

CP Violation Highlights: Circa 2005

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CP VIOLATION HIGHLIGHTS: CIRCA 2005

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Abstract

Recent highlights in CP violation phenomena are reviewed. B-factory results imply that CP-violation phase in the CKM matrix is the dominant contributor to the observed CP violation in K and B-physics. Deviations from the predictions of the CKM-paradigm due to beyond the Standard Model CP-odd phase are likely to be a small perturbation. Therefore, large data sample of clean B's will be needed. Precise determination of the unitarity triangle, along with time dependent CP in penguin dominated hadronic and radiative modes are discussed. *Null tests* in B, K and top-physics and separate determination of the K-unitarity triangle are also emphasized.

1 B-factories help attain an important milestone: Good and bad news

The two asymmetric B-factories at SLAC and KEK have provided a striking confirmation of the CKM paradigm ¹⁾. Existing experimental information from the indirect CP violation parameter, ϵ for the $K_L \rightarrow \pi\pi$, semileptonic $b \rightarrow ue\nu$ and $B^0 - \bar{B}^0$ mixing along with lattice calculations predict that in the SM, $(\sin 2\beta) \simeq .70 \pm .10$ ^{2, 3, 4)}. This is in very good agreement with the BELLE and BABAR result ⁵⁾:

$$\mathcal{A}_{CP}(B^0 \rightarrow \psi K^0) = \sin 2\beta = .726 \pm .037 \quad (1)$$

This leads to the conclusion that the CKM phase of the Standard Model (SM) is the dominant contributor to \mathcal{A}_{CP} . That, of course, also means that CP-odd phase(s) due to beyond the Standard Model (BSM) sources may well cause only small deviations from the SM in B-physics.

Actually, there are several reasons to think that BSM phase(s) may cause only small deviations in B-physics. In this regard, SM itself teaches a very important lesson.

2 Important lesson from the CKM-paradigm

We know now that the CKM phase is $0(1)$ (actually, the CP violation parameter η is $0(.3)$ ^{2, 3, 4)}). The CP effects that it causes on different observables though is quite different. In K-decays, the CP asymmetries are $\leq 10^{-3}$. In charm physics, also there are good reasons to expect small observable effects. In top physics, the CKM phase causes completely negligible effects ^{6, 7)}. Thus only in B-decays, the large asymmetries (often $0(1)$) are caused by the CKM phase. So even if the BSM phase(s) are $0(1)$ it is unlikely that again in B-physics they will cause large effects just as the SM does.

3 Remember the m_ν

Situation with regard to BSM CP-odd phase(s) (χ_{BSM}) is somewhat reminiscent of the neutrino mass (m_ν) ⁸⁾. There was no good reason for m_ν to be zero; similarly, there are none for χ_{BSM} to be zero either. In the case of ν 's, there were the solar ν results that were suggestive for a very long time; similarly, in the case of χ_{BSM} , the fact that in the SM, baryogenesis is difficult to accommodate serves as the beacon.

It took decades to show m_ν is not zero: Δm^2 had to be lowered from \sim

$O(1-10)eV^2$ around 1983 down to $O(10^{-4}eV^2)$ before $m_\nu \neq 0$ was established via neutrino oscillations. We can hope for better luck with χ_{BSM} but there is no good reason to be too optimistic; therefore, we should not rely on luck but rather we should seriously prepare for this possibility.

To recapitulate, just as the SM-CKM phase is $O(1)$, but it caused only $O(10^{-3})$ CP symmetries in K- decays, an $O(1)$ BSM-CP-odd phase may well cause only very small asymmetries in B-physics. To search for such small effects:

- 1) We need lots and lots of clean B's (*i.e.* $O(10^{10})$ or more)
- 2) Intensive study of B_s mesons (in addition to B's) becomes very important as comparison between the two types of B-mesons will teach us how to improve quantitative estimates of flavor symmetry breaking effects.
- 3) We also need clean predictions from theory (wherein item 2 should help).

4 Improved searches for BSM phase

Improved searches for BSM-CP-odd phase(s) can be subdivided into the following main categories:

- a) Indirect searches with theory input
- b) Indirect searches without theory input
- c) Direct searches.

4.1 Indirect searches with theory input

Among the four parameters of the CKM matrix, λ, A, ρ and η , $\lambda = 0.2200 \pm 0.0026$, $A \approx 0.850 \pm 0.035$ ⁹⁾ are known quite precisely; ρ and η still need to be determined accurately. Efforts have been underway for many years to determine these parameters. The angles α, β, γ , of the unitarity triangle (UT) can be determined once one knows the 4-CKM parameters.

A well studied strategy for determining these from experimental data requires knowledge of hadronic matrix elements. Efforts to calculate several of the relevant matrix elements on the lattice, with increasing accuracy, have been underway for past many years. A central role is played by the following four inputs ^{2, 3, 4)}:

- B_K from the lattice with ϵ from experiment
- $f_B\sqrt{B_B}$ from the lattice with Δm_d from experiment
- ξ from the lattice with $\frac{\Delta m_s}{\Delta m_d}$ from experiment

- $\frac{b \rightarrow ul\nu}{b \rightarrow cl\nu}$ from experiment, along with input from phenomenology especially heavy quark symmetry as well as the lattice.

As mentioned above, for the past few years, these inputs have led to the important constraint: $\sin 2\beta_{SM} \approx 0.70 \pm 0.10$ which is found to be in very good agreement with direct experimental determination, Eq. 1.

Despite severe limitations (e.g. the so-called quenched approximation) these lattice inputs provided valuable help so that with B-Factory measurements one arrives at the very important conclusion that in $B \rightarrow J/\psi K^0$ the CKM-phase is the dominant contributor; any new physics (NP) contribution is unlikely to be greater than about 15%.

What sort of progress can we expect from the lattice in the next several years in these (indirect) determination of the UT? To answer this it is useful to look back and compare where we were to where we are now. Perhaps this gives us an indication of the pace of progress of the past several years. Lattice calculations of matrix elements around 1995 ¹⁰⁾ yielded (amongst other things) $\sin 2\beta \approx 0.59 \pm 0.20$, whereas the corresponding error decreased to around ± 0.10 around 2001 ²⁾. In addition to β , such calculations also now constrain $\gamma (\approx 60^\circ)$ with an error of around 10° ²⁾.

There are three important developments that should help lattice calculations in the near future:

1. Exact chiral symmetry can be maintained on the lattice. This is especially important for light quark physics.
2. Relatively inexpensive methods for simulations with dynamical quarks (esp. using improved staggered fermions ¹¹⁾) have become available. This should help overcome limitations of the quenched approximation.
3. About a factor of 20 increase in computing power is now being used compared to a few years ago.

As a specific example one can see that the error on B_K with the 1st use of dynamical domain wall fermions ¹²⁾ now seems to be reduced by about a factor of two ¹³⁾. In the next few years or so errors on lattice determination of CKM parameters should decrease appreciably, perhaps by a factor of 3. So the error in $\sin 2\beta_{SM} \pm 0.10 \rightarrow \pm 0.03$; $\gamma \pm 10^\circ \rightarrow 4^\circ$ etc. While this increase in accuracy is very welcome, and will be very useful, there are good reasons to believe, experiment will move ahead of theory in direct determinations of unitarity angles in the next 5 years. (At present, experiment is already ahead of theory for $\sin 2\beta$).

4.2 Indirect searches without theory input: Elements of a superclean UT

One of the most exciting developments of recent years in B-physics is that methods have been developed so that all three angles of the UT can be determined cleanly with very small theory errors. This is very important as it can open up several ways to test the SM-CKM paradigm of CP violation; in particular, the possibility of searching for small deviations. Let us very briefly recapitulate the methods in question:

- Time dependent CP asymmetry (TDCPA) measurements in $B^0, \bar{B}^0 \rightarrow \psi K^0$ type of final states should give the angle β very precisely with an estimated irreducible theory error (ITE) of $\leq O(0.1\%)$ ¹⁴).
- Direct CP (DIRCP) studies in $B^\pm \rightarrow "K^\pm" D^0, \bar{D}^0$ gives γ very cleanly ^{15, 16}).
- TDCPA measurements in $B^0, \bar{B}^0 \rightarrow "K^0" D^0, \bar{D}^0$ gives $(2\beta + \gamma)$ and also β very cleanly ^{17, 18}).
- In addition, TDCPA measurements in $B_s \rightarrow KD_s$ type modes also gives γ very cleanly ¹⁹).
- Determination of the rate for the CP violating decay $K_L \rightarrow \pi^0 \nu \bar{\nu}$ is a very clean way to measure the Wolfenstein parameter η , which is indeed the CP-odd phase in the CKM matrix ²⁰).

It is important to note that the ITE for each of these methods is expected to be $\leq 1\%$, in fact perhaps even $\leq 0.1\%$.

- Finally let us briefly mention that, TDCPA studies of $B^0, \bar{B}^0 \rightarrow \pi\pi$ or $\rho\pi$ or $\rho\rho$ gives α ^{21, 22, 23}). However, in this case, isospin conservation needs be used and that requires, *assuming* that electro-weak penguins (EWP) make negligible contribution. This introduces some model dependence and may cause an error of order a few degrees, *i.e.* for α extraction the ITE may well end up being O(a few %). However, given that there are three types of final states each of which allows a determination of α , it is quite likely that further studies of these methods will lead to a reduction of the common source of error originating from isospin violation due to the EWP.

It is extremely important that we make use of these opportunities afforded to us by as many of these very clean redundant measurements as possible. In order to exploit these methods to their fullest potential and

get the angles with errors of order ITE will, for sure, require a SUPER-B Factory(SBF) 8, 30, 31, 32).

This in itself constitutes a strong enough reason for a SBF, as it represents a great opportunity to precisely nail down the important parameters of the CKM paradigm.

4.2.1 Prospects for precision determination of γ

Below we briefly discuss why the precision extraction of γ seems so promising.

For definiteness, let us recall the basic features of the ADS method ²⁴). In this interference is sought between two amplitudes of roughly similar size *i.e.* $B^- \rightarrow K^- D^0$ and $B^- \rightarrow K^- \bar{D}^0$ where the D^0 and \bar{D}^0 decay to common final states such as the simple two body ones like $K^+ \pi^-$, $K^+ \rho^-$, $K^+ a_1^-$, $K^{+*} \pi^-$ or they may also be multibody modes e.g. the Dalitz decay $K^+ \pi^- \pi^0$, $K^+ \pi^- \pi^+ \pi^-$ etc. It is easy to see that the interference is between a colored allowed B decay followed by doubly Cabibbo suppressed D decay and a color-suppressed B decay followed by Cabibbo allowed D decay and consequently then interference tends to be maximal and should lead to large asymmetries.

For a given (common) final state of D^0 and \bar{D}^0 the amplitude involves three unknowns: the color suppressed $\text{Br}(B^- \rightarrow K^- \bar{D}^0)$, which is not directly accessible to experiment ²⁴), the strong phase $\xi_{f_i}^K$ and the weak phase γ . Corresponding to each such final state (FS) there are two observables: the rate for B^- decay and for the B^+ decay.

Thus, if you stick to just one common FS of D^0 , \bar{D}^0 , you do not have enough information to solve for γ . If you next consider two common FS of D^0 and \bar{D}^0 then you have one additional unknown (a strong phase) making a total of 4-unknowns with also 4-observables. So with two final states the system becomes soluble, *i.e.* we can then use the experimental data to solve not only the value of γ but also the strong phases and the suppressed Br for $B^- \rightarrow K^- \bar{D}^0$. With N common FS of D^0 and \bar{D}^0 , you will have $2N$ observables and $N + 2$ unknowns. We need $2N \geq (N + 2)$ *i.e.* $N \geq 2$. The crucial point, though, is that there are a very large number of possible common modes of D^0 and \bar{D}^0 which can all be used to improve the determination of γ .

Let us briefly mention some of the relevant common modes of D^0 and \bar{D}^0 :

- The CP-eigenstate modes, originally discussed by GLW ²¹): $K_S [\pi^0, \eta, \eta', \rho^0, \omega]; \pi^+ \pi^-, \dots$
- CP-non-eigenstates (CPNES), discussed by GLS ²⁶): $K^{*+} K^-, \rho^+ \pi^- \dots$
These are singly Cabibbo suppressed modes.
- CPNES modes originally discussed by ADS ^{24, 25}): $K^{+(*)} [\pi^-, \rho^-, a_1^- \dots]$

- There are also many multibody modes, such as the Dalitz D^0 decays: $K_S\pi^+\pi^-$ (27) or $K^+\pi^-\pi^0$ (25) etc; and also modes such as $K^-\pi^+\pi^-\pi^+$, $K^-\pi^+\pi^-\pi^+\pi^0$, or indeed $K^-\pi^+ + n\pi$ (17, 28, 29). Furthermore, multibody modes such as $B^+ \rightarrow K_i^+ D^0 \rightarrow (K\pi)^+ D^0$ or $(Kn\pi)^+ D^0$ (28, 33) can also be used.

Fig. 1 and Fig. 2 show how combining different strategies helps a great deal. In the fig we show χ^2 versus γ . As indicated above when you consider an individual final state of D^0 and \bar{D}^0 then of course there are 3 unknowns (the strong phase, the weak phase (γ) and the “unmeasurable” Br) and only two observables (the rate for B^- and the rate for B^+). So in the figure, for a fixed value of γ , we search for the minimum of the χ^2 by letting the strong phase and the “unmeasurable” Br take any value they want.

Fig. 1 and Fig. 2 show situation with regard to under determined and over determined cases respectively. The upper horizontal line corresponds roughly to the low luminosity i.e. comparable to the current B-factories (30, 32) whereas the lower horizontal curve is relevant for a super B-factory. In Fig. 1 in blue is shown the case when only the input from (GLW) CPES modes of D^0 is used; note all the CPES modes are included here. You see that the resolution on γ then is very poor. In particular, this method is rather ineffective in giving a lower bound; its upper bound is better.

In contrast, a single ADS mode ($K^+\pi^-$) is very effective in so far as lower bound is concerned, but it does not yield an effective upper bound (red).

Note that in these two cases one has only two observables and 3 unknowns. In purple is shown the situation when these two methods are combined. Then at least at high luminosity there is significant improvement in attaining a tight upper bound; lower bound obtained by ADS alone seems largely unaffected.

Shown in green is another under determined case consisting of the use of a single ADS mode, though it includes K^{*-} as well D^{*0} ; this again dramatically improves the lower bound. From an examination of these curves it is easy to see that combining information from different methods and modes improves the determination significantly (28).

Next we briefly discuss some over determined cases (Fig. 2). In purple all the CPES modes of D^0 are combined with just one doubly Cabibbo-suppressed (CPNES) mode. Here there are 4 observables for the 4 unknowns and one gets a reasonable solution at least especially for the high luminosity case.

The black curve is different from the purple one in only one respect; the black one also includes the D^{0*} from $B^- \rightarrow K^- D^{0*}$ where subsequently the D^{0*} gives rise to a D^0 . Comparison of the black one with the purple shows considerable improvement by including the D^{0*} . In this case the number of observables (8) exceeds the number of unknowns (6).

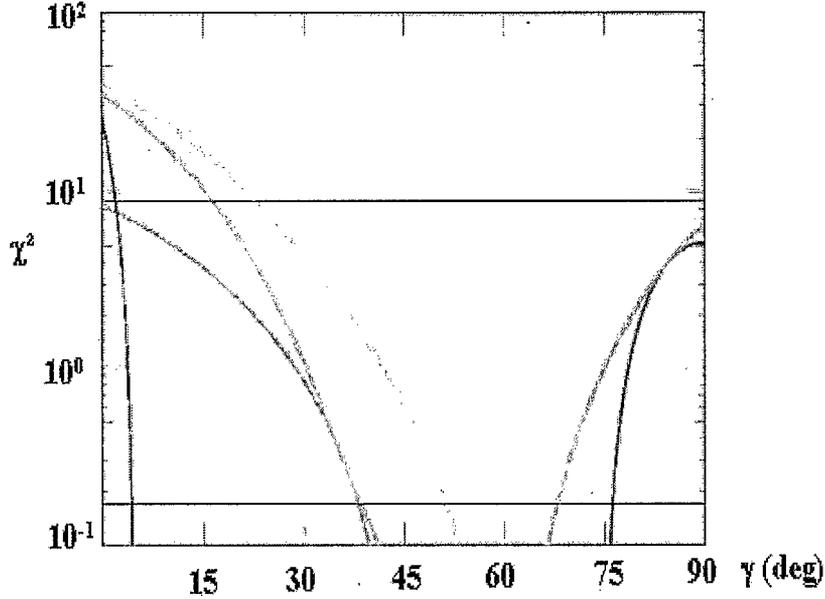


Figure 1: γ determination with incomplete input (i.e. cases when the number of observables is less than the number of unknown parameters). The upper horizontal line corresponds to low-luminosity i.e. around current B-factories whereas the lower horizontal curve is relevant for a SBF. Blue uses all CPES modes of D^0 , red is with only $K^+\pi^-$ and purple uses combination of the two. Green curve again uses on D^0 , $\bar{D}^0 \rightarrow K^+\pi^-$ but now includes K^{*-} and D^{*0} ; see text for details.

Actually, the D^{0*} can decay to D^0 via two modes: $D^{0*} \rightarrow D^0 + \pi$ or $D^0 + \gamma$. Bondar and Gershon³⁴⁾ have made a very nice observation that the strong phase for the γ emission is opposite to that of the π emission. Inclusion (blue curves) of both types of emission increases the number of observables to 12 with no increase in number of unknowns. So this improves the resolving power for γ even more.

The orange curves show the outcome when a lot more input is included; not only K^- , K^{*-} , D^0 , D^{0*} but also Dalitz and multibody decays of D^0 are included. But the gains now are very modest; thus once the number of observables exceeds the number of unknowns by a few (say $O(3)$) further increase in input only has a minimal impact.

Table 1: *Projections for direct determination of UT.*

	Now(0.2/ab)	2/ab	10/ab	ITE
$\sin 2\phi_1$	0.037	0.015	0.015(?)	0.001
$\alpha(\phi_2)$	13°	$4^\circ(?)$	$2^\circ(?)$	$1^\circ(?)$
$\gamma(\phi_3)$	$\pm 20^\circ \pm 10^\circ \pm 10^\circ$	5° to 2°	$< 1^\circ(?)$	0.05°

Let us briefly recall that another important way to get these angles is by studying time-dependent CP (TDCP) (or mixing-induced CP (MIXCP)) violation via $B^0 \rightarrow D^{0(*)} K^0$. Once again, all the common decay modes of D^0 and \bar{D}^0 can be used just as in the case of direct CP studies involving B^\pm decays. Therefore, needless to say input from charm factory (29, 35, 36) also becomes desirable for MIXCP studies of $B^0 \rightarrow D^{0(*)} K^0$ as it is for direct CP using B^\pm . It is important to stress that this method gives not only the combinations of the angles ($2\beta + \gamma \equiv \alpha - \beta + \pi$) but also in addition this is another way to get β cleanly (17, 18). In fact whether one uses B^\pm with DIRCP or $B^0 - \bar{B}^0$ with TDCP these methods are very clean with (as indicated above) the ITE of $\approx 0.1\%$. However, the TDCP studies for getting γ (with the use of β as determined from ψK_s) is less efficient than with the use of DIRCP involving B^\pm . Once we go to luminosities $\geq 1ab^{-1}$, though, the two methods for γ should become competitive. Note that this method for getting β is significantly less efficient than from the ψK_s studies (17).

Table 1 summarizes the current status and expectations for the near future for the UT angles. With the current $O(0.4/ab)$ luminosity between the two B-factories, $\gamma \approx (69 \pm 30)$ degrees. Most of the progress on γ determination so far is based on the use of the Dalitz mode, $D^0 \rightarrow K_s \pi^+ \pi^-$ (27). However, for now, this method has a disadvantage as it entails a modelling of the resonances involved; though model independent methods of analysis, at least in principle, exist (17, 27, 28). The simpler modes (e.g. $K^+ \pi^-$) require more statistics but they would not involve such modelling error as in the Dalitz method. Also the higher CP asymmetries in those modes should have greater resolving power for determination of γ . The table shows the statistical, systematic and the resonance-model dependent errors on γ separately. Note that for now i do not think the model dependent error (around 10 degrees) ought to be added in quadrature. That is why the combined error of ± 30 degrees is somewhat inflated to reflect that. The important point to note is that as more B's are accumulated, more and more decay modes can be included in determination of γ ; thus for the next several years the accuracy on γ is expected to improve faster than $1/\sqrt{N_B}$, N_B being the number of B's.

4.3 Direct searches: Two important illustrations

B-decays offers a wide variety of methods for searching for NP or for BSM-CP-odd phase(s). First we will elaborate a bit on the following two methods.

- Penguin dominated hadronic final states in $b \rightarrow s$ transitions.
- Radiative B-decays.

Then we will provide a brief summary of the multitude of possibilities that a SBF offers, in particular, for numerous important approximate null tests (ANTs).

4.4 Penguin dominated hadronic final states in $b \rightarrow s$ transitions

For the past couple of years, experiments at the two B-factories have been showing some indications of a tantalizing possibility *i.e.* a BSM-CP-odd phase in penguin dominated $b \rightarrow s$ transitions. Let us briefly recapitulate the basic idea.

Fig. 3 show the experimental status ⁵⁾. With about 250×10^6 B-pairs in each of the B-factories, there are two related possible indications. In particular, BABAR finds about a 3σ deviation in $B \rightarrow \eta' K_s$. Averaging over the two experiments, this is reduced to about 2.3σ . Secondly adding all such penguin dominated modes seems to indicate a 3.5σ effect.

Since $B \rightarrow \eta' K_s$ seems to be so prominently responsible for the indications of deviations in the current data sample, let us briefly discuss this particular FS. That the mixing induced CP in $\eta' K_s$ can be used to test the SM was 1st proposed in ³⁷⁾. This was triggered in large part by the discovery of the unexpectedly large Br for $B \rightarrow \eta' K_s$. Indeed ref. ³⁷⁾ emphasized that the large Br may be very useful in determining $\sin 2\beta$ with $B \rightarrow \eta' K_s$ and comparing it with the value obtained from $B \rightarrow \psi K_s$. In fact it is precisely the large Br of $B \rightarrow \eta' K_s$ that is making the error of the TDCP measurement the smallest amongst all the penguin dominated modes presently studied. Note also that there is a corresponding proposal to use the large Br of the inclusive $\eta' X_s$ for searching for NP with the use of direct CP ^{38, 39)}.

Ref. ³⁷⁾ actually suggested use of TDCP studies not just in $\eta' K_s$ but in fact also $[\eta, \pi^0, \omega, \rho, \phi \dots] K_s$ to test the SM. These are, indeed most of the modes currently being used by BABAR & BELLE.

Simple analysis in ³⁷⁾ suggested that in all such penguin dominated ($b \rightarrow s$) modes Tree/Penguin is small, < 0.04 . In view of the theoretical difficulties in reliably estimating these effects, Ref ³⁷⁾ emphasized that it would be very difficult in the SM to accomodate $\Delta S > 0.10$, as a cautious bound.

4.4.1 Final state interaction effects

The original papers (40, 41, 37) predicting,

$$\Delta S_f = S_f - S_{\psi K} \approx 0 \quad (2)$$

used naive factorization; in particular, FSI were completely ignored. A remarkable discovery of the past year is that in several charmless 2-body B-decays direct CP asymmetry is rather large. This means that FSI (CP-conserving) phase(s) in exclusive B-decays need not be small (42). Since these are non-perturbative (43), model dependence becomes unavoidable. Indeed characteristically these FSI phase(s) arise formally from $O(1/m_B)$ corrections:

- In pQCD (44) a phenomenological parameter k_T , corresponding to the transverse momentum of partons, is introduced in order to regulate the end point divergences encountered in power corrections. This in turn gives rise to sizable strong phase difference from penguin induced annihilation.
- In QCDF (45), in its nominal version, the direct CP asymmetry in many channels (e.g. $B^0 \rightarrow K^+\pi^-, \rho^-\pi^+, \pi^+\pi^-, \dots$) has the opposite sign compared to the experimental findings. Just like in the pQCD approach where the annihilation topology play an important role in giving rise to large strong phases, and for explaining the penguin-dominated VP modes, it has been suggested in (46) that in a specific scenario (S4), for QCDF to agree with the Br of penguin-dominated PV modes as well as with the measured sign of the direct asymmetry in the prominent channel $B^0 \rightarrow K^+\pi^-$, a large annihilation contribution be allowed by choosing $\rho_A = 1$, $\phi_A = -55^\circ$ for PP, $\phi_A = -20^\circ$ for PV and $\phi_A = -70^\circ$ for VP modes.
- In our approach (42), QCDF is used for short-distance (SD) physics; however, to avoid double-counting, we set the above two parameters [ρ_A , ϕ_A] as well as two additional parameters [ρ_H , ϕ_H] that they have (46) to zero. Instead we try to include long-distance ($1/m_B$) corrections by using on-shell rescattering of 2-body modes to give rise to the needed FS phases.

So, for example, color-suppressed modes such as $B^0 \rightarrow K^0\pi^0$ gets important contributions from color allowed processes: $B^0 \rightarrow K^{-(*)}\pi^+(\rho^+), D_S^{-(*)}D^{+(*)}$. The coupling strengths at the three vertices of such a triangular graph are chosen to give the known rates of corresponding physical processes such as

$B^0 \rightarrow D_S^-^* D^{+(*)}$, $D^* \rightarrow D + \pi$ etc. Furthermore, since these vertices are not elementary and the exchanged particles are off-shell, form-factors have to be introduced so that loop integrals become convergent. Of course, there is no way to determine these reliably. We vary these as well as other parameters so that Br's are in rough agreement with experiment, then we calculate the CP-asymmetries.

Recall the standard form for the asymmetries:

$$\frac{\Gamma(\overline{B}(t) \rightarrow f) - \Gamma(B(t) \rightarrow f)}{\Gamma(\overline{B}(t) \rightarrow f) + \Gamma(B(t) \rightarrow f)} = S_f \sin(\Delta mt) + A_f \cos(\Delta mt) \quad (3)$$

The TDCP asymmetry (S_f) and direct CP asymmetry [$A_f \equiv -C_f$ (BaBar notation)] both depend on the strong phase. Thus measurements of direct CP asymmetry A_f (in addition to S_f) allows tests of model calculations, though in practice its real use may be limited to those cases where the direct CP asymmetry is not small. This is the case, for example, for $\rho^0 K_S$ and ωK_S ⁴⁷).

It is also important to realize that not only there is a correlation between S_f and A_f for FS in B^0 decays, but also that the model entails specific predictions for direct CP in the charged counterparts. So, for example, in our model for FSI, large direct CP asymmetry is also expected in the charged counterparts of the above two modes.

In addition to two body modes there are also very interesting 3-body modes such as $B^0 \rightarrow K^+ K^- K_S(K_L)$, $K_S K_S K_S(K_L)$. These may also be useful to search for NP as they are also penguin dominated. We use resonance-dominance of the relevant two body channels to extend our calculation of LD rescattering phases in these decays ⁴⁸).

Tables 2 and 3 summarize our results for ΔS and A for two body and 3-body modes. We find that ^{47, 48}) $B^0 \rightarrow \eta' K_S$, ϕK_S and $3K_S$ are cleanest ⁴⁹), i.e. central values of ΔS as well as the errors are rather small, O(a few%). Indeed we find that even after including the effect of FSI, ΔS in most of these penguin-dominated modes, it is very difficult to get $\Delta S > 0.10$ in the SM. Thus we can reiterate (as in ³⁷) that $\Delta S > 0.10$ would be a strong evidence for NP.

Having said that, it is still important to stress that genuine NP in these penguin dominated modes must show up in many other channels as well. Indeed, on completely model independent grounds ⁸), the underlying NP has to be either in the 4-fermi vertex (bss \bar{s}) or (bsg, $g = gluon$). In either case, it has to materialize into a host of other reactions and phenomena and it is not possible that it only effects time dependent CP in say $B \rightarrow \eta' K_s$ and/or ϕK_s and/or $3K_s$. For example, for the 4-fermi case, we should also expect non-standard effects in $B_d \rightarrow \phi(\eta') K^*$, $B^{+-} \rightarrow \phi(\eta') K^{+(*)}$, $B_s \rightarrow \phi\phi(\eta')$...In

Table 2: Direct CP asymmetry parameter \mathcal{A}_f and the mixing-induced CP parameter ΔS_f^{SD+LD} for various modes. The first and second theoretical errors correspond to the SD and LD ones, respectively (see ⁴⁷) for details). The $f_0 K_S$ channel is not included as we cannot make reliable estimate of FSI effects on this decay; table adopted from ⁴⁷.

Final State	ΔS_f		$\mathcal{A}_f(\%)$	
	SD+LD	Expt	SD+LD	Expt
ϕK_S	$0.03^{+0.01+0.01}_{-0.04-0.01}$	-0.38 ± 0.20	$-2.6^{+0.8+0.0}_{-1.0-0.4}$	4 ± 17
ωK_S	$0.01^{+0.02+0.02}_{-0.04-0.01}$	$-0.17^{+0.30}_{-0.32}$	$-13.2^{+3.9+1.4}_{-2.8-1.4}$	48 ± 25
$\rho^0 K_S$	$0.04^{+0.09+0.08}_{-0.10-0.11}$	—	$46.6^{+12.9+3.9}_{-13.7-2.6}$	—
$\eta' K_S$	$0.00^{+0.00+0.00}_{-0.04-0.00}$	-0.30 ± 0.11	$2.1^{+0.5+0.1}_{-0.2-0.1}$	4 ± 8
ηK_S	$0.07^{+0.02+0.00}_{-0.05-0.00}$	—	$-3.7^{+4.4+1.4}_{-1.8-2.4}$	—
$\pi^0 K_S$	$0.04^{+0.02+0.01}_{-0.03-0.01}$	$-0.39^{+0.27}_{-0.29}$	$3.7^{+3.1+1.0}_{-1.7-0.4}$	-8 ± 14

the second case not only there should be non-standard effects in these reactions but also in $B_{d(u)} \rightarrow X_s \gamma, K^* \gamma, B_s \rightarrow \phi \gamma \dots$ and also in the corresponding $l^+ l^-$ modes. Unless corroborative evidence is seen in many such processes, the case for NP due to the non-vanishing of ΔS is unlikely to be compelling, especially if (say) $\Delta S \lesssim 0.15$.

4.4.2 Averaging issue

As already emphasized in ³⁷, to the extent that penguin contributions dominate in these many modes and *tree/penguin* is only a few percent testing the SM by adding $\Sigma \Delta S_f$, where $f = K_S + \eta' (\phi, \pi, \omega, \rho, \eta, K_S K_S \dots)$, is sensible at least from a theoretical standpoint. At the same time it is important to emphasize that a convincing case for NP requires unambiguous demonstration of significant effects (i.e. $\Delta S > 0.10$) in several individual channels.

4.4.3 Sign of ΔS

For these penguin-dominated modes, ΔS_f is primarily proportional to the hadronic matrix element $\langle f | \bar{u} \Gamma b \bar{s} \Gamma' u | B^0 \rangle$. Therefore, in the SM for several of the final states (f), ΔS_f could have the same sign. So a systematic trend of ΔS_f being positive or negative (*and small of $O(a \text{ few } \%)$*) does not necessarily mean NP.

The situation wrt to $\eta' K_S$ is especially interesting. As has been known for the past many years this mode has a very large Br, almost a factor of 7 larger than the similar two body $K \pi$ mode. This large Br is of course also the reason why the statistical error is the smallest, about a factor of two less than any

Table 3: Mixing-induced and direct CP asymmetries $\sin 2\beta_{\text{eff}}$ (top) and \mathcal{A}_f (bottom), respectively, in $B^0 \rightarrow K^+K^-K_S$ and $K_S K_S K_S$ decays. Results for $(K^+K^-K_L)_{CP\pm}$ are identical to those for $(K^+K^-K_S)_{CP\mp}$; table taken from 48)

Final State	$\sin 2\beta_{\text{eff}}$	Expt.
$(K^+K^-K_S)_{\phi K_S}$ excluded	$0.749^{+0.080+0.024+0.004}_{-0.013-0.011-0.015}$	$0.57^{+0.18}_{-0.17}$
$(K^+K^-K_S)_{CP+}$	$0.770^{+0.113+0.040+0.002}_{-0.031-0.023-0.013}$	
$(K^+K^-K_L)_{\phi K_L}$ excluded	$0.749^{+0.080+0.024+0.004}_{-0.013-0.011-0.015}$	0.09 ± 0.34
$K_S K_S K_S$	$0.748^{+0.000+0.000+0.007}_{-0.000-0.000-0.018}$	0.65 ± 0.25
$K_S K_S K_L$	$0.748^{+0.001+0.000+0.007}_{-0.001-0.000-0.018}$	
	\mathcal{A}_f (%)	Expt.
$(K^+K^-K_S)_{\phi K_S}$ excluded	$0.16^{+0.95+0.29+0.01}_{-0.11-0.32-0.02}$	-8 ± 10
$(K^+K^-K_S)_{CP+}$	$-0.09^{+0.73+0.16+0.01}_{-0.00-0.27-0.01}$	
$(K^+K^-K_L)_{\phi K_L}$ excluded	$0.16^{+0.95+0.29+0.01}_{-0.11-0.32-0.02}$	-54 ± 24
$K_S K_S K_S$	$0.74^{+0.02+0.00+0.00}_{-0.06-0.01-0.06}$	31 ± 17
$K_S K_S K_L$	$0.77^{+0.12+0.08+0.06}_{-0.28-0.11-0.07}$	

other mode being used in the test. For this reason, it is gratifying that $\eta'K_S$ also happens to be theoretically very clean in several of the model calculations. This has the important repercussion that confirmation of a significant deviation from the SM, may well come 1st by using the $\eta'K_S$ mode, perhaps well ahead of the other modes⁵⁰⁾.

4.4.4 Concluding remarks on penguin-dominated modes

Concluding this section we want to add that while at present there is no clear or compelling deviation from the SM the fact still remains that this is a very important approximate null test (ANT). It is exceedingly important to follow this test with the highest luminosity possible to firmly establish that as expected in the SM, ΔS_f is really $\lesssim 0.05$ and is not significantly different from this expectation. To establish this firmly, for several of the modes of interest, may well require a SBF.

5 Time dependent CP in exclusive radiative B-decays

$\text{Br}(B \rightarrow \gamma X_{s(d)})$ and direct CP asymmetry $a_{CP}(B \rightarrow \gamma X_{s(d)})$ are well known tests of the SM^{51, 52, 53, 54)}. Both of these use the inclusive reaction where the theoretical prediction for the SM are rather clean; the corresponding exclusive cases are theoretically problematic though experimentally more accessible.

In 1997 another important test ⁵⁵⁾ of the SM was proposed which used mixing induced CP (MICP) or time-dependent CP (TDCP) in exclusive modes such as $B^0 \rightarrow K^*\gamma, \rho\gamma, \dots$. This is based on the simple observation that in the SM, photons produced in reactions such as $B \rightarrow K^*\gamma, K_2^*\gamma, \rho\gamma, \dots$ are predominantly right-handed whereas those in \bar{B}^0 decays are predominantly left-handed. To the extent that FS of B^0 and \bar{B}^0 are different MICP would be suppressed in the SM. Recall, the LO H_{eff} can be written as

$$H_{\text{eff}} = -\sqrt{8}G_F \frac{em_b}{16\pi^2} F_{\mu\nu} \left[F_L^q \bar{q}\sigma^{\mu\nu} \frac{1+\gamma_5}{2} b + F_R^q \bar{q}\sigma^{\mu\nu} \frac{1-\gamma_5}{2} b \right] + h.c. \quad (4)$$

Here F_L^q (F_R^q) corresponds to the amplitude for the emission of left (right) handed photons in the $b_R \rightarrow q_L\gamma_L$ ($b_L \rightarrow q_R\gamma_R$) decay, *i.e.* in the $\bar{B} \rightarrow \bar{F}\gamma_L$ ($\bar{B} \rightarrow \bar{F}\gamma_R$) decay.

5.1 Application to $B^0, B_s \rightarrow$ vector meson + photon

Thus, based on the SM, LO H_{eff} , in b-quark decay (*i.e.* \bar{B} decays), the amplitude for producing wrong helicity (RH) photons $\propto m_q/m_b$ where $m_q = m_s$ or m_d for $b \rightarrow s\gamma$ or $b \rightarrow d\gamma$ respectively. Consequently the TDCP asymmetry is given by,

$$\begin{aligned} B^0 \rightarrow K^{*0}\gamma & : A(t) \approx (2m_s/m_b) \sin(2\beta) \sin(\Delta mt) , \\ B^0 \rightarrow \rho^0\gamma & : A(t) \approx 0 , \\ B_s \rightarrow \phi\gamma & : A(t) \approx 0 , \\ B_s \rightarrow K^{*0}\gamma & : A(t) \approx -(2m_d/m_b) \sin(2\beta) \sin(\Delta mt) , \end{aligned} \quad (5)$$

where K^{*0} is observed through $K^{*0} \rightarrow K_S\pi^0$.

Interestingly not only emission of wrong-helicity photons from B decays is highly suppressed, in many extensions of the SM, *e.g.* Left-Right Symmetric models (LRSM) or SUSY ^{56, 57, 58)} or Randall-Sundrum (warped extra dimension ⁵⁹⁾) models, in fact they can be enhanced by the ratio m_{heavy}/m_b where m_{heavy} is the mass of the virtual fermion in the penguin-loop. In LRSM as well as some other extensions this enhancement can be around m_t/m_b . So while in the SM the asymmetries are expected to be very small, they can be sizeable in LRSM ⁵⁵⁾ (see Table 4) as well as in many other models.

5.2 Generalization to $B^0, B_s \rightarrow$ two pseudoscalars + photon

An important generalization was made in Ref ⁶⁰⁾. It was shown that the basic validity of this test of the SM does not require the final state to consist of a

Process	SM	LRSM
$A(B \rightarrow K^* \gamma)$	$2 \frac{m_s}{m_b} \sin 2\beta \sin(\Delta m_t)$	$\sin 2\omega \cos 2\beta \sin(\Delta m_t)$
$A(B \rightarrow \rho \gamma)$	≈ 0	$\sin 2\omega \sin(\Delta m_t)$

Table 4: Mixing-induced CP asymmetries in radiative exclusive B-decays in the SM and in the LRSM. Note $|\sin 2\omega| \lesssim 0.67$ is allowed (55, 8)

spin one meson (a resonance such as K^* or ρ) in addition to a photon. In fact the hadronic final states can equally well be two mesons; *e.g.* $K_S(\pi^0, \eta', \eta, \phi \dots)$ or $\pi^+ \pi^-$. Inclusion of these non-resonant final states, in addition to the resonances clearly enhances the sensitivity of the test considerably. For the case when the two mesons are antiparticle of each other *e.g.* $\pi^+ \pi^-$, then there is the additional advantage that both the magnitude and the weak phase of any new physics contribution may be determined from a study of the angular distribution (60).

5.3 Theoretical subtleties

In principle, photon emission from the initial light-quark is a non-perturbative, long-distance, contamination to the interesting signal of the short-distance dipole emission from H_{eff} (61, 62). Fortunately, it can be shown (60) that predominantly these LD photons have the same helicity as those from H_{eff} .

Another important source of SM contamination was recently emphasized in Ref. (63) from processes such as $b \rightarrow s\gamma$ + gluon which are from non-dipole operators. Such processes do not fix the helicity of the photon and so can make a non-vanishing SM contribution to mixing induced CP.

It was emphasized in Ref (60) that the presence of such non-dipole contributions can be separated from the dipole contributions, though, it may require larger amount of data, the resolution to this problem is data driven.

To briefly recapitulate, the different operator structure in H_{eff} would mean, that in contrast to the pure dipole case, the time dependent CP asymmetry (S) would be a function of the Dalitz variables, the invariant mass (s) of the meson pair, and the photon angle of emission (z). A difference in the values of S for two resonances of identical J^{PC} would also mean presence of non-dipole contributions. Schematically, we may write:

$$dS^i/(dsdz) = [A_\sigma + A_0^i] + B^i s + C^i z \quad (6)$$

where A_σ is the ‘‘universal’’ contribution that one gets from the dipole operator of the H_{eff} no matter if it is a resonance, or a non-resonance mode. It is

distinct from the contribution of the 4-quark operators as not only it is independent of energy (s) or angle (z) Dalitz variables but also it is independent of the specific nature of the hadronic FS (*i.e.* resonant or non-resonant). The remaining contributions are all originating from 4-quark operators; not only they dependent on energy and angle but also the coefficients are expected to vary from one FS to another. In particular the 4-quark operators may give a FS dependent (energy and angle independent) constant A_0^2 . It is easy to convince oneself that with sufficient data the important term A_σ , at least in principle, can be separated. Once that is done its size should be indicative of whether it is consistent with expectations from SM or requires new physics to account for it.

5.4 Approximate null tests aglore!

If the effects of a BSM CP-odd phase on B-physics are small, then searching for these via **null tests** becomes especially important. Since CP is not an exact symmetry of the SM, it is very difficult if not impossible to find exact null tests. Fortunately clean environment at a SBF should allow many interesting approximate null tests (ANTs); see Table 5 8).

Clearly there is a plethora of powerful tests for a new CP-odd phase and /or new physics that a SBF should allow us to do. Perhaps especially noteworthy (in addition to penguin-dominated hadronic and radiative B decays) are the numerous very interesting tests pertaining to $B \rightarrow X(K, K^*..)l^+l^-$ (51, 52).

Furthermore search for the transverse polarization (64, 65) of the τ in $B \rightarrow X(D, D^*..) \tau \nu_\tau$ due to their unique cleanliness are extremely interesting especially in light of the discovery of neutrino mass and the potential richness of neutrinos with the possible presence of Majorana neutrinos in simple ground-up extensions of the SM as well as in many other approaches (66, 67).

Sensitivity of each of these to NP as well as theoretical cleanliness (*i.e.* how reliable SM predictions are) for each is also indicated. It should be clear that for most of these tests $> 5 \times 10^9$ B-pairs are essential, that is a SBF.

6 K-Unitarity Triangle

For the past many years, effort has been directed towards constraining the UT especially the parameters ρ and η by a combination of information from K and B-physics, as mentioned briefly in Section 1. With the advent of B-factories and significant advance that has been already made (and a lot more is expected to come) it has become possible to construct the UT purely from B-physics (3, 4). In fact it may also be very interesting and important to construct a separate

Table 5: Final states and observables in B - decays useful in searching for effects of New Physics. Reliability of SM predictions (*i.e.* how clean) and sensitivity to new physics are each indicated by stars (5 = *best*); table adopted from ⁸⁾

Final State	Observable	how clean	how sensitive
$\gamma[K_s^*, \rho, \omega]$	TDCP	5*	5*
$K_s[\phi, \pi^0, \omega, \eta', \eta, \rho^0]$	TDCP	4.5*	5*
$K^*[\phi, \rho, \omega]$	TCA	4.5*	5*
$[\gamma, l^+l^-][X_s, X_d]$	DIRCP	4.5*	5*
same	Rates	3.5*	5*
$J/\psi K$	TDCP, DIRCP	4*	4*
$J/\psi K^*$	TCA	5*	4*
$D(*)\tau\nu_\tau$	TCA (p_l^\mp)	5*	4*
same	Rate	4*	4*

UT from K-decays. This could become particularly useful in search for small deviations. Reactions that are relevant for a K-UT are ⁶⁸⁾:

- Indirect CP-violation parameter, ϵ_K with the hadronic matrix elements (parameter B_K) from the lattice. With the dawning of the era of dynamical simulations using discretizations that preserve chiral-flavor symmetries of the continuum ¹²⁾, lattice should be able to significantly reduce the errors on B_K ¹³⁾.
- Accurate measurements of the BR of $K^+ \rightarrow \pi^+\nu\bar{\nu}$ can give a clean determination of $|V_{td}|$ ²⁰⁾. Important progress has been recently made in the 1st step towards an accurate determination of this Br ⁶⁹⁾. Charm quark contribution in the penguin graph is difficult to reliably estimate but this is expected to be subdominant ⁷⁰⁾.
- Measurement of the BR of $K_L \rightarrow \pi^0\nu\bar{\nu}$ can give an extremely clean value of η , *i.e.* ImV_{td} . This is clearly very challenging experimentally; however, it is unique in its cleanliness, perhaps on the same footing as γ from BKD processes discussed above.
- After enormous effort, the experimentalists have determined the direct CP violation parameter ϵ'/ϵ with considerable accuracy ^{71, 72)}. For theory a reliable calculation remains a very important outstanding challenge. Recently it has become clear that not only chiral symmetry on the lattice is essential for this calculation but also the quenched approximation suffers here from very serious pathology ^{73, 74)}. As mentioned

above, since the past 2-3 years considerable effort is being expended in generation of dynamical configurations with domain wall quarks which possess excellent chiral properties. In the near future we should expect to see the application of these new generation of lattices for study of ϵ'/ϵ . It remains to be seen as to how accurately the current generation of computers can allow this important calculation to be done.

7 Neutron electric dipole moment: a classic ANT of the SM

In the SM, neutron electric dipole moment (nedm) cannot arise at least to two EW loops; thus is expected to be exceedingly small, *i.e.* $\lesssim 10^{-31} \text{ecm}$. Long series of experiments over the past several decades now place a 90 %CL bound of $\lesssim 6.3 \times 10^{-26} \text{ecm}$ ⁷⁵). So the expectation from the SM is many orders of magnitude below the current experimental bound. In numerous extensions of the SM, including SUSY, warped extra dimensions etc. nedm close to or even somewhat bigger than the current experimental bound occurs ^{76, 59}). Thus continual experimental improvements of this bound remains a very promising way to discover new BSM CP-odd phase(s).

8 Top quark electric dipole moment: another clean null test of the SM

The top quark is so heavy compared to the other quarks that the GIM-mechanism is extremely effective. Thus in the decays of the top-quark, in the SM, all FCNC are extremely suppressed. Once again, top quark edm cannot arise in the SM to two EW loops and is therefore expected to be extremely small. In many BSM scenarios with extra Higgs doublets ^{78, 79}), LRSM, SUSY ⁷), the top quark can acquire edm at one loop and consequently can be considerably bigger (See Table 6). Therefore searches for the top dipole moment at the International Linear Collider will be an important goal ^{7, 77}). Indeed if sufficient high luminosity could be attained top quark edm of around 10^{-19}ecm may well be detectable (See Table 7).

9 Summary

The new millennium marks the spectacular success of B-factories leading to a milestone in our understanding of CP-violation; in particular, for the first time CKM paradigm of CP violation is quantitatively confirmed.

Direct measurement of $\sin 2\beta$ by the B-factories agrees remarkably well with the theoretical expectation from the SM to about 10%. Furthermore, first relatively crude *direct* determination of the other two angles (α & γ) also are

Table 6: Expectations for top edm form-factor in SM and beyond; adopted from 7)

type of moment ($e - cm$) \downarrow	\sqrt{s} (GeV) \downarrow	Standard Model	Neutral Higgs $m_h = 100 - 300$	Supersymmetry $m_{\tilde{g}} = 200 - 500$
$ \Im m(d_t^Y) $	500	$< 10^{-30}$	$(4.1 - 2.0) \times 10^{-19}$	$(3.3 - 0.9) \times 10^{-19}$
	1000		$(0.9 - 0.8) \times 10^{-19}$	$(1.2 - 0.8) \times 10^{-19}$
$ \Re e(d_t^Y) $	500	$< 10^{-30}$	$(0.3 - 0.8) \times 10^{-19}$	$(0.3 - 0.9) \times 10^{-19}$
	1000		$(0.7 - 0.2) \times 10^{-19}$	$(1.1 - 0.3) \times 10^{-19}$
$ \Im m(d_t^Z) $	500	$< 10^{-30}$	$(1.1 - 0.2) \times 10^{-19}$	$(1.1 - 0.3) \times 10^{-19}$
	1000		$(0.2 - 0.2) \times 10^{-19}$	$(0.4 - 0.3) \times 10^{-19}$
$ \Re e(d_t^Z) $	500	$< 10^{-30}$	$(1.6 - 0.2) \times 10^{-19}$	$(0.1 - 0.3) \times 10^{-19}$
	1000		$(0.2 - 1.4) \times 10^{-19}$	$(0.4 - 0.1) \times 10^{-19}$

Table 7: Attainable $1\text{-}\sigma$ sensitivities to the CP-violating dipole moment form factors in units of $10^{-18} e\text{-cm}$, with ($P_e = \pm 1$) and without ($P_e = 0$) beam polarization. $m_t = 180 \text{ GeV}$. Table taken from 7, 80).

	$20 \text{ fb}^{-1}, \sqrt{s} = 500 \text{ GeV}$			$50 \text{ fb}^{-1}, \sqrt{s} = 800 \text{ GeV}$		
	$P_e = 0$	$P_e = +1$	$P_e = -1$	$P_e = 0$	$P_e = +1$	$P_e = -1$
$\delta(\Re e d_t^Y)$	4.6	0.86	0.55	1.7	0.35	0.23
$\delta(\Re e d_t^Z)$	1.6	1.6	1.0	0.91	0.85	0.55
$\delta(\Im m d_t^Y)$	1.3	1.0	0.65	0.57	0.49	0.32
$\delta(\Im m d_t^Z)$	7.3	2.0	1.3	4.0	0.89	0.58

consistent with theoretical expectations. While these findings are good news for the SM, at the same time, they imply that most likely the effect of BSM CP-odd phase on B-physics is likely to be a small perturbation. Thus discovery of new BSM-CP-odd source(s) of CP violation in B-physics is likely to require very large, clean, data samples and extremely clean predictions from theory.

For the search of such small deviations approximate null tests of the SM gain new prominence.

Also important for this purpose is the drive to directly determine all three angles of the UT with highest precision possible, *i.e.* with errors roughly around the errors allowed by theory. It should be clear that to accomplish this important goal would require a Super-B Factory.

Specifically regarding penguin-dominated hadronic FS, that have been much in the recent news, the current data does not show any convincing signal for deviation from the SM; however, it is a very important and sensitive test for new physics and its of vital importance to reduce the experimental errors to O(5%); for this purpose too a SBF may well be needed.

Outside of B-Physics, K-unitarity triangle, neutron electric dipole moment and top quark dipole moment are also very important *approximate null tests* of the SM that should be pursued vigorously.

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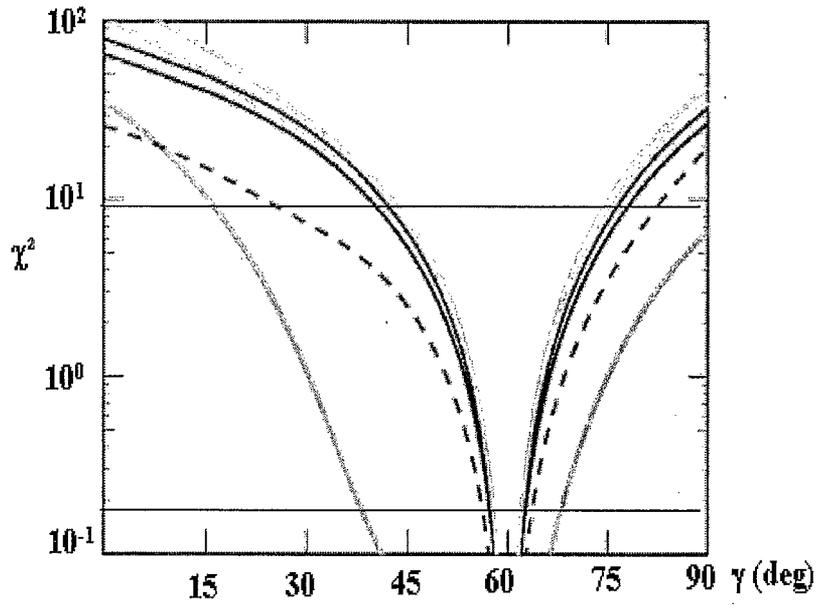


Figure 2: γ extraction with over-determined cases. Purple curve shows the effect of combining GLW (all CPES modes) with one ADS ($K^+\pi^-$) mode; black curve differs from purple only in that it also includes D^0 from D^{*0} ; blue curves show the effect of properly including the correlated strong phase between $D^{0*} \rightarrow D^0 + \pi$ and $D^{0*} \rightarrow D^0 + \gamma$. Orange curve includes lot more input including Dalitz and multibody modes. see text for details (See also Fig 1). Adopted from ²⁸).

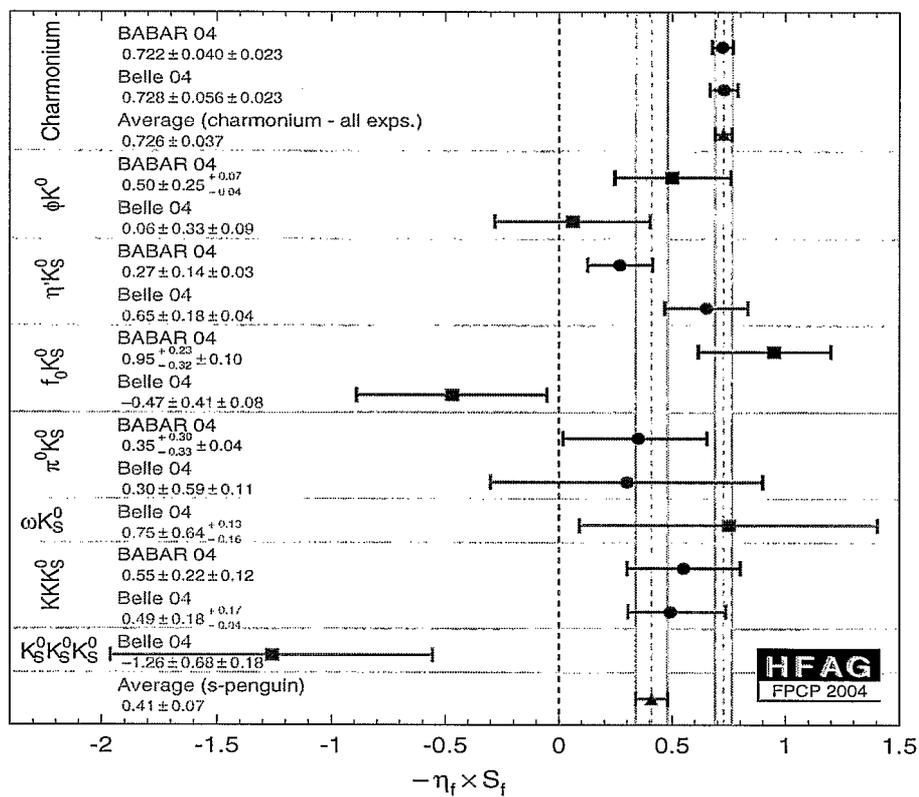


Figure 3: Experimental status of $\sin 2\beta$ from penguin-dominated modes; taken from 5).

1 Guidelines

Dear Author,

This note describes the instructions for the preparation of your paper which will appear in the proceedings of LaThuileFPSpro, following the recommendations provided by the editor, The Frascat