Combined Strategies for $\gamma(\phi_3)$ with $B \to DK$

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Note $(\phi_1, \phi_2, \phi_3) \equiv (\beta, \alpha, \gamma)$

Talk based on Atwood and Soni, hep-ph/0312100

OUTLINE

1. Introduction & Motivation:

   Clean determination of all 3 angles with precision $\approx ITE$ is a goal of paramount importance for B-Physics necessitating a Super-B effort.

2. Framework for Analysis

3. Features of a Numerical Study

   - Inclusion of D^0 from $B \to$ "K"$[D^{*0} \to D^0 + \pi^0(\gamma)]$ can extend the reach significantly.
   - Inclusion of self-tagging modes of B^0 can be helpful.
   - Although flavor tagging of $\bar{D}^0$ in $B^- \to K^-\bar{D}^0$ is very challenging, even an (relatively) imprecise determination may be helpful for constraining $\gamma(\phi_3)$ as well as for consistency checks.
   - D^0 studies at a charm factory can play a very valuable role.

4. Summary and Outlook

ELEMENTS of a PRISTINE UT

- TDCPA in $B^0 \to \psi K^0$; gives $\phi_1(\beta)$
- DIRCP in $B^\pm \to$ "$K^\pm$" $D^0, \bar{D}^0$; gives $\gamma(\phi_3)$
- TDCPA in $B^0 \to$ "K^0" $D^0, \bar{D}^0$; gives $\phi_3(\gamma)$ OR $\phi_2(\alpha)$ AND $\beta(\phi_1)$

  Also, incidentally

- TDCPA in $B_s \to KD_s$; gives $\phi_3(\gamma)$.
- AND DIRCP in $K_L \to \pi^0 \nu\bar{\nu}$ gives $\phi_1(\beta)$

  Note that the irreducible theory error (ITE) in each of these methods is expected to be $< 1\%$

- Using TDCPA studies in *all* three final states $B \to \pi\pi$, $\rho\pi$ and $\rho\rho$ should give a very good determination of $\phi_2(\alpha)$ (may be with $ITE \approx 1\%$?) although each final state by itself is likely to have (at least) several percent theory error, with our present level of understanding.

It is extremely important that we make use of the opportunity 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.

This end 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.

Thereby thru internal inconsistencies one may search for BSM CP-odd phase(s) [χ_{BSM}] even if their effect on B-physics is relatively small

Remember the m_ν

Situation wrt χ_{BSM} is reminiscent of m_ν

There were no good reason(s) to think that m_ν should be zero; similarly there are none for χ_{BSM} to be zero either.

In the case of ν's there were the solar neutrino results that were suggestive for a very longtime; similarly in the case of χ_{BSM} baryogenesis is the beacon.

It took decades to show m_ν is not zero; [Δm^2 had to be lowered (around 1983) from $O(1-10)\,ev^2$ down to $O(10^{-4})\,ev^2$ before m_ν was discovered.] let's hope we have better luck with χ_{BSM} but there is no good reason to be too optimistic; therefore dont think we ought to rely on luck.

Soni's$^{\mathbf{RECENT}}$ Obsession

- Post-Bfactory confirmation that CKM phase is the dominant source in a_{CP} (B $\rightarrow \psi K_s$) suggests that even if X_{BSM} exists and is $O(1)$ its effects in B-physics may well be small.

- While difficult to reliably say, how small; in planning B-expts, it may be best to target $a_{CP}[\chi_{BSM}]$ very small, say $O(10^{-3}) \approx \epsilon_K$ Our enlightened understanding of the CKM-phase (post B-factory results) is that it is $O(1)$ and while it causes large asymmetry in B-physics, in K-decays its effects are miniscule.

- In suggesting the target, $a_{CP}[\chi_{BSM}] \approx 10^{-3}$, we are taking cue from this SM example. Thus even isospin symmetry (widely used) can cause problems. So:

  $\Rightarrow$ Need lots and lots of **CLEAN** B's (i.e. $O(10^{10})$ or more).

  $\Rightarrow$ Intensive study of B_s mesons (in addition to B's) becomes very important.

  $\Rightarrow$ Need extremely clean predictions from theory.

Clean unitarity angles from FS with $D^0(\bar{D}^0)$

In $B^{\pm}, B^0, \bar{B}^0$ decays final states containing $D^0(\bar{D}^0)$ are of crucial importance:

- $\gamma(\phi_3)$ via (DIRCP) $B^{\pm} \to$ "$K^{\pm}$" $+ D^0, \bar{D}^0$ followed by D^0 and $\bar{D}^0$ decays to common final states (e.g. $K^+\pi^-$, $K_s\omega$...)
- $\delta[= (\beta - \alpha + \pi) \equiv (2\beta + \gamma)]$ **AND** $\phi_1(\beta)$ via (TDCP) $B^0(\bar{B}^0) \to$ "K^0" $D^0, \bar{D}^0$ (again) followed by D^0 and $\bar{D}^0$ decays to common FS.
- Multitude of common FS of D^0,$\bar{D}^0$ should greatly fecilitate the analysis esp. wrt the discrete ambiguities and the final error.
- Furthermore, "$K^{\pm}$" $\equiv K^{\pm}, K^{*\pm}$ and similarly for "K^0".
- Note charged and neutral B (in DIRCP and TDCP) are using the same common FS of $D^0, \bar{D}^0$,therefore needed information e.g. FS phases (possibly obtainable from charm factories) feciltates analysis in both cases.

Basic Ideas

Gronau-London-Wyler construction

Can extract γ cleanly by measuring 5 of the following 6 quantities:

(1) A($B^+ \to D^0_{CP} K^+$); (2) A($B^+ \to D^0 K^+$)

(3) A($B^+ \to \bar{D}^0 K^+$); (4) A($B^- \to D^0_{CP} K^-$)

(5) A($B^- \to \bar{D}^0 K^-$); (6)A($B^- \to D^0 K^-$)

Flavor tagging of $\bar{D}^0$ in (say) $B^- \to \bar{D}^0 K^-$ is big challenge:

- semi-leptonic tag suffers from serious background from prompt semi-leptonic decays of B
- Hadronic tag receives significant contamination from doubly caibbo suppresed decays
- One may try to by-pass the difficulty by taking the needed BR from theory....This is a fine interim measure but NOT drsirable in the long-run as its extremely important that we prepare ourselves for small deviations from the SM

- The interference between direct and DCS D^0 decays is near maximal as its between $[CLA(B-decay)] \times [DCS(D^0-decay)]$ versus $[CLS(B-decay)] \times [CBA(D^0-decay)]$
  Crudely this goes as $\frac{V_{ub}}{N_c} \times \frac{1}{V_{cb}V_{cd}V_{us}} \approx 70\%$. Therefore, in the ADS approach one tries to cash on these DCS modes of D^0 that are expected to selectively exhibit largish CP asymmetries to extract a clean γ

- Grossman, Ligeti and Soffer [GLS] studied an important variation recently which uses singly-cabibbo-suppressed [SCS] (common) decay modes of D^0 and $\bar{D}^0$. This are expected to have larger BR but smaller asymmetries (compared to DCS)

- In principle any 2 common decay modes [say F_1 and F_2] of D^0 and $\bar{D}^0$ suffice as then there are 4 observables (i.e. BR's of $B^\pm \to$ "$K^\pm$"$[D^0(\bar{D}^0) \to F_1, F_2]$) and there are 4-parameters (i.e. the "unmeasurable" BR($B^- \to$ "K^-"$\bar{D}^0$, 2 strong phases and the GEM γ that we are after). However,to overcome discrete ambiguities and improve determination redundacy is valuable

Multitude of Common Final States of D^0,$\bar{D}^0$

1. **CPES** [Gronau-London-Wyler],Cabibbo-allowed(CBA) or singly-Cabibbo- suppressed (SCBS) e.g. K_s (π^0,η,η',ω, ρ^0); $\pi^+\pi^-$, K^+K^-.... Have smallish asymmetry but largish eff. BR
2. **CPNES** [Grossman-Ligeti-Soffer], SCBS, e.g. K^+K^{*-},$\pi^+(\rho^-,a_1^-)$... Have smallish asymmetries but largish eff. Br
3. **CPNES** [Atwood-Dunietz-Soni], doubly-Cabibbo-suppressed (DCBS) e.g. $K^+(\pi^-,a_1^-,\rho^-)$; $K^{*+}(\pi^-...)$... Have largish asymmetry but smallish eff. Br

Additional avenues for optimization

- In the original B decay, $K^\pm$ may be replaced with $K^{*\pm}$
- Furthermore, an even more interesting and potentially powerful possibilty is that D^0 may also be replaced by D^{0*}

Just these 2 generalizations improve the potential of the method dramatically; although many other variations are also possible.

Additional Variations

1. **Three body modes via a Dalitz analysis**

   Three body modes of $D^0, \bar{D}^0$ another important way to capitalize on the large interference between direct and DCS modes was also intially suggested by ADS (PRL'97) as a powerful way to get $(\phi_3)\gamma$ as each point in the Dalitz plot can then be viewed as a distinct mode. For an explicit case study using $D^0 \to K^+\pi^-\pi^0$ as an example, see ADS, hep-ph/0008090; also see BELLE, hep-ex/0308043.

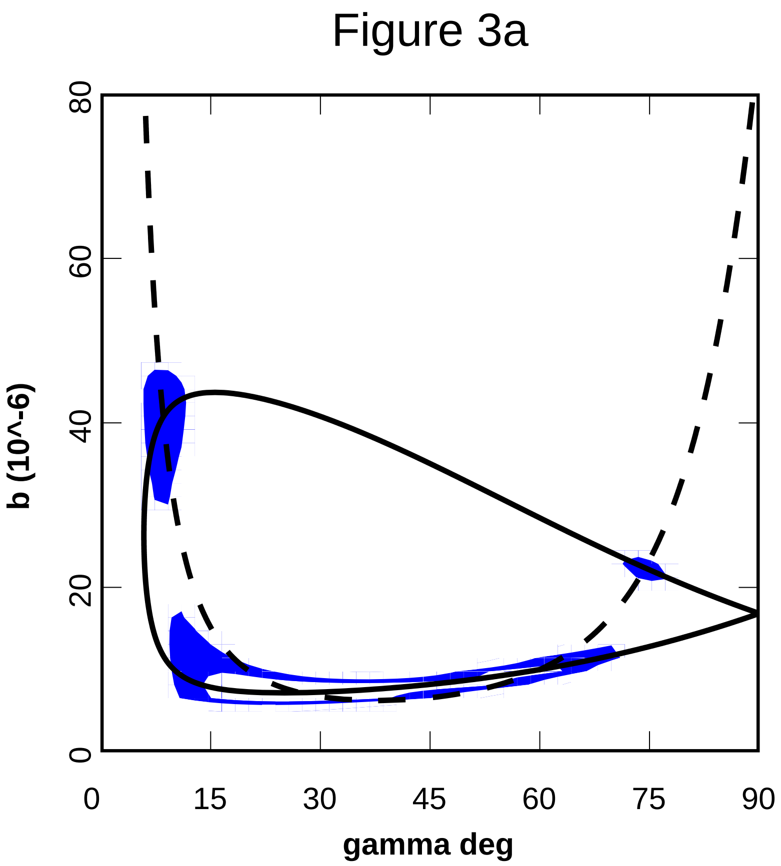
2. **Other multibody modes**

   - $B^\pm \to K^\pm D^0 \pi^0$ suggested by Aleksan,Petersen and Soffer, hep-ph/0209194
   - $B^\pm \to K^\pm [D^0 \to$ multibody], Giri, Grossman, Soffer and Zupan
   - $B^\pm \to K^\pm [D^0 \to$ **"moreclusive"**], Atwood and Soni hep-ph/0206045
   - Charm factory can be especially helpful for moreclusive anal-

ysis, see Atwood and Soni, hep-ph/0304085

⇒ **Therefore very high degree of redundancy should become available.**

Discrete ambiguities aglore with only 2 modes



The likelihood distribution is shown as a function of γ and $b(K^*)$ assuming that $N_{B\bar{B}}(acceptance) = 10^8$ and assuming only the $K^+\pi^-$ and $K_s\pi^0$ modes of D^0,$\bar{D}^0$ are measured in $B^\pm \to K^\pm D^0, \bar{D}^0$ decays. The outer edge of the the shaded regions correspond to 90% confidence while the inner edge corresponds to 68% confidence. The solid line shows solution for $K^+\pi^-$ only and dashed one for $K_s\pi^0$ only. From Atwood,Dunietz,Soni,hep-ph/0008090

Illustrative Study with $(4-8)\times 10^8$ $B\bar{B}\,pairs$

[See Atwood and Soni, hep-ph/0312100]

Aim: Explore effectiveness of combining various strategies

With data samples likely to be available in the near future a single strategy is unlikely to work; besides fixed sample of $B\bar{B}\,pairs$ will contain CPES, DCS as well as SCS modes....

ASSUME(1): detection efficiencies for $\pi^{\pm}$,$K^{\pm}$ and π^0 (η) is 0.95,0.8 and 0.5 respectively

ASSUME(2): Acceptance cuts to discriminate against continuum backgrounds will reduce the final acceptance by factor of $3-6$

ASSUME(3): For now ignore $D^0\bar{D}^0$ mixing (see Appendix to paper)

Important features of the study

- Altogether four types of intial (charged) B decays are considered: (1) $B^\pm \to K^\pm D^0$; (2) $B^\pm \to K^{*\pm} D^0$; (3) $B^\pm \to K^\pm D^{0*}$; and (4) $B^\pm \to K^{*\pm} D^{0*}$

- When D^{0*} is involved we take $D^{0*} \to D^0 + \gamma(\pi)$ before the D^0 goes to the hadronic FS

- The D^0 is considered to decay into 6 types of possible FS: (1) $K^+\pi^-$; (2) $K^{*+}+\pi^-$; (3) $K^+\pi^-+n\pi$; (4) CP odd FS; (5)K^*+K^- and (6) $K^{*-}K^+$

- For each of the 4 $B^\pm$ decays we take the six subsequent D^0 decays to have the following number of events:
  $K^+\pi^-\,(25)$;$K^{*+}\pi^-\,(14)$;$CPES-\,(827)$;
  $K^+\pi^- + n\pi\,(106)$;$K^{*+}K^-\,(50)$; $K^{*-}K^+\,(50)$

- Whenever strong phase(s) are needed for numerical illustration we choose them (a) arbitrarily, (b) randomly.
  (In the quantities studied no appreciable differences were seen)

- In the case of $K^{*\pm}D^{0*}$ FS, **FOR NOW** no angular analysis is done; instead we assume that the 3 helicities are equally probable.

Framework for analysis

For a given decay of the form $B^- \to K^{(*)-}[\mathbf{D}^{(*)0} \to F]$ where F is in general an exclusive or inclusive final state, let us denote

$d = Br(B^- \to K^{(*)-}[D^{(*)0} \to F])$

$\bar{d} = Br(B^+ \to K^{(*)+}[D^{(*)0} \to \bar{F}])$

where in the case of $\mathbf{D}^*0$ it cascades down to $\mathbf{D}^0$ before a $\mathbf{D}^0 \to F$ decay. In terms of the B and D branching ratios and the strong and weak phases, these quantities are given by

$d = ac_F + b\bar{c}_F + 2R_F\sqrt{ac_F b\bar{c}_F}\cos(\zeta_B + \zeta_F + \gamma)$

$\bar{d} = ac_F + b\bar{c}_F + 2R_F\sqrt{ac_F b\bar{c}_F}\cos(\zeta_B + \zeta_F - \gamma)$

where $a = Br(B^- \to K^{(*)-}D^{(*)0})$, $b = Br(B^- \to K^{(*)-}\bar{D}^{(*)0})$, ζ_B is the strong phase difference of the B^- decay, ζ_F is the strong phase difference for the D^0 decay, $c_F = Br(D^0 \to F)$; $\bar{c}_F = Br(\bar{D}^0 \to F)$ and R_F is the coherence factor (needed for inclusive decays). See later. Also, $d_{av} = (d + \bar{d})/2$; $A_{CP} = (d - \bar{d})/(d + \bar{d})$ is thus the PRA.

Some numerical results

CP asymmetries in various channels $[\gamma = 60°]$

The PRA with arbitarily assigned strong phases. (Randomly chosen strong phases tend to give similar results)

	$K^+\pi^-$	$K^{*+}\pi^-$	$CPES-$	$K^{*+}K^-$
$B^- \to K^- D^0$	**-58.2%**	**-8.1%**	**-17.1%**	**-17.1%**
$B^- \to K^{*-} D^0$	**-54.3%**	**-63.3%**	**+11.6%**	**-15.0%**
$B^- \to K^- D^{*0}$	**-76.9%**	**-39.4%**	**-4.1%**	**-12.1%**
$B^- \to K^{*-} D^{*0}$	**+58.4%**	**-13.5%**	**+15.8%**	**+14.6%**

of B's needed for CP-observability

The number of $B\bar{B}$ pairs needed to see a 3 σ signal of CP asymmetry in units of 10^8; detection efficiencies as stated previously are included alongwith factor of 5 for cuts against background rejection.

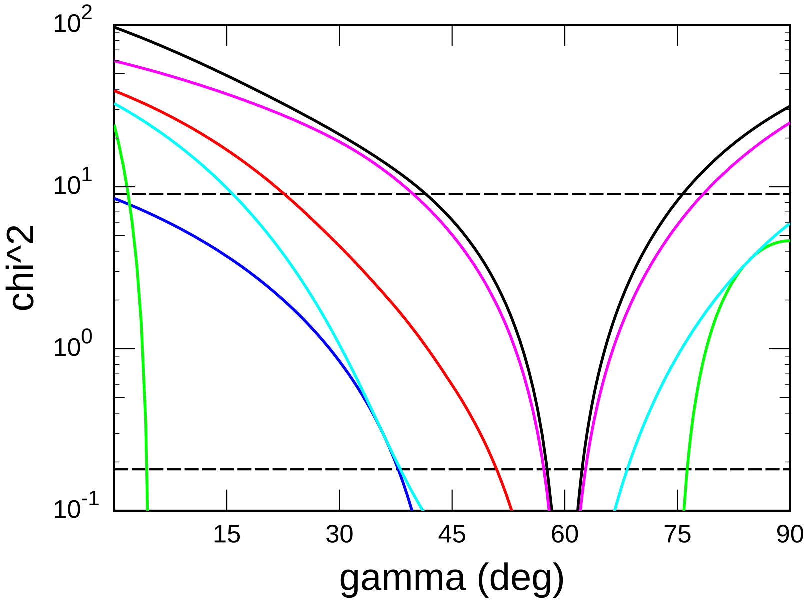
	$K^+\pi^-$	$K^{*+}\pi^-$	$CPES-$	$K^{*+}K^-$
$B^- \to K^- D^0$	**6.05**	**508**	**1.73**	**122**
$B^- \to K^{*-} D^0$	**7.17**	**7.95**	**2.27**	**150**
$B^- \to K^- D^{*0}$	**4.53**	**28.0**	**31.8**	**259**
$B^- \to K^{*-} D^{*0}$	**4.34**	**211**	**0.9**	**267**

$\Rightarrow$ **With about 5×10^8 B-pairs in the $K^+\pi^-$ as well as CPES modes of D^0 PRA ought to become observable.**

Improved determination by combining different types of modes

$N_{B\bar{B}} = 4 - 8 \times 10^8$ (including efficiencies);for details see Atwood and Soni, hep-ph/0312...

The minimum value of χ^2 is shown as a function of γ for vari-



ous combinations of data in the sample calculation. The green line shows the result using just the $B^- \to K^-[D^0 \to CPES-]$ data. The blue line shows the result using just $B^- \to K^-[D^0 \to K^+\pi^-]$ data. The turqoise curve shows the result taking both $B^- \to K^-[D^0 \to K^+\pi^-]$ and $B^- \to K^-[D^0 \to CPES-]$ data together. The red line shows the result using $B^- \to K^{(*)-}[D^{(*)0} \to$

$K^+\pi^-]$. In the black curve, all four of the initial B^- decays where the D^0 decays to the same two final states are considered. Thus this black curve results from taking together data of the form $B^- \to K^{(*)-}[D^{(*)0} \to K^+\pi^-]$ and $B^- \to K^{(*)-}[D^{(*)0} \to CPES-]$.

- The purple curve only includes data from two parent B^- decays, i.e. $B^- \to K^- D^0$ as well as $B^- \to K^-[D^{*0} \to D^0 + \pi^0(\gamma)]$ with either of the two D^0 decaying to $K^+\pi^-$ as well as CPES-.

- The upper horizontal curve corresponds to about 5×10^8 B-pairs while the bottom one to luminosity about 50 times bigger i.e. a Super-B Factory.

- **This(purple) combination seems to be very effective and gives a $3-\sigma$ determination of γ to be about (60 ± 15 deg) with around 5×10^8 B-pairs and within a few (around 2) degrees with a few $\times 10^{10}$ B-pairs**

- Also comparing purple (includes D^0 from D^{*0}) with turqoise, (which does not include D^{*0}) suggests inclusion of D^0 from D^{*0} helps a great deal.

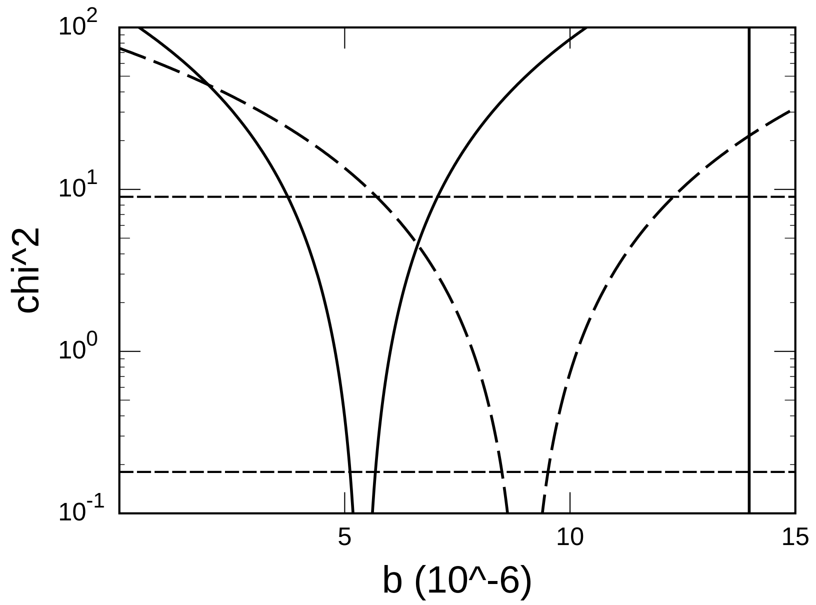
- Note that for the purple there are 8 observables for 6 unknowns; so that does a lot better than the turqoise where the number of observables equal number of paramters $=$ 4.

- **Infact the lower horizontal line indicates that the reduction in error (by including D^0 from D^{*0}) is roughly a factor of 5 i.e. a saving in effective luminosity of a factor of 25 and not just 2 as one may naively expect.**

Determination of the Br of color-suppressed modes

Recall the color suppressed Br [e.g. $B^- \to K^- \bar{D}^0; K^{*-} \bar{D}^0$...] are very difficult to measure experimentally. The semi-leptonic flavor-tagging and thereby distinguishing D^0 versus $\bar{D}^0$ suffers from huge backgrounds from prompt semi-leptonic decays of $B^- \to l^- \nu_l X_c$, etc. A hadronic tag of $\bar{D}^0$ [e.g. $\bar{D}^0 \to K^+ \pi^-$] suffers from large background from of color allowed $B^- \to K^- D^0$ followed by DCS $D^0 to K^+ \pi^-$....key to giving rise to large CP asymmetry as noted in ADS.

Thus these color-suppressed Br's are treated as unknowns and must be determined along with $\gamma(\phi_3)$ and the strong phase(s).



The minimum value of χ^2 is shown as a function of $Br(B^- \to K^-\bar{D}^0)$ and $Br(B^- \to K^{*-}\bar{D}^0)$ using data for all the combinations of $B^- \to K^{(*)-}\mathbf{D}^{(*)0}$ followed by $\mathbf{D}^0 \to K^+\pi^-$; $CPES-$; $K^+\pi^- + n\pi$, $K^{*+}\pi^-$. The dependence on $Br(B^- \to K^-\bar{D}^0)$ is indicated by the solid line while the dependence on $Br(B^- \to K^{*-}\bar{D}^0)$ is shown by the dashed curve.

The 3-sigma error on Br's ($B^- \to K^-\bar{D}^0$ and $B^- \to K^{*-}\bar{D}^0$) is $\pm 13\%$ and 7% respectively at the SBF

Possible Role of Charm Factory

[see Atwood and Soni, hep-ph/hep-ph/0304085. For earlier works related to CF see: Soffer; ADS; Silva and Soffer; Gronau, Grossman and Rosner]

Just about the most important application of a Charm Factory (CF) is to help in CKM determinations via BKD Modes. There are a number of ways in which this can be done:

1. Measurements of the Br's of some of the D decay modes that enter the analysis; specifically determinations of the DCS D decays such as K^+ (K^{*+}) $[\pi^-, \rho^-, a_1^-]$.
2. Improving the constraints on the $D^0 - \bar{D}^0$ mixing parameters, x_D, y_D can be very helpful.
3. Another very interesting application is to use a CF factory to determine two parameters needed for being able to use (exclusive and) **moreclusive** decays of $D^0, \bar{D}^0$

Moreclusive states

moreclusive $\equiv$ more general than inclusive; i.e sum over points in phase space of e.g. a 3 body (exclusive decay mode) (in say a Dalitz plot) is a sum over various quantum mechanical amplitudes and so is the case for (say) $D^0 \to K^- + X$ which represents a sum over many exclusive modes.

Thus, a decay such as $D^0 \to K^-\pi^+$ would be an exclusive state while for a three body decay such as $D^0 \to K^-\pi^+\pi^0$, each point on the Dalitz plot must also be considered a distinct exclusive state. **Moreclusive states are inclusive either because they are integrated over phase space or include states with different particle content.**

In particular, the determination of γ using decays of the form $B^- \to K^- D^0$ where the D^0 subsequently decays to moreclusive final states is highly desirable. **For such an analysis CF is very valuable as it can be used to determine two crucial**

parameters: R_F **("coherence coefficient") and** ζ_F **(average strong phase)** This can be done by exploiting the **entangled** state of $D^0\bar{D}^0$. The important point is that in $\psi(3770) \to D^0\bar{D}^0$ the D's have an antisymmetrical wavefunction in flavor space: $(|D^0\rangle|\bar{D}^0\rangle - |\bar{D}^0\rangle|D^0\rangle)/\sqrt{2}$

Formalism for Moreclusive states

Let F be a (moreclusive) inclusive state, so that we may write:

$F = f_i$ where f_i are the exclusive states which make up F. Primarily we are interested in final states which are common to D^0 and $\bar{D}^0$ decay. Two categories of such final states of particular interest are DCS states such as $K^+\pi^-$ and CP eigenstates such as $K_S\pi^0$. For each $f_i \in F$, let us denote:

$A(f_i) = \mathcal{M}(D^0 \to f_i)$

$\bar{A}(f_i) = \mathcal{M}(\bar{D}^0 \to f_i)$

$\zeta(f_i) = \arg(A^*(f_i)\bar{A}(f_i))$

so $\zeta(f_i)$ is the strong phase difference between D^0 and $\bar{D}^0$ decay to f_i.

Because both the channels $B^- \to K^- D^0$ and $B^- \to K^- \bar{D}^0$ can contribute to the overall process $B^- \to K^- F$ for the inclusive state F, we can regard the object that decays into F to be a quantum mechanical mixture of D^0 and $\bar{D}^0$.

Denoting this state by $|I>$, then

$$|I\rangle = a|D^0\rangle + be^{i\lambda}|\bar{D}^0\rangle$$

where a and b are real. We can thus expand the decay rate for the mixed state $|I>$ to F as:

$$\Gamma(I \to F) = \sum_i \Big\{ a^2|A(f_i)|^2 + b^2|\bar{A}(f_i)|^2$$
$$+ 2ab|A(f_i)|\ |\bar{A}(f_i)| \cos(\zeta(f_i) + \lambda) \Big\}$$
$$= a^2 A(F)^2 + b^2 \bar{A}(F)^2 + 2R_F ab A(F)\bar{A}(F) \cos(\zeta(F) + \lambda)$$

Here, $A(F)^2 = \sum |A(f_i)|^2$; $\bar{A}(F)^2 = \sum |\bar{A}(f_i)|^2$

$R_F e^{i\zeta(F)} = \frac{\sum |A(f_i)||\bar{A}(f_i)|e^{i\zeta(f_i)}}{A(F)\bar{A}(F)}$

The key point to note is that R_F and $\zeta(F)$ are independent of a, b and λ. The decay rate of I thus depends only on four parameters of F, namely $A(F)$, $\bar{A}(F)$, R_F and ζ_F, regardless of how many states make up F. **We can think of $A(F)$ and $\bar{A}(F)$ as the average amplitudes of D and $\bar{D}$ decay to F while $\zeta(F)$ is the average strong phase difference for F and R_F is a measure of the coherence of F.** Note that $0 \leq R_F \leq 1$.

Now, as an illustration, consider $\psi(3770) \rightarrow [via D^0 \bar{D}^0] FG$

$$\Gamma(FG) = \Gamma_0 \Bigg[A_F^2 \bar{A}_G^2 + \bar{A}_F^2 A_G^2 - 2 R_F R_G A_F \bar{A}_F A_G \bar{A}_G \cos(\zeta(F) - \zeta(G)) \Bigg]$$

By judiciously constructing different observables, R_F and ζ's can be solved for as shown in hep-ph/0304085

Numerical Results from an illustrative toy model

[Atwood and Soni hep-ph/0304085]

The modes used in the toy model for $D^0 \to K^- X$ where X contains at most one π^0.

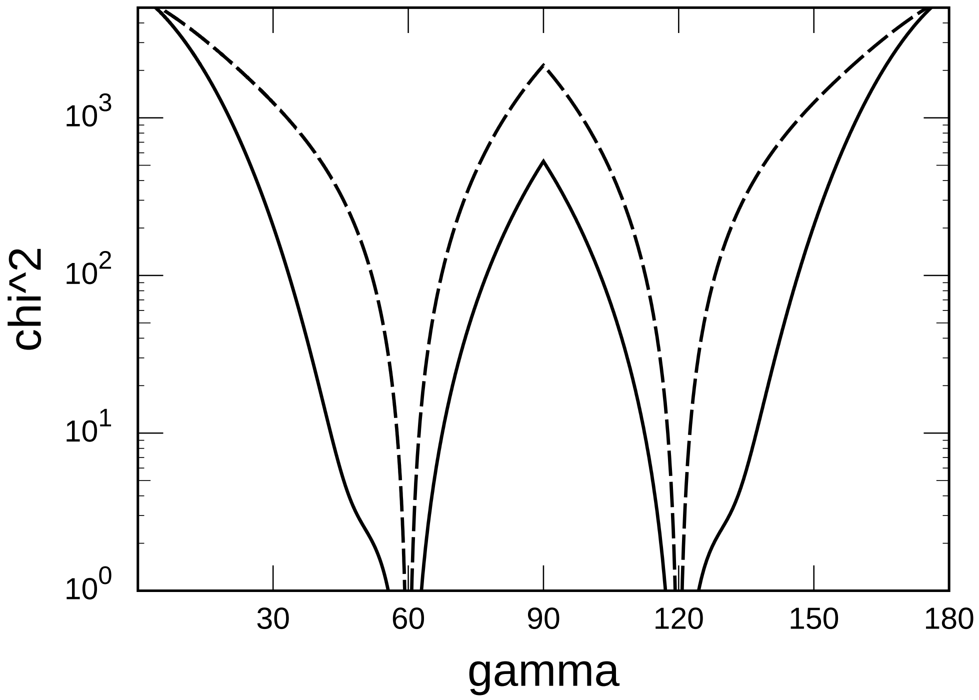
Mode	Sub-mode	Br
$K^-\pi^+$		3.8%
$K^-\pi^+\pi^0$		13.1%
	$K^-[\rho^+ \to \pi^+\pi^0]$	8.64%
	$\pi^+[K^{*-} \to K^-\pi^0]$	5.02%
	$\pi^0[\bar{K}^{*0} \to K^-\pi^0]$	1.46%
$K^-\pi^-\pi^+\pi^+$		7.46%
	$K-\pi^+[\rho^0 \to \pi^+\pi^-]$	4.7%
	$[K^{*0} \to K^-\pi^+][\rho^0 \to \pi^+\pi^-]$	0.97%
	$K^-[a_1^+ \to \pi^+\pi^+\pi^-]$	3.6%
	$[K_1^-(1270) \to K^-\pi^+\pi^-]\pi^+$	0.37%
	4-body continuum	1.74%
$K^-\pi^-\pi^+\pi^+\pi^0$		4.0%

The parameters for the three different inclusive modes resulting in our toy model.

Mode	Br	ζ	R
$\mathcal{F}_1$	11.0%	-34°	0.74
$\mathcal{F}_2$	24.9%	-86°	0.29
$\mathcal{F}_3$	19.3%	30°	0.91
CP eigenstates	5%		1

The 3-σ error in degrees in the determination of γ with $\hat{N}_B = 10^9$ for the various toy models considered, for $\gamma = 60^\circ$ and $\zeta_k = -50^\circ$. The first three rows refer to exclusive states where we take $\eta(K^+\pi^-) = 120^\circ$ and $\zeta(K^+\pi^-) = 60^\circ$ while the last two rows refer to the inclusive states $\mathcal{F}_i$.

Input	$\gamma = 60^\circ$; $\zeta_k = -50^\circ$
$K^{*+}\pi^-$ with CPES-	10.0°
$K^{*+}\pi^-$ and $K^+\pi^-$ with CPES-	9.1°
$K^{*+}\pi^-$ and $K^+\pi^-$ with CPES- using $\psi(3770)$	3.4°
$\mathcal{F}$ with CPES-	12.0°
$\mathcal{F}_1$, $\mathcal{F}_2$ and $\mathcal{F}_3$ with CPES-	2.3°



χ^2 is plotted as a function of γ for input generated assuming $\gamma = 60^\circ$ and $\zeta_k = -50^\circ$ using various combinations of inclusive states with $\hat{N}_B = 10^9$ together with $\psi(3770)$ factory data. The solid curve uses only $\mathcal{F}$ and CPES-. The dashed line uses information from $\mathcal{F}_{1-3}$ together with CPES-.

Summary and Outlook

- $B \to KD^0$ methods with **DIRECT AND TDCP** provide a very clean way to extract CKM angles, with irreducible theory error $O(.1\%)$.
- However, unlike $\phi_1(\beta)$ from $B \to \psi K_s$, BKD method will require intensive phenomenological studies, due to the multitude of possiblities, before we can develop optimal strategy or harness the richness of the final states.
- Current study suggests inclusion of $B \to$ "K" D^{0*} followed by $D^{0*} \to \gamma(\pi)D^0$ may be quite helpful.
- **At a Super-B Factory, by combining different strategies, as illustrated, $\phi_3(\gamma)$ may be determined with a $3-\sigma$ error of a few degrees.**

  Background were not fully taken into account but also not all possible input has been used. (e.g. DALITZ, SCS...)
- It should be emphasized that just about the best application of

Charm Factory is to the physics of CKM via BKD. Info thus obtained can be very helpful both for DIRECT and for TD CP. SBF data with input from CF could lead to very precise determination of CKM angles.