

Probing New Physics With b Decays

Sheldon Stone*

Physics Dept., Syracuse University, USA, 13244-1130

I discuss how b decays can be used to unravel new physics beyond the Standard Model. Decays second order in the weak interaction involving loops and CP violation are emphasized. This information is complementary to that obtainable with higher energy machines.

.....
Presented at Snowmass 2001, Working Group on Flavor Physics, P2, Snowmass, CO, July, 2001.

*Stone@physics.syr.edu

I. INTRODUCTION

There are many reasons why we believe that the Standard Model is incomplete and there must be physics beyond. One is the plethora of “fundamental parameters,” for example quark masses, mixing angles, etc... The Standard Model cannot explain the smallness of the weak scale compared to the GUT or Planck scales; this is often called “the hierarchy problem.” It is believed that the CKM source of CP violation in the Standard Model is not large enough to explain the baryon asymmetry of the Universe [1]; we can also take the view that we will discover additional large unexpected effects in b and/or c decays. Finally, gravity is not incorporated. John Ellis said “My personal interest in CP violation is driven by the search for physics beyond the Standard Model” [2].

We must realize that *all* our current measurements are a combination of Standard Model and New Physics; any proposed models must satisfy current constraints. Since the Standard Model tree level diagrams are probably large, let's consider them a background to New Physics. Therefore loop diagrams and CP violation are the best places to see New Physics. The most important current constraints on New Physics models are

- The neutron electric dipole moment, $d_N < 6.3 \times 10^{-26}$ e-cm.
- $\mathcal{B}(b \rightarrow s\gamma) = (3.23 \pm 0.42) \times 10^{-4}$ and $\mathcal{B}(b \rightarrow s\ell^+\ell^-) < 4.2 \times 10^{-5}$.
- CP violation in K_L decay, $\epsilon_K = (2.271 \pm 0.017) \times 10^{-3}$.
- B^0 mixing parameter $\Delta m_d = (0.487 \pm 0.014) \text{ ps}^{-1}$.

II. GENERIC TESTS FOR NEW PHYSICS

We can look for New Physics either in the context of specific models or more generically, for deviations from the Standard Model expectation.

One example is to examine the rare decays $B \rightarrow K\ell^+\ell^-$ and $B \rightarrow K^*\ell^+\ell^-$ for branching ratios and polarizations. According to Greub et al. [3], “Especially the decay into K^* yields a wealth of new information on the form of the new interactions since the Dalitz plot is sensitive to subtle interference effects.”

Another important tactic is to test for inconsistencies in Standard Model predictions independent of specific non-standard models. The unitarity of the CKM matrix allows us to construct six relationships. These may be thought of as triangles in the complex plane shown in Fig. 1.

All six of these triangles can be constructed knowing four and only four independent angles [4][5][6]. These are defined as:

$$\beta = \arg\left(-\frac{V_{tb}V_{td}^*}{V_{cb}V_{cd}^*}\right), \quad \gamma = \arg\left(-\frac{V_{ub}^*V_{ud}}{V_{cb}^*V_{cd}}\right), \quad (1)$$

$$\chi = \arg\left(-\frac{V_{cs}^*V_{cb}}{V_{ts}^*V_{tb}}\right), \quad \chi' = \arg\left(-\frac{V_{ud}^*V_{us}}{V_{cd}^*V_{cs}}\right). \quad (2)$$

(α can be used instead of γ or β .) Two of the phases β and γ are probably large while χ is estimated to be small ≈ 0.02 , but measurable, while χ' is likely to be much smaller.

It has been pointed out by Silva and Wolfenstein [4] that measuring only angles may not be sufficient to detect new physics. For example, suppose there is new physics that arises in

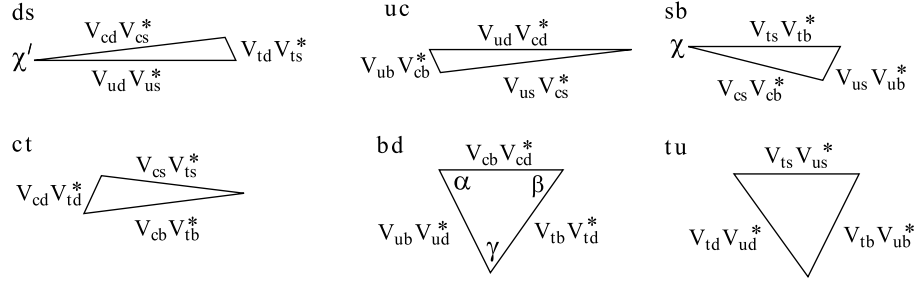


FIG. 1: The six CKM triangles. The bold labels, e.g. **ds** refer to the rows or columns used in the unitarity relationship. The angles defined in equation (1) are also shown.

$B^0 - \overline{B}^0$ mixing. Let us assign a phase θ to this new physics. If we then measure CP violation in $B^0 \rightarrow J/\psi K_s$ and eliminate any Penguin pollution problems in using $B^0 \rightarrow \pi^+ \pi^-$, then we actually measure $2\beta' = 2\beta + \theta$ and $2\alpha' = 2\alpha - \theta$. So while there is new physics, we miss it, because $2\beta' + 2\alpha' = 2\alpha + 2\beta$ and $\alpha' + \beta' + \gamma = 180^\circ$.

A. A Critical Check Using χ

The angle χ , defined in equation 1, can be extracted by measuring the time dependent CP violating asymmetry in the reaction $B_s \rightarrow J/\psi \eta^{(\prime)}$, or if one's detector is incapable of quality photon detection, the $J/\psi \phi$ final state can be used. However, in this case there are two vector particles in the final state, making this a state of mixed CP, requiring a time-dependent angular analysis to extract χ , that requires large statistics.

Measurements of the magnitudes of CKM matrix elements all come with theoretical errors. Some of these are hard to estimate. The best measured magnitude is that of $\lambda = |V_{us}/V_{ud}| = 0.2205 \pm 0.0018$. Silva and Wolfenstein [4] [5] show that the Standard Model can be checked in a profound manner by seeing if:

$$\sin \chi = \left| \frac{V_{us}}{V_{ud}} \right|^2 \frac{\sin \beta \sin \gamma}{\sin(\beta + \gamma)}. \quad (3)$$

Here the precision of the check will be limited initially by the measurement of $\sin \chi$, not of λ . This check can reveal new physics, even if other measurements have not shown any anomalies. Other relationships to check include:

$$\sin \chi = \left| \frac{V_{ub}}{V_{cb}} \right|^2 \frac{\sin \gamma \sin(\beta + \gamma)}{\sin \beta}, \quad \sin \chi = \left| \frac{V_{td}}{V_{ts}} \right|^2 \frac{\sin \beta \sin(\beta + \gamma)}{\sin \gamma}. \quad (4)$$

The astute reader will have noticed that these two equations lead to the non-trivial relationship:

$$\sin^2 \beta \left| \frac{V_{td}}{V_{ts}} \right|^2 = \sin^2 \gamma \left| \frac{V_{ub}}{V_{cb}} \right|^2. \quad (5)$$

This constrains these two magnitudes in terms of two of the angles. Note, that it is in principle possible to determine the magnitudes of $|V_{ub}/V_{cb}|$ and $|V_{td}/V_{ts}|$ without model dependent errors by measuring β , γ and χ accurately. Alternatively, β , γ and λ can be used to give a much more precise value than is possible at present with direct methods. For example, once β and γ are known $|V_{ub}/V_{cb}|^2 = \lambda^2 \sin^2 \beta / \sin^2(\beta + \gamma)$.

Table I lists the most important physics quantities and the decay modes that can be used to measure them. The necessary detector capabilities include the ability to collect purely hadronic final states labeled here as “Hadron Trigger,” the ability to identify charged hadrons labeled as “ $K\pi$ sep,” the ability to detect photons with good efficiency and resolution and excellent time resolution required to analyze rapid B_s oscillations. Measurements of $\cos(2\phi)$ can eliminate 2 of the 4 ambiguities in ϕ that are present when $\sin(2\phi)$ is measured.

TABLE I: Required CKM Measurements for b 's

Physics Quantity	Decay Mode	Hadron Trigger	$K\pi$ sep	γ det	Decay time σ
$\sin(2\alpha)$	$B^0 \rightarrow \rho\pi \rightarrow \pi^+\pi^-\pi^0$	✓	✓	✓	
$\cos(2\alpha)$	$B^0 \rightarrow \rho\pi \rightarrow \pi^+\pi^-\pi^0$	✓	✓	✓	
$\text{sign}(\sin(2\alpha))$	$B^0 \rightarrow \rho\pi$ & $B^0 \rightarrow \pi^+\pi^-$	✓	✓	✓	
$\sin(\gamma)$	$B_s \rightarrow D_s^\pm K^\mp$	✓	✓		✓
$\sin(\gamma)$	$B^- \rightarrow \bar{D}^0 K^-$	✓	✓		
$\sin(\gamma)$	$B^0 \rightarrow \pi^+\pi^-$ & $B_s \rightarrow K^+K^-$	✓	✓		✓
$\sin(2\chi)$	$B_s \rightarrow J/\psi\eta', J/\psi\eta$			✓	✓
$\sin(2\beta)$	$B^0 \rightarrow J/\psi K_s$				
$\cos(2\beta)$	$B^0 \rightarrow J/\psi K^0, K^0 \rightarrow \pi\ell\nu$		✓		
$\cos(2\beta)$	$B^0 \rightarrow J/\psi K^{*0}$ & $B_s \rightarrow J/\psi\phi$				
x_s	$B_s \rightarrow D_s^+\pi^-$	✓			✓
$\Delta\Gamma$ for B_s	$B_s \rightarrow J/\psi\eta', D_s^+\pi^-, K^+K^-$	✓	✓	✓	✓

B. Finding Inconsistencies

Another interesting way of viewing the physics was given by Peskin [7]. Non-Standard Model physics would show up as discrepancies among the values of (ρ, η) derived from independent determinations using CKM magnitudes ($|V_{ub}/V_{cb}|$ and $|V_{td}/V_{ts}|$), or B_d^0 mixing (β and α), or B_s mixing (χ and γ).

C. Required Measurements Involving β

Besides a more precise measurement of $\sin 2\beta$ we need to resolve the ambiguities. There are two suggestions on how this may be accomplished. Kayser [8] shows that time dependent measurements of the final state $J/\psi K^0$, where $K^0 \rightarrow \pi\ell\nu$, give a direct measurement of $\cos(2\beta)$ and can also be used for CPT tests. Another suggestion is to use the final state $J/\psi K^{*0}$, $K^{*0} \rightarrow K_S\pi^0$, and to compare with $B_s \rightarrow J/\psi\phi$ to extract the sign of the strong interaction phase shift assuming SU(3) symmetry, and thus determine $\cos(2\beta)$ [9].

D. Required Measurements Involving α and γ

It is well known that $\sin(2\beta)$ can be measured without problems caused by Penguin processes using the reaction $B^0 \rightarrow J/\psi K_s$. The simplest reaction that can be used to measure $\sin(2\alpha)$

is $B^0 \rightarrow \pi^+\pi^-$. This reaction can proceed via both the Tree and Penguin diagrams shown in Fig. 2.

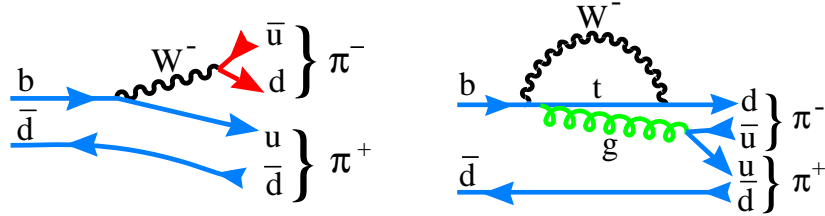


FIG. 2: Decay diagrams for $\bar{B}^0 \rightarrow \pi^+\pi^-$. (left) Via tree level V_{ub} moderated decay. (right) Via a Penguin process.

Current measurements show a large Penguin component. The ratio of Penguin *amplitude* to Tree *amplitude* in the $\pi^+\pi^-$ channel is about 15% in magnitude. Thus the effect of the Penguin must be determined in order to extract α . The only model independent way of doing this was suggested by Gronau and London, but requires the measurement of $B^\mp \rightarrow \pi^\mp \pi^0$ and $B^0 \rightarrow \pi^0 \pi^0$, the latter being rather daunting.

There is however, a theoretically clean method to determine α . The interference between Tree and Penguin diagrams can be exploited by measuring the time dependent CP violating effects in the decays $B^0 \rightarrow \rho\pi \rightarrow \pi^+\pi^-\pi^0$ as shown by Snyder and Quinn [10].

The $\rho\pi$ final state has many advantages. First of all, it has been seen with a relatively large rate. The branching ratio for the $\rho^0\pi^+$ final state as measured by CLEO is $(1.5 \pm 0.5 \pm 0.4) \times 10^{-5}$, and the rate for the neutral B final state $\rho^\pm\pi^\mp$ is $(3.5^{+1.1}_{-1.0} \pm 0.5) \times 10^{-5}$, while the $\rho^0\pi^0$ final state is limited at 90% confidence level to $< 5.1 \times 10^{-6}$ [11]. (BABAR [12] measures $\mathcal{B}(B^0 \rightarrow \rho^\pm\pi^\mp)$ as $(28.9 \pm 5.4 \pm 4.3) \times 10^{-6}$.) These measurements are consistent with some theoretical expectations [13]. Furthermore, the associated vector-pseudoscalar Penguin decay modes have conquerable or smaller branching ratios. Secondly, since the ρ is spin-1, the π spin-0 and the initial B also spinless, the ρ is fully polarized in the (1,0) configuration, so it decays as $\cos^2\theta$, where θ is the angle of one of the ρ decay products with the other π in the ρ rest frame. This causes the periphery of the Dalitz plot to be heavily populated, especially the corners. A sample Dalitz plot is shown in Fig. 3. This kind of distribution is good for maximizing the interferences, which helps minimize the error. Furthermore, little information is lost by excluding the Dalitz plot interior, a good way to reduce backgrounds.

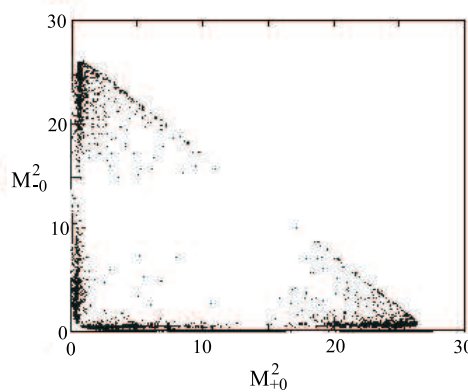


FIG. 3: The Dalitz plot for $B^0 \rightarrow \rho\pi \rightarrow \pi^+\pi^-\pi^0$ from Snyder and Quinn.

To estimate the required number of events Snyder and Quinn preformed an idealized analysis that showed that a background-free, flavor-tagged sample of 1000 to 2000 events was sufficient.

The 1000 event sample usually yields good results for α , but sometimes does not resolve the ambiguity. With the 2000 event sample, however, they always succeeded.

This technique not only finds $\sin(2\alpha)$, it also determines $\cos(2\alpha)$, thereby removing two of the remaining ambiguities. The final ambiguity can be removed using the CP asymmetry in $B^0 \rightarrow \pi^+\pi^-$ and a theoretical assumption [14].

Several model dependent methods using the light two-body pseudoscalar decay rates have been suggested for measuring γ . The basic idea in all these methods can be summarized as follows: $B^0 \rightarrow \pi^+\pi^-$ has the weak decay phase γ . In order to reproduce the observed suppression of the decay rate for $\pi^+\pi^-$ relative to $K^\pm\pi^\mp$ we require a large negative interference between the Tree and Penguin amplitudes. This puts γ in the range of 90° . There is a great deal of theoretical work required to understand rescattering, form-factors etc... We are left with several ways of obtaining model dependent limits, due to Fleischer and Mannel [15], Neubert and Rosner [16], Fleischer and Buras [17], and Beneke *et al.* [18]. The latter make a sophisticated model of QCD factorization and apply corrections. Fig. 4 shows values of γ that can be found in their framework, once better data are obtainable.

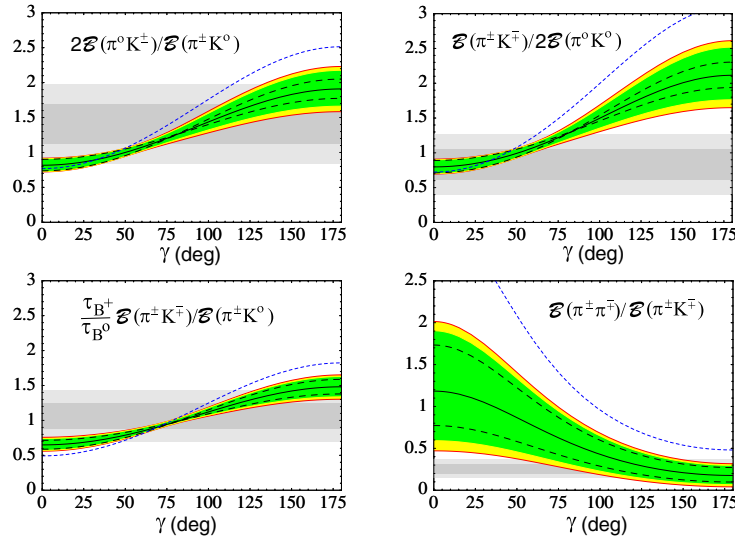


FIG. 4: Model predictions from Beneke *et al.* as a function of the indicated rate ratios. The dotted curve shows the predictions from naive factorization. The curved bands show the total model uncertainties where the inner band comes from theoretical input uncertainties, while the outer band allows for errors to corrections on the theory. The specific sensitivity to $|V_{ub}|$ is showed as the dashed curves. The gray bands show the current data with a 1σ error while the lighter bands are at 2σ .

In fact, it may be easier to measure γ than α in a model independent manner. There have been two methods suggested.

(1) Time dependent flavor tagged analysis of $B_s \rightarrow D_s^\pm K^\mp$. This is a direct model independent measurement [19]. Here the Cabibbo suppressed V_{ub} decay interferes with a somewhat less suppressed V_{cb} decay via B_s mixing as illustrated in Fig. 5 (left). Even though we are not dealing with CP eigenstates here there are no hadronic uncertainties, though there are ambiguities.

(2) Measure the rate differences between $B^- \rightarrow \bar{D}^0 K^-$ and $B^+ \rightarrow D^0 K^+$ in two different D^0 decay modes such as $K^-\pi^+$ and K^+K^- . This method makes use of the interference between the tree and doubly-Cabibbo suppressed decays of the D^0 , and does not depend on any theoretical modeling [20][21]. See Fig. 5 (right).

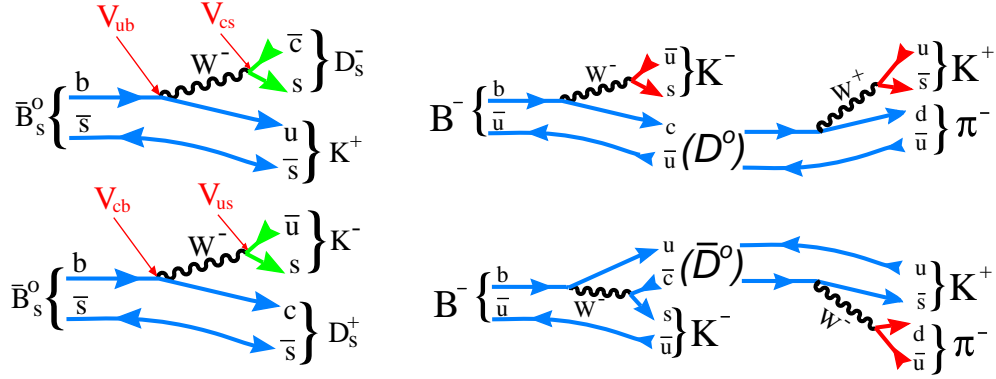


FIG. 5: (left) The two diagram diagrams for $B_s \rightarrow D_s^\pm K^\mp$ that interfere via B_s mixing. (right) The two interfering decay diagrams for $B^- \rightarrow \bar{D}^0 K^-$ where one is a $b \rightarrow u$ transition and the other a doubly-Cabibbo suppressed decay.

E. New Physics Tests in Specific Models

F. Supersymmetry

Supersymmetry is a kind of super-model. The basic idea is that for every fundamental fermion there is a companion boson and for every boson there is a companion fermion. There are many different implementations of couplings in this framework [22]. In the most general case we pick up 80 new constants and 43 new phases. This is clearly too many to handle so we can try to see things in terms of simpler implementations. In the minimum model (MSSM) we have only two new fundamental phases. One, θ_D , would arise in B^0 mixing and the other, θ_A , would appear in B^0 decay. A combination would generate CP violation in D^0 mixing, call it $\phi_{K\pi}$ when the $D^0 \rightarrow K^- \pi^+$ [23]. Table II shows the CP asymmetry in three different processes in the Standard Model and the MSSM.

TABLE II: CP Violating Asymmetries in the Standard Model and the MSSM.

Process	Standard Model	New Physics
$B^0 \rightarrow J/\psi K_s$	$\sin 2\beta$	$\sin 2(\beta + \theta_D)$
$B^0 \rightarrow \phi K_s$	$\sin 2\beta$	$\sin 2(\beta + \theta_D + \theta_A)$
$D^0 \rightarrow K^- \pi^+$	0	$\sim \sin \phi_{K\pi}$

Two direct effects of New Physics are clear here. First of all, the difference in CP asymmetries between $B^0 \rightarrow J/\psi K_s$ and $B^0 \rightarrow \phi K_s$ would show the phase ϕ_A . Secondly, there would be finite CP violation in $D^0 \rightarrow K^- \pi^+$ where none is expected in the Standard Model.

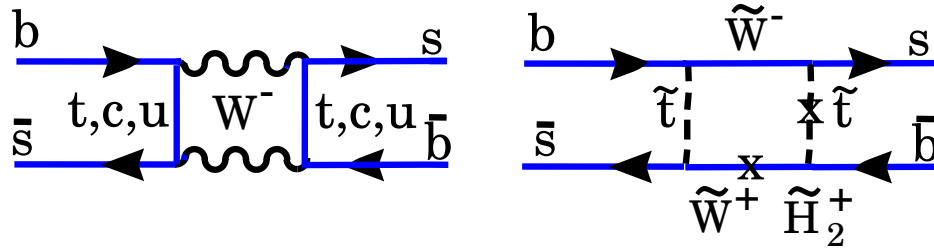
Manifestations of specific SUSY models lead to different patterns. Table III shows the expectations for some of these models in terms of these variables and the neutron electric dipole moment d_N ; see [23] for details. Note, that “Approximate CP” has already been ruled out by the measurements of $\sin 2\beta$.

In the context of the MSSM there will be significant contributions to B_s mixing, and the CP asymmetry in the charged decay $B^\pm \rightarrow \phi K^\mp$. The contribution to B_s mixing significantly enhances the CP violating asymmetry in modes such as $B_s \rightarrow J/\psi \eta$. (Recall the CP asymmetry in this mode is proportional to $\sin 2\chi$ in the Standard Model.) The Standard Model

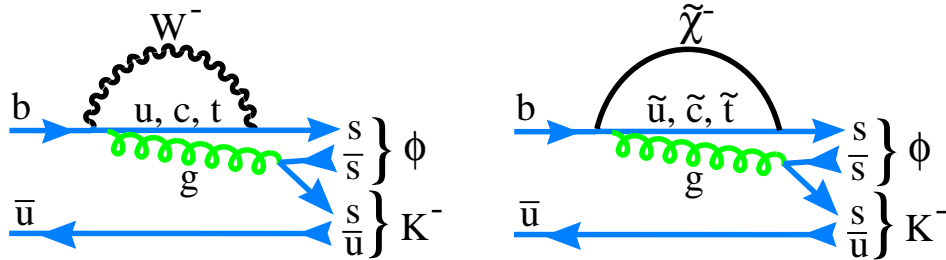
TABLE III: Some SUSY Predictions.

Model	$d_N \times 10^{-25}$	θ_D	θ_A	$\sin \phi_{K\pi}$
Standard Model	$\leq 10^{-6}$	0	0	0
Approx. Universality	$\geq 10^{-2}$	$\mathcal{O}(0.2)$	$\mathcal{O}(1)$	0
Alignment	$\geq 10^{-3}$	$\mathcal{O}(0.2)$	$\mathcal{O}(1)$	$\mathcal{O}(1)$
Heavy squarks	$\sim 10^{-1}$	$\mathcal{O}(1)$	$\mathcal{O}(1)$	$\mathcal{O}(10^{-2})$
Approx. CP	$\sim 10^{-1}$	$-\beta$	0	$\mathcal{O}(10^{-3})$

and MSSM diagrams are shown in Fig. 6. The expected CP asymmetry in the MSSM is $\approx \sin \phi_\mu \cos \phi_A \sin(\Delta m_{st})$, which is approximately 10 times the expected value in the Standard Model [24].

FIG. 6: The Standard Model (left) and MSSM (right) contributions to B_s^0 mixing.

We observed that a difference between CP asymmetries in $B^0 \rightarrow J/\psi K_s$ and ϕK_s arises in the MSSM due to a CP asymmetry in the decay phase. It is possible to observe this directly by looking for a CP asymmetry in $B^\pm \rightarrow \phi K^\mp$. The Standard Model and MSSM diagrams are shown in Fig. 7. Here the interference of the two diagrams provides the CP asymmetry. The predicted asymmetry is equal to $(M_W/m_{squark})^2 \sin \phi_\mu$ in the MSSM, where m_{squark} is the relevant squark mass [24].

FIG. 7: The Standard Model (left) and MSSM (right) contributions to $B^- \rightarrow \phi K^-$.

The ϕK and ϕK^* final states have been observed, first by CLEO [25] and subsequently by BABAR [26]. The average branching ratio is $\mathcal{B}(B^- \rightarrow \phi K^-) = (6.8 \pm 1.3) \times 10^{-6}$ showing that in principle large samples can be acquired especially at hadronic machines.

G. Other New Physics Models

There are many other specific models that predict New Physics in b decays. I list here a few of these with a woefully incomplete list of references, to give a flavor of what these models predict.

- *Two Higgs and Multi-Higgs Doublet Models*- They predict large effects in ϵ_K and CP violation in $D^0 \rightarrow K^- \pi^+$ with only a few percent effect in B^0 [23]. Expect to see 1-10% CP violating effects in $b \rightarrow s\gamma$ [27].
- *Left-Right Symmetric Model*- Contributions compete with or even dominate over Standard Model contributions to B_d and B_s mixing. This means that CP asymmetries into CP eigenstates could be substantially different from the Standard Model prediction [23].
- *Extra Down Singlet Quarks*- Dramatic deviations from Standard Model predictions for CP asymmetries in b decays are not unlikely [23].
- *FCNC Couplings of the Z boson*- Both the sign and magnitude of the decay leptons in $B \rightarrow K^* \ell^+ \ell^-$ carry sensitive information on new physics. Potential effects are on the order of 10% compared to an entirely negligible Standard Model asymmetry of $\sim 10^{-3}$ [28]. These models also predict a factor of 20 enhancement of $b \rightarrow d \ell^+ \ell^-$ and could explain a low value of $\sin 2\beta$ [29].
- *Noncommutative Geometry*- If the geometry of space time is noncommutative, i.e. $[x_\mu, x_\nu] = i\theta_{\mu\nu}$, then CP violating effects may be manifest at a low energy. For a scale < 2 TeV there are comparable effects to the Standard Model [30].
- *MSSM without new flavor structure*- Can lead to CP violation in $b \rightarrow s\gamma$ of up to 5% [31]. Ali and London propose [32] that the Standard Model formulas are modified by Supersymmetry as

$$\Delta m_d = \Delta m_d(\text{SM}) \left[1 + f \left(m_{\chi_2^\pm}, m_{\tilde{t}_R}, m_{H^\pm}, \tan\beta \right) \right] \quad (6)$$

$$\Delta m_s = \Delta m_s(\text{SM}) \left[1 + f \left(m_{\chi_2^\pm}, m_{\tilde{t}_R}, m_{H^\pm}, \tan\beta \right) \right] \quad (7)$$

$$|\epsilon_K| = \frac{G_F^2 f_K^2 M_K M_W^2}{6\sqrt{2}\pi^2 \Delta M_K} B_K (A^2 \lambda^6 \bar{\eta}) [y_c (\eta_{ct} f_3(y_c, y_t) - \eta_{cc}) + \eta_{tt} y_t f_s(y_t) \left[1 + f \left(m_{\chi_2^\pm}, m_{\tilde{t}_R}, m_{H^\pm}, \tan\beta \right) \right] A^2 \lambda^4 (1 - \bar{\rho})] \quad , \quad (8)$$

where $\Delta m(\text{SM})$ refers to the Standard Model formula and the expression for $|\epsilon_K|$ would be the Standard Model expression if f were set equal to zero. Ali and London show that it is reasonable to expect that $0.8 > f > 0.2$ so since the CP violating angles will not change from the Standard Model, determining the value of (ρ, η) using the magnitudes $\Delta m_s/\Delta m_d$ and $|\epsilon_K|$ will show an inconsistency with values obtained using other magnitudes and angles.

- *Extra Dimensions*- We are beginning to see let us expect that $0.8 > f > 0.2$ so since the CP violating angles will not change from the Standard Model, determining the value of (ρ, η) using the magnitudes $\Delta m_s/\Delta m_d$ and $|\epsilon_K|$ will papers predicting b decay phenomena when the world has extra dimensions. See [33].

I close this section with a quote from Masiero and Vives [34]: “The relevance of SUSY searches in rare processes is not confined to the usually quoted possibility that indirect searches can arrive ‘first’ in signaling the presence of SUSY. Even after the possible direct observation of SUSY particles, the importance of FCNC and CP violation in testing SUSY remains of utmost relevance. They are and will be complementary to the Tevatron and LHC establishing low energy supersymmetry as the response to the electroweak breaking puzzle.”

I agree, except that I would replace “SUSY” with “New Physics.”

III. CONCLUSIONS

It is clear that precision studies of b decays can bring a wealth of information to bear on new physics, that probably will be crucial in sorting out anything seen at the LHC. This is possible because we do expect to have data samples large enough to test these ideas from existing and approved experiments. In Table IV I show the expected rates in BTeV for one year of running (10^7 s) and an e^+e^- B -factory operating at the $\Upsilon(4S)$ with a total accumulated sample of 500 fb^{-1} , about what is expected around 2006. (LHCb numbers are the same order of magnitude as the BTeV numbers for many of the modes.)

Acknowledgements

This work was supported by the U. S. National Science Foundation. My colleagues at BTeV and CLEO contributed much to my understanding. In particular I thank, M. Artuso, J. Butler and T. Skwarnicki.

TABLE IV: Comparison of BTeV and B -factory Yields on Different Time Scales.

Mode	BTeV ($10^7 s$)			B -factory (500 fb^{-1})		
	Yield	Tagged [†]	S/B	Yield	Tagged [†]	S/B
$B_s \rightarrow J/\psi \eta^{(\prime)}$	22000	2200	>15			
$B^- \rightarrow \phi K^-$	11000	11000	>10	700	700	4
$B^0 \rightarrow \phi K_s$	2000	200	5.2	250	75	4
$B^0 \rightarrow K^{*0} \mu^+ \mu^-$	4400	4400	11	~50	~50	?
$D^{*+} \rightarrow \pi^+ D^0; D^0 \rightarrow K^- \pi^+$	$\sim 10^8$	$\sim 10^8$	large	8×10^5	8×10^5	large

[†] Tagged here means that the initial flavor of the B is determined.

-
- [1] M. B. Gavela, P. Hernández, J. Orloff and O. Pène O, *Mod. Phys. Lett. A* **9**, 795 (1993) [hep-ph/9312215].
 - [2] J. Ellis, Nucl. Phys. Proc. Suppl. **99A**, 331 (2000) [hep-ph/0011396].
 - [3] F. J. Greub, A. Ioannissian and D. Wyler, *Phys. Lett. B* **346**, 149 (1995) [hep-ph/9408382].
 - [4] J. P. Silva, L. Wolfenstein, *Phys. Rev. D* **55**, 5331 (1997) [hep-ph/9610208].
 - [5] R. Aleksan, B. Kayser and D. London, *Phys. Rev. Lett.* **73**, 18 (1994) [hep-ph/9403341].
 - [6] I. I. Bigi and A. I. Sanda, “On the Other Five KM Triangles,” [hep-ph/9909479].
 - [7] M. E. Peskin, “Theoretical Summary Lecture for EPS HEP99,” to appear in proceedings [hep-ph/0002041].
 - [8] B. Kayser, “Cascade Mixing and the CP-Violating Angle Beta,” [hep-ph/9709382]. Previous work in this area was done by Y. Azimov, *Phys. Rev. D* **42** (1990) 3705.
 - [9] A. Dighe, I. Dunietz and R. Fleischer, *Phys. Lett. B* **433**, 1998 (147) [hep-ph/9804254].
 - [10] A. E. Snyder and H. R. Quinn, *Phys. Rev. D* **48** (1993) 2139.
 - [11] Y. Gao and F. Würthwein, CLEO preprint [hep-ex/9904008].
 - [12] M. Bona, BABAR preprint BABAR-CONF-01/71, SLAC-PUB-9045 [hep-ex/0111017].
 - [13] A. Ali, G. Kramer, and C.D. Lu, *Phys. Rev. D* **59**, 014005 (1999) [hep-ph/9805403].
 - [14] Y. Grossman and H. R. Quinn, *Phys. Rev. D* **56**, 7259 (1997) [hep-ph/9705356].
 - [15] R. Fleischer and T. Mannel, *Phys. Rev. D* **57**, 2752 (1998) [hep-ph/9704423].
 - [16] M. Neubert and J. L. Rosner, *Phys. Rev. Lett.* **81**, 5076 (1998) [hep-ph/9809311].
 - [17] A. J. Buras and R. Fleischer, “Constraints on γ and Strong Phases from $B \rightarrow \pi K$ Decays,” presented at ICHEP 2000, Osaka, Japan, July 2000. To appear in the Proceedings [hep-ph/0008298].
 - [18] M. Beneke, G. Buchalla, M. Neubert and C. T. Sachrajda, “QCD factorization for $B \rightarrow \pi K$ decays,” Contribution to ICHEP 2000, July 2000, Osaka, Japan, to appear in the Proceedings [hep-ph/0007256].
 - [19] D. Du, I. Dunietz and Dan-di Wu, *Phys. Rev. D* **34**, 3414 (1986); R. Aleksan, I. Dunietz, and B. Kayser, *Z. Phys. C* **54**, 653 (1992); R. Aleksan, A. Le Yaouanc, L. Oliver, O. Pène and J.-C. Raynal, *Z. Phys. C* **67**, 251 (1995) [hep-ph/9407406].
 - [20] D. Atwood, I. Dunietz and A. Soni, *Phys. Rev. Lett.* **78**, 3257 (1997).
 - [21] M. Gronau and D. Wyler, *Phys. Lett. B* **265**, 172 (1991).
 - [22] A. Masiero and O. Vives, “New Physics Behind the Standard Model’s Door?,” Int. School on Subnuclear Physics, Erice, Italy, 1999 [hep-ph/0003133].
 - [23] Y. Nir, “CP Violation In and Beyond the Standard Model,” IASSNS-HEP-99-96 [hep-ph/9911321] (1999).
 - [24] I. Hinchliff and N. Kersting, “Constraining CP Violating Phases of the MSSM,” *Phys. Rev. D* **63**, 015003 (2001) [hep-ph/0003090].
 - [25] R. A. Briere et al., *Phys. Rev. Lett.*, **86**, 3718 (2001) [hep-ex/0101032].
 - [26] B. Aubert et al., , *Phys. Rev. Lett.*, **87**, 151801 (2001) [hep-ex/0105001].
 - [27] L. Wolfenstein and Y.L. Wu, *Phys. Rev. Lett.* **74**, 2809 (1994) [hep-ph/9410253].
 - [28] G. Buchalla, G. Hiller, and G. Isidori, *Phys. Rev. D* **63**, 014015 (2000) [hep-ph/0006136].
 - [29] G. Barenboim, F. J. Botella, and O. Vives O, 2001a, *Phys. Rev. D* **64**, 015007 (2001) [hep-ph/0012197].
 - [30] I. Hinchliff and N. Kersting, “CP Violation from Noncommutative Geometry,” LBNL-47750 [hep-ph/0104137].
 - [31] A. Bartl, et al., *Phys. Rev. D* **64**, 076009 (2001) [hep-ph/0103324].
 - [32] A. Ali, G. Kramer and C. D. Lu, *Phys. Rev. D* **59**, 014005 (1999) [hep-ph/9805403].

- [33] K. Agashe, N. G. Deshpande and G. H. Wu, “Universal Extra Dimensions and $b \rightarrow s\gamma$,” *Phys. Lett.* **B 514**, 309 (2001) [hep-ph/0105084]; G. Barenboim, F. J. Botella and O. Vives, “Constraining Models With Vector-Like Fermions from FCNC in K and B Physics,” *Nucl. Phys.* **B 613**, 285 (2001) [hep-ph/01050306]; G. C. Branco, A. de Gouvea and M. N. Rebelo, “Split Fermions in Extra Dimensions and CP Violation,” *Phys. Lett.* **B 506**, 115 (2001) [hep-ph/0012289]; D. Chang, W. Y. Keung and R. N. Mohapatra, “Models for Geometric CP Violation With Extra Dimensions,” *Phys. Lett.* **B 515**, 431 (2001) [hep-ph/0105177]; J. Papavassiliou and A. Santamaria, “Extra Dimensions at the One Loop Level: $Z \rightarrow b\bar{b}$ and $B - \bar{B}$ Mixing,” *Phys. Rev.* **D 63**, 016002 (2001) [hep-ph/016002].
- [34] A. Masiero and O. Vives, New Physics in CP Violation Experiments, *Ann. Rev. of Nucl. & Part. Science* **51**, (2001) [hep-ph/0104027].