \times 10^{-6}$ at 90% confidence level (C.L.).

3.3. α from $B^0 \rightarrow \rho\pi$

The third mode used to measure the angle α is $B^0 \rightarrow \pi^+\pi^-\pi^0$. This is not a CP eigenstate, and four flavor-charge configurations ($B^0(\bar{B}^0) \rightarrow \rho^\pm\pi^\mp$) must be considered. The corresponding isospin analysis is extremely complicated involving pentagonal relations among the different amplitudes, and cannot be solved for the 12 unknowns with the present statistics. It was however pointed out [25] that the variation of the strong phase of the interfering ρ resonances in the Dalitz plot provides the necessary degrees of freedom to constrain α with only the irreducible ($\alpha \rightarrow \alpha + \pi$) ambiguity. The two B -Factory experiments have both performed this analysis. *BABAR* [26] constrain $\alpha = (87^{+45}_{-13})^\circ$; *Belle* [27] obtain the tighter constraint $68^\circ < \alpha < 95^\circ$ at 68% C.L. for the solution compatible with the SM.

3.4. α from $B^0 \rightarrow a_1\pi$

The channel $B^0 \rightarrow a_1\pi$, which has the same quark content as the previous modes, has been recently explored in [28]. With a sample of 608 ± 52 signal events, *BABAR* adopt a quasi-two-body approach to obtain a precise measurement of $\alpha_{eff} = (78.6 \pm 7.3)^\circ$. Following the proposal in [29], *BABAR* are also measuring branching fractions in the SU(3)-related modes $B \rightarrow a_1K$ [30] and $B \rightarrow K_1\pi$ to constrain $|\alpha - \alpha_{eff}|$.

4. Measurements of γ

Several ways have been proposed to measure the angle γ at the B Factories. The most effective methods to date exploit direct CP violation in $B^- \rightarrow D^{(*)0}(\bar{D}^{(*)0})K^-$ decays. The tree-level decay amplitudes for the $B^- \rightarrow D^{(*)0}K^-$ and $B^- \rightarrow \bar{D}^{(*)0}K^-$ transitions differ by a factor $r_B^{(*)} e^{i(\delta_B^{(*)}-\gamma)}$, where $r_B^{(*)}$ is the magnitude of the $(b \rightarrow u/b \rightarrow c)$ amplitude ratio, and $\delta_B^{(*)}$ the strong phase difference. Estimates of $r_B^{(*)}$ considering CKM and color suppression factors predict small values, $r_B^{(*)} \simeq 0.1 \div 0.2$. Different mechanisms have been proposed to obtain interference from identical D^0 or \bar{D}^0 final states. We shall review recent results in the next subsections.

4.1. The GLW method

In the GLW method [31] neutral D mesons are reconstructed in CP -even (D_{CP+}) and CP -odd (D_{CP-}) eigenstates, as well as in flavor eigenstates (D^0 or \bar{D}^0). The observables $R_{CP\pm} \equiv (\mathcal{B}_{CP\pm}^- + \mathcal{B}_{CP\pm}^+)/(\mathcal{B}_{D^0K^-}^- + \mathcal{B}_{\bar{D}^0K^+}^+)/2$ and $A_{CP\pm} \equiv (\mathcal{B}_{CP\pm}^- - \mathcal{B}_{CP\pm}^+)/(\mathcal{B}_{CP\pm}^- + \mathcal{B}_{CP\pm}^+)$ are measured³. These quantities are sensitive to the angle γ : $R_{CP\pm} = 1 + r_B^2 \pm 2r_B \cos \delta_B \cos \gamma$, $A_{CP\pm} = \pm 2r_B \sin \delta_B \sin \gamma / R_{CP\pm}$. *BABAR* [32] recently published updated measurement in $B^\pm \rightarrow D^*K^\pm$, with $D^{*0} \rightarrow D^0\gamma$, $D^0\pi^0$, and $D^0(\bar{D}^0)$ reconstructed in CP -even (K^+K^- , $\pi^+\pi^-$), CP -odd ($K_s^0\pi^0$, $K_s^0\omega$, $K_s^0\phi$), and flavor-specific modes ($K^-\pi^+$), obtaining $A_{CP+} = -0.11 \pm 0.09 \pm 0.01$, $A_{CP-} = +0.06 \pm 0.10 \pm 0.02$, $R_{CP+} = 1.31 \pm 0.13 \pm 0.04$, $R_{CP-} = 1.10 \pm 0.12 \pm 0.04$. The accuracy of these measurements does not allow a determination of γ with the GLW method alone, but contributes improving the overall precision when combined with the other methods.

4.2. The ADS method

The idea in the ADS approach [33] is to select decays with similar overall amplitudes, in order to maximize the interference and therefore the sensitivity to CP asymmetries. This is achieved

³We use the compact notation $\mathcal{B}_{CP\mp}^- = \mathcal{B}(B^- \rightarrow D_{CP\mp}K^-)$, $\mathcal{B}_{D^0}^- = \mathcal{B}(B^- \rightarrow D^0K^-)$, $\mathcal{B}_{\bar{D}^0}^- = \mathcal{B}(B^- \rightarrow \bar{D}^0K^-)$, and analogously for the B^+ decays.

selecting favored $B \rightarrow D$ decays followed by suppressed D decays, or viceversa. Analogously to the GLW case, it is possible to define ratios of branching fractions of suppressed and favored decays as $R_{ADS} = \mathcal{B}_{B \rightarrow D_{sup}K} / \mathcal{B}_{B \rightarrow D_{fav}K} = r_D^2 + r_B^2 + 2r_B r_D \cos \gamma \cos \delta_B$, and CP asymmetries as $A_{ADS} = (\mathcal{B}_{B^- \rightarrow D_{sup}K^-} - \mathcal{B}_{B^+ \rightarrow D_{sup}K^+}) / SUM = 2r_D r_B \sin \gamma \sin \delta_B / R_{ADS}$. Belle [34] recently published an updated analysis of the suppressed decay chain $B^- \rightarrow DK^-$, $D \rightarrow K^+\pi^-$, based on $657 \times 10^6 B\bar{B}$ pairs. They do not observe a statistically significant signal in the suppressed mode, and obtain $R_{ADS} = (8.0^{+6.3+2.0}_{-5.7-2.8}) \times 10^{-3}$, $A_{ADS} = (-0.13^{+0.97}_{-0.88} \pm 0.26)$. These numbers are used to set a 90% C.L. upper limit on $r_B < 0.19$.

4.3. Dalitz plot method

Selecting three-body decays of D^0 and \bar{D}^0 such as $K_s^0 h^+ h^-$ ($h = \pi, K$), the Dalitz plot distribution depends on the interference of Cabibbo allowed, doubly-Cabibbo suppressed and CP eigenstate decay amplitudes. Neglecting mixing and CP violation in the $D^0 \bar{D}^0$ meson system, the amplitude for $B^\mp \rightarrow D[K_s^0 h^+ h^-]K^\pm$ can be written as $\mathcal{A}_\mp^{(*)}(m_-^2, m_+^2) \propto \mathcal{A}_{D\mp} + \lambda r_B^{(*)} e^{i(\delta_B^{(*)} \mp \gamma)} \mathcal{A}_{D\pm}$, where m_-^2 and m_+^2 are the squared invariant masses of the $K_s^0 h^-$ and $K_s^0 h^+$ combinations respectively, $\lambda = -1$ for $D^{0*} \rightarrow \gamma D^0$ and $= 1$ otherwise, and \mathcal{A}_{D+} (\mathcal{A}_{D-}) are the amplitudes of the $D^0(\bar{D}^0) \rightarrow K_s^0 h^+ h^-$ decay, described with a detailed model involving several intermediate resonances and extracted from large control samples of flavor-tagged $D^{*+} \rightarrow D^0 \pi^+$ decays produced in $c\bar{c}$ events. The 'cartesian' variables $x_\mp^{(*)} = r_B^{(*)} \cos(\delta_B^{(*)} \mp \gamma)$, $y_\mp^{(*)} = r_B^{(*)} \sin(\delta_B^{(*)} \mp \gamma)$ are used by the experiments to avoid the bias due to $r_B^{(*)}$ being positive definite. In their preliminary work [35] based on $657 \times 10^6 B\bar{B}$ pairs, the Belle collaboration reconstruct the decays $B^\mp \rightarrow D^{(*)0} K^\mp$, with $D^{*0} \rightarrow D^0 \pi^0$ and $D^0 \rightarrow K_s^0 \pi^+ \pi^-$, producing new and more precise results for the $(x, y)_\mp^{(*)}$ parameters. With a statistical procedure they find $r_B = 0.16 \pm 0.04$, $r_B^* = 0.21 \pm 0.08$ and $\gamma = (76^{+12}_{-13})^\circ$. *BABAR* is also publishing an updated result [36], based on $383 \times 10^6 B\bar{B}$ pairs. In addition to the modes used by Belle, *BABAR* also reconstruct the decays

$D^{*0} \rightarrow D^0 \gamma$, $B^\mp \rightarrow D^0 K^{*\mp} [K_s^0 \pi^\mp]$, and $D^0 \rightarrow K_s^0 K^+ K^-$. As an illustration, results for $(x, y)_\mp$ in the $B^\mp \rightarrow D^0 K^\mp$ mode from *BABAR* and Belle are shown in Fig. 4. Thanks to the larger num-

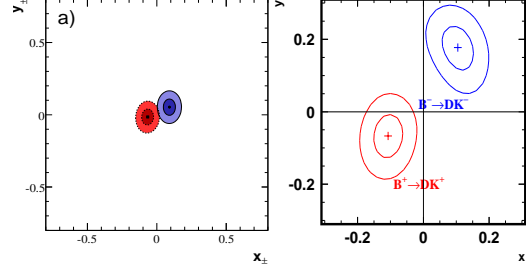


Figure 4. One- and two-sigma 2-dimensional C.L. contours in the (x_\mp, y_\mp) plane from *BABAR* (left) and Belle (right).

ber of reconstructed channels and to a better analysis efficiency, *BABAR* determines the $(x, y)_\mp^{(*)}$ parameters with the same accuracy as Belle despite the smaller data sample, finding 3 sigma evidence of CP violation. However, the *BABAR* data favor smaller r_B values ($r_B = 0.086 \pm 0.035$, $r_B^* = 0.135 \pm 0.051$, $\kappa r_s = 0.163^{+0.088}_{-0.105}$)⁴, and thus a larger error for γ ($\gamma = (76^{+23}_{-24})^\circ$).

5. Summary and outlook

The B Factories have established CP violation in several B decays, and measured $\sin 2\beta$ in charmonium decays with precision better than 4%. All β measurements in many different channels are consistent. Some channels, such as the penguin-dominated $b \rightarrow s$ modes are particularly promising because they are especially sensitive to heavy virtual states.

The angle α is being studied in charmless $B^0 \rightarrow \pi\pi$, $\rho\rho$ and $\rho\pi$ transitions. The first measurements of the $B^0 \rightarrow \rho^0 \rho^0$ decay confirm the indication that the effect of penguin amplitudes is relatively small in $\rho\rho$ decays, which in fact yield the most stringent constraints on α . New channels such as $B^0 \rightarrow a_1 \pi$ and SU(3)-related decays are being studied, and will hopefully contribute to

⁴The amplitude ratio in $B^\mp \rightarrow D^0 K^{*\mp}$ events is described by κr_s , with κ taking into account non-resonant $K_s^0 \pi^\mp$ contributions.

improve the determination of α , which will eventually be limited by penguin pollution.

A precise measurement of the angle γ , simply unthinkable at the beginning of the B -Factory era, is now a reality thanks to the large accumulated statistics and the number of B decays sensitive to this angle. Several new measurements of $B^\mp \rightarrow D^0 K^\mp$ transitions have appeared recently, and strong evidence for direct CP violation in these decays is building up. The Dalitz method in particular provides the most stringent constraints to date.

All measurements of CKM angles are at present statistically limited, and will therefore become more precise in the near future, when the $BABAR$ collaboration analyze their full dataset, and Belle continue to accumulate new data.

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