Signals of NP in exclusive Radiative B-decays

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Outline: The incredible power of Radiative B's

1) Rate for b -> s …over a decade of constrainig NP!

2) Rate for b -> d (excl. and incl.) for $|V_{td}|/V_{ts}|$

3) Dir CP b ->s and b ->d in SM and extensions; valueable tests of SM

4) Mixing induced & dir. CP clean tests of SM using exclusive B-decays…

PRIMARY FOCUS

a) ags(97)…B -> V γ

b) aghsl…B -> P_1 P_2 γ ;enhanced sensitivity to NP

c) aghsII…B->PVγ; SM pollution drastically reduced

5) Summary and Outlook

REMINDER: $(\varphi_1, \varphi_2, \varphi_3) = (\beta, \alpha, \gamma)$

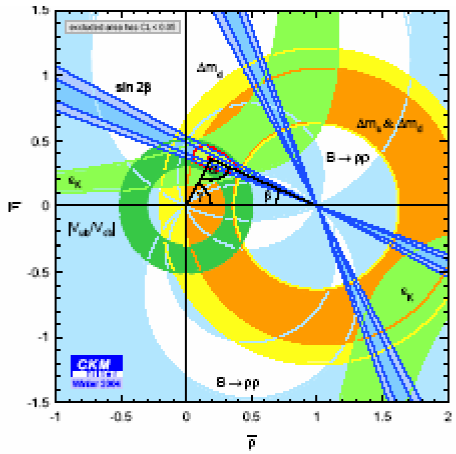
Twin Problems of SM

- ***Hierarchy Problem*** → **strongly suggests threshold for NP cannot be too far from the EW scale**
- ***Coincidence Problem*** → **experimental searches apparently show no sign of NP**
- **A possible resolution: signals are hiding beneath the error bars**

ï$_K$ = $10^{a\,3}$

- **Since none of the tests that have been done so far is better than around 10%, this possibility should be taken seriously.**
- **More sensitive tests are needed → requires *higher luminosities* and also improvement in our calculational prowess**

“COINCIDENCE”



Types of CP

- **CPV in Mixing (a la neutral K)**
- **CPV in interference of mixing and decays**
- **Direct CPV**
- **Uniqueness of B…In the SM – CKM paradigm implies that only in B CPVeffects are large.In K’s they are minisicule, also extremely small in charm, and vanishingly small in t-physics. Thus it is extremely important that we explore all types of CPV effects in B as that’s the only place where SM effects are expected to be largest to allow us to precisely nail down CKM-parameters**

Should 10% tests be good enough?

Vital Lessons from our past

- ***LESSON # 1: Remember ε_K***

- Its extremely important to reflect on the severe and tragic consequences if Cronin et al had decided in 1963 that O(10%) searches for ε were good enough! Imagine what an utter disaster for our field that would have been.

Note also even though CKM-CP-odd phase is O(1) (as we now know)
in the SM due to this O(1) phase only in B-physics we saw large effects…
in K (miniscule), D(very small), t(utterly negligible).

Understanding the fundamental SM parameters to accuracy only of O(10%) would leave us extremely vulnerable …..Improvement of our understanding should be our crucial HOLY GRAIL!

Lesson #2

Remember m_ν

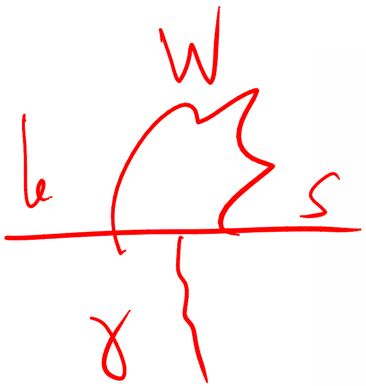
Just as there was never any good reason for $m_\nu = 0$ there is none for BSM-CP-odd phase not to exist

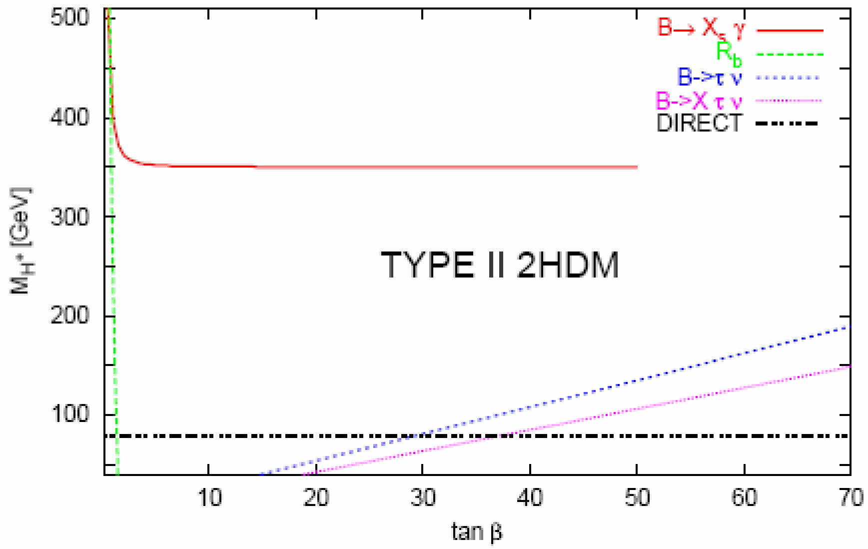
$\Delta m^2 \sim 1\,\mathrm{eV}^2$ ~ 1980 -> $\Delta m^2 \sim 10^{-4}\,\mathrm{eV}^2$ …'97

Osc. Discovered….

Similarly for BSM-CP-odd phase, we may need to look for much smaller deviations than the current O(10%)

Illustrative Examples of constraints on models from $B \to X_s \gamma$





BEATS direct COLLIDER LIMITS!

Direct and indirect lower bounds on M_{H^+} from different processes in the 2HDM of Type II as a function of $\tan\beta$. See Gambino and Misiak, hep-ph/0104034

Direct CP-asymmetry

- As testing the SM with measurement of inclusive Br is now becoming less effective improved determination of the (inclusive) direct CP asymmery is gaining in sensitivity. Recall, in the SM,
- **A_{CP} (B -> X_s γ) ~ 0.6% …….SM**
- **BaBar ($89X10^6$) =0.025+-0.05+-0.015**
- **Belle ($152X10^6$) =0.002+-0.05+-0.030**
- **-> Precise measurement & test of SM will require ~10^{10} B's; i.e a SUPER-B-Factory**…
- **With improved measurement of A_{CP} (B -> X_s γ) should provide powerful (perhaps even better than Br) constrain on NP models**.

A_{CP} (B -> X_d γ)

- Expected to be much bigger (opp. sign)
  In principle may be accessible with fewer
  # of B's as # of B's needed scales
  $\sim Br/(A_{CP})^2$

Direc CP vidlation in Radiative B decays in and beyond the SM

Kiers,soni and Wu hep-ph/0006280 (some input from refs. below)

Model	$A_{CP}^{B\to X_s\gamma}(\%)$	$A_{CP}^{B\to X_d\gamma}(\%)$
SM	0.6	-16
2HDM (Model II)	≈ 0.6	≈ -16
3HDM	-3 to +3	-20 to +20
T2HDM	$\approx$ 0 to +0.6	$\approx$ -16 to +4
Supergravity[*]	$\approx$ -10 to +10	-(5 - 45) and (2
SUSY with squark mixing[+]	$\approx$ -15 to +15	
SUSY with R-parity violation[+*]	$\approx$ -17 to +17	

* : T. Goto et al hep-ph/9812369; M. Aoki et al, hep-ph/9811251. + : C.-K Chua et al hep-ph/9808431; Y.G.Kim et al NPB544,64(99); Kagan and Neubert,hep-ph/9803368.

Salvaging exclusive modes for precision tests

- Prior to ~97, exclusive modes remain unexploited for precision tests…
- This is quite unfortunate as experimentally exclusive modes are far more straightforward compared to inclusive ones
- Precision tests of the SM using time dependent *or* direct CP involving

- I. $B^0 \to K^*(\rho)\ \gamma$…, Atwood,Gronau and A.S.;PRL'97

- II. $B^0 \to \{K_S\pi^0(\eta',\eta),\pi\pi\ldots\}\gamma$; Atwood,Gershon,Hazumi & AS, PRD'05

- III $B^{+-0}, B_s \to \{K\phi(\omega,\rho),\eta'(\pi)\ \phi(\omega,\rho), \ldots.\}\gamma$; *Atwood,Gershon, Hazumi & AS…WIP*

Mixing Induced CP in Radiative B-decays

Key point: γ in b decays is predominantly LH whereas γ in $\bar{b}$ decays is predominantly RH

$\Rightarrow$ esp. sensitive to presence of RH currents due BSM

LO H_{eff}

In the SM TDCP in $B \to \gamma[\rho, \omega, K^*, ..] \propto m_d/m_b$ or m_s/m_b.

BSM [e.g. LRSM, SUSY...] can cause large asymmetries

See: Atwood, Gronau and A. S. PRL, '97; recent ext. to several models Chua and Hou hep-ph/0110106; Gotto et al hep-ph/0306093; Gronau and Pirjol hep-ph/0205065.. In General, (for $q = s, d$)

$$H_{eff} = -\sqrt{8} G_F \frac{e m_b}{16\pi^2} F_{\mu\nu} [\frac{1}{2} F_L^q \bar{q} \sigma^{\mu\nu} (1 + \gamma_5) b + \frac{1}{2} F_R^q \bar{q} \sigma^{\mu\nu} (1 - \gamma_5) b]$$

In the SM, $\frac{F_R^q}{F_L^q} \approx \frac{m_q}{m_b}$ Mixing induced CP asymmetry in $B - \bar{B}$ decay requires both B and $\bar{B}$ be able to decay to the same final state i.e. a state with the same photon helicity $\propto \frac{F_R^q}{F_L^q} \to m_q/m_b \to 0$.

In contrast, in a LR model as an example $\frac{F_R^q}{F_L^q}$ can be appreciably bigger as presence of RH currents $\Rightarrow m_t/m_b$ enhancement for $\frac{F_R^q}{F_L^q}$

Limitation of inclusive measurements

- Though inclusive Br (B->X_s γ)measurement provides an excellent test of the SM (now to
~10% accuracy), it is rather insensitive to
testing the presence of “forbidden” helicity
(i.e. RH photons in b-quark decays)…
- {This is because rate monitors the incoherent
sum of LH & RH}
- ***Monitoring polarization of the photon is crucial…***
- ***THIS IS WHERE heretofore unexploited exclusive radiative decays come in handy***.

Time Dependent CP Asymmetry in $B(t) \to M^0\gamma$

For a state tagged as a B rather than a $\bar{B}$ at $t = 0$ and with $CP|M^0 >= \xi|M^0 >$; with $\xi = \pm 1$:

$$\begin{aligned} A(\bar{B} \to M^0\gamma_L) &= A\cos\psi e^{i\phi_L} \ , \\ A(\bar{B} \to M^0\gamma_R) &= A\sin\psi e^{i\phi_R} \ , \\ A(B \to M^0\gamma_R) &= \xi A\cos\psi e^{-i\phi_L} \ , \\ A(B \to M^0\gamma_L) &= \xi A\sin\psi e^{-i\phi_R} \ . \end{aligned}$$

Here $tan\psi = \frac{F_R^q}{F_L^q}$ and $\phi_{L,R}$ are CP-odd weak phases. Thus, with ϕ_M as the mixing phase, $\Gamma(t) \equiv \Gamma(B(t) \to M^0\gamma)$,

$$\Gamma(t) = e^{-\Gamma t}|A|^2[1 + \xi\sin(2\psi)\sin(\phi_M - \phi_L - \phi_R)\sin(\Delta m t)] \ .$$

This leads to a time-dependent CP asymmetry,

$$A(t) \equiv \frac{\Gamma(t) - \bar{\Gamma}(t)}{\Gamma(t) + \bar{\Gamma}(t)} = \xi\sin(2\psi)\underbrace{\sin(\phi_M - \phi_L - \phi_R)}_{\text{CP-odd phase}}\sin(\Delta m t) \ .$$

QCD

Thus, in the SM:

$$\text{for } B^0 : \quad \phi_M = 2\beta ,$$
$$\text{for } B_s : \quad \phi_M = 0 , \tag{4}$$

and

$$\text{for } b \to s\gamma : \quad \sin(2\psi) \approx \frac{2m_s}{m_b} , \quad \phi_L = \phi_R \approx 0 ,$$
$$\text{for } b \to d\gamma : \quad \sin(2\psi) \approx \frac{2m_d}{m_b} , \quad \phi_L = \phi_R \approx \beta , \tag{5}$$

Cancels

Thus as illustrative examples (in the SM): USING LO H_{eff}

$$B^0 \to K^{*0}\gamma : A(t) \approx (2m_s/m_b)\sin(2\beta)\sin(\Delta m t) ,$$
$$B^0 \to \rho^0\gamma : A(t) \approx 0 ,$$
$$B_s \to \phi\gamma : A(t) \approx 0 ,$$
$$B_s \to K^{*0}\gamma : A(t) \approx -(2m_d/m_b)\sin(2\beta)\sin(\Delta m t) , \tag{6}$$

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

LRSM: $G = SU(2)_L X SU(2)_R X U(1)$

$$\begin{pmatrix} u \\ d \end{pmatrix}_{L,R}$$
$$\begin{pmatrix} \nu_e \\ e \end{pmatrix}_{L,R}$$

Many attractive features,e.g. ν mass arises naturally. Using $K_L - K_S$ mass diff one gets a rather imposing bound $m_R \geq 1.5 TeV$ [Beall, Bander and A. S'82]. Given that $m_\nu \neq 0$ (and TeV no longer such an imposing scale) model ought to reconsidered as a nice effective low energy theory. Done recently [Kiers et al, hep-ph/0205082] Taking, $< \Phi >= \begin{pmatrix} \kappa & 0 \\ 0 & \kappa' \end{pmatrix}$ and setting $|\kappa'/\kappa| = m_b/m_t$ leads to striking simplification:

$\Rightarrow$ CKM angle hierarchy arises

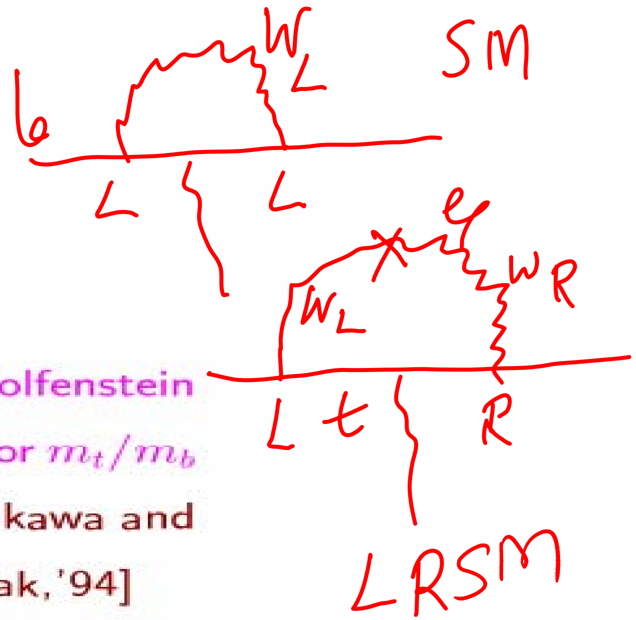
$\Rightarrow (CKM)_R = (CKM)_L$

$\Rightarrow \delta_R = \delta_L$

endowing the model with considerable predictive power.

The $W_L - W_R$ mixing is described by

$$\begin{pmatrix} W_1^+ \\ W_2^+ \end{pmatrix} = \begin{pmatrix} \cos\zeta & e^{-i\omega}\sin\zeta \\ -\sin\zeta & e^{-i\omega}\cos\zeta \end{pmatrix} \begin{pmatrix} W_L^+ \\ W_R^+ \end{pmatrix} .$$



Although ζ is small, $\leq 3 \times 10^{-3}$, [see Beall and A.S'81; Wolfenstein '84] that's considerably offset by helicity enhancement factor m_t/m_b

Radiative B-decays previously examined in LRSM [see Fujikawa and Yamada, '94; Basu, Fujikawa, Yamada,'94; Cho and Misiak,'94]

$F_L \propto F(x) + \eta_{QCD} + \zeta \frac{m_t}{m_b} e^{i\omega} \tilde{F}(x)$; $F_R \propto \zeta \frac{m_t}{m_b} e^{-i\omega} \tilde{F}(x)$. where $x = (m_t/m_{W_1})^2$, $\eta_{QCD} = -0.18$. Also Assuming $\frac{BR(B \to X_s\gamma)_{EXP}}{BR(B \to X_s\gamma)_{SM}} = 1.0 \pm 0.1 \Rightarrow |\sin(2\omega)| = 0.67$

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

$\Rightarrow$ whereas in the SM negligible asymmetries, in the LRSM can be O(50%) even if $BR(B \to X_s\gamma)$ is in very good agreement with the SM.

B-Factory Signals for a WED

(Agashe,Perez,Soni,hep-ph/0406101(PRL);0408134)

- RS1 with a WARPED EXTRA DIMENSION (WED) provides an elegant solution to the HP
- In this framework, due to warped higher-dimensional spacetime, the mass scales (i.e. flavors) in an effective 4D description depend on location in ED. Thus, e.g. the light fermions are localized near the Plank brane where the effective cut-off is much higher than TeV so that FCNC's from HDO are greatly suppressed.. The top quark,on the other hand is localized on the TeV brane so that it gets a large 4D top Yukawa coupling.

Key features of WED

- **Amielorating the Flavor Problem. This provides an understanding of hierarchy of fermion masses w/o hierarchies in fundamental 5D params. Thus "solving" the SM flavor problem.**

Flavor violations Most flavor-violating effects arise due to the violation of RS-GIM mechanism by the large top mass.

This originates from the fact that $(t,b)_L$ is localized on the TeV brane.

Basics of the framework

between the relevant models considered below. The basic set-up of our models is the RS1 framework [1]. The space time of the model is described by a slice of ADS_5 with curvature scale, $k \sim M_{Pl}$, the $4D$ Planck mass. The Planck brane is located at $\theta = 0$, where θ is the compact extra dimension coordinate. The TeV brane is located at $\theta = \pi$. The metric of RS1 can be written as:

$$(ds)^2 = \frac{1}{(kz)^2}\left[\eta_{\mu\nu} dx^\mu dx^\nu - (dz)^2\right], \tag{1}$$

where $kz = e^{kr_c\theta}$. We assume that $k\pi r_c \sim \log\left(M_{\mathrm{Pl}}/\mathrm{TeV}\right)$ to solve the hierarchy problem,

$$\left(z_h \equiv \frac{1}{k}\right) \leq z \leq \left(z_v \equiv \frac{e^{k\pi r_c}}{k}\right), \tag{2}$$

where $z_v \sim \mathrm{TeV}^{-1}$.

The gauge group of the models under study is given by [9, 10] $SU(3)_c \times SU(2)_L \times SU(2)_R \times U(1)_{B-L}$. The gauge symmetry is broken on the Planck brane down to the SM gauge group and in the TeV brane it is broken down to $SU(3)_c \times SU(2)_D \times U(1)_{B-L}$. $SU(2)_D$ is the diagonal subgroup of the two $SU(2)$'s present in the bulk.

Contrasting B-Factory Signals from WED with those from the SM

SM

	Δm_{B_s}	$S_{B_s\to\psi\phi}$	$S_{B_d\to\phi K_s}$	$Br[b\to s l^+ l^-]$	$S_{B_{d,s}\to K^*,\phi\gamma}$	$S_{B_{d,s}\to\rho,K^*\gamma}$
RS1	$\Delta m_{B_s}^{SM}[1+O(1)]$	$O(1)$	$\sin 2\beta \pm O(.2)$	$Br^{SM}[1+O(1)]$	$O(1)$	$O(1)$
SM	$\Delta m_{B_s}^{SM}$	λ_c^2	$\sin 2\beta$	Br^{SM}	$\frac{m_s}{m_b}\left(\sin 2\beta, \lambda_c^2\right)$	$\frac{m_d}{m_b}\left(\lambda_c^2, \sin 2\beta\right)$

NOT A Precise Model

Exploring flavor structure of supersymmetry breaking from rare B decays and unitarity triangle

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(Dated: 12/8/2003)

Abstract

We study effects of supersymmetric particles in various rare B decay processes as well as in the unitarity triangle analysis. We consider three different supersymmetric models, the minimal supergravity, SU(5) SUSY GUT with right-handed neutrinos, and the minimal supersymmetric standard model with U(2) flavor symmetry. In the SU(5) SUSY GUT with right-handed neutrinos, we consider two cases of the mass matrix of the right-handed neutrinos. We calculate direct and mixing-induced CP asymmetries in the $b \to s\gamma$ decay and CP asymmetry in $B_d \to \phi K_S$ as well as the B_s–$\bar{B}_s$ mixing amplitude for the unitarity triangle analysis in these models. We show that large deviations are possible for the SU(5) SUSY GUT and the U(2) model. The patterns and correlations of deviations from the standard model will be useful to discriminate the different SUSY models in future B experiments.

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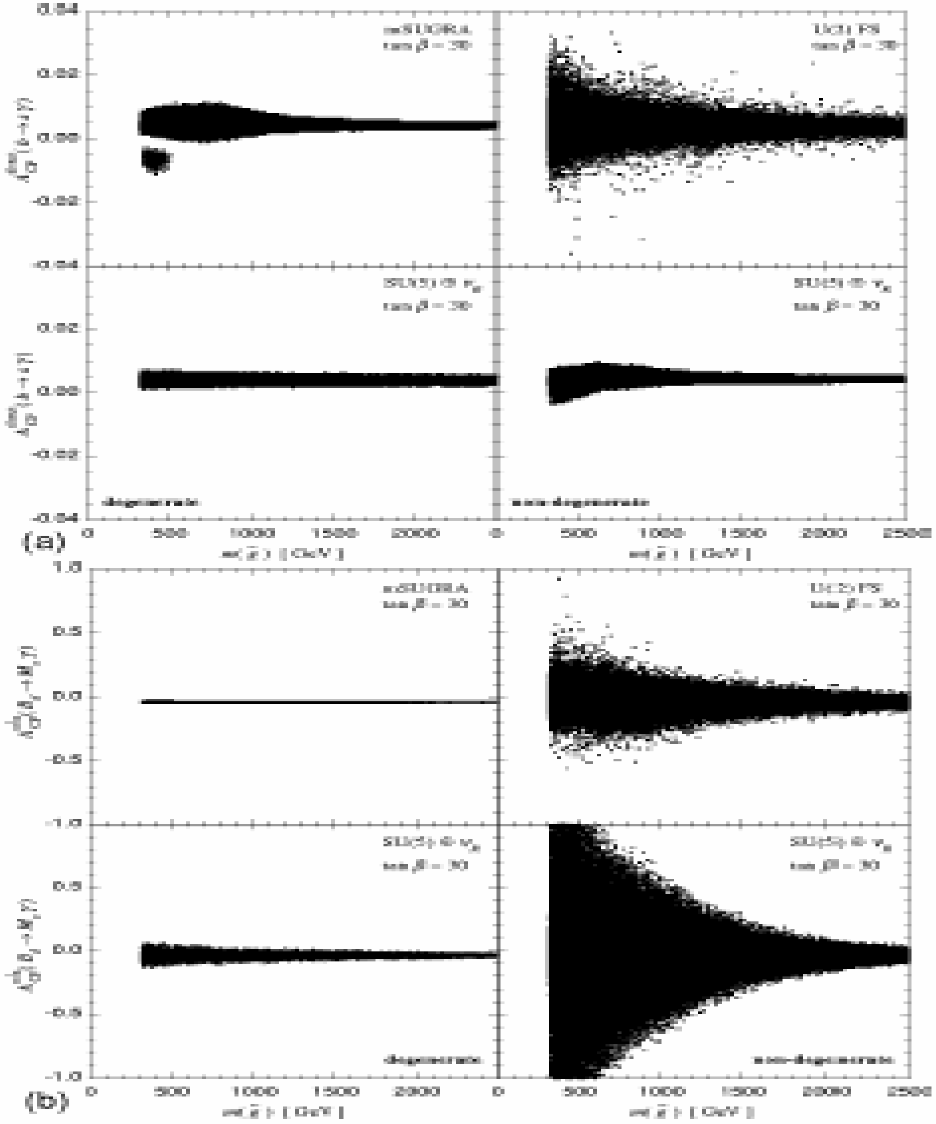
$A_{cp}\, B \to X_s \gamma$

GOTO et al



$S_{cp}(t)\, B \to K^* \gamma$

SYNERGY

FIG. 6: (a) The direct CP asymmetry in $b \to s\gamma$, and (b) the mixing-induced CP asymmetry in $B_d \to M_s \gamma$ as functions of the gluino mass.

TAMING OF the higher order corrections

- Practically decade after AGS'97observation, Grinstein, Grossman, Ligeti and Pirjol (PRD'05), examined higher order corrections and identfied a potentially important source for "wrong" helicity photons

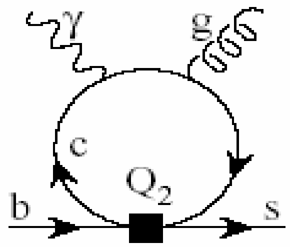


Figure 1: Dominant contribution to $b \to s\gamma g$. A second diagram with photon and gluon vertices exchanged is implied.

higher order corrections

- Their (SCET) analysis,confirming earlier work, showed these corrections are $1/m_b$ suppressed. Grinstein and Pirjol did a dimensional analysis (not an actual computation of the ME), PRD'06, claimed corrections could be rather sizeable, rendering,
- $S(t) \sim \sin 2\varphi_1 \times O(0.1)$. Since an extra gluon is involved it requires either suppression also by α_s (hard glue) or participation by (suppressed) higher Fock states…..

THEREFORE IN ALL LIKELIHOOD,GP's RESULT IS A GENEROUS OVERESTIMATE

EXPLICIT CALCULATIONS

- Already two very important explicit computations of these higher order corrections have recently become available:
- I. M.Matsumori and A. I. Sanda, PRD'06

  use pQCD and find S(t) = (3.5+-1.7)%

FOLL. TALK

II. P. Ball and R. Zwicky, hep-ph/0609037,

In another very commendable study use QCDSR and find S(t)=[2.2+-1.2(+0-1)]%

BOTH THESE STUDIES SHOW GRINSTEIN et al.

CORRECTION IS ACTUALLY VERY SMALL and they

largely substantiate original AGS estimate confirming the cleanliness of this test of the SM

Important Generalizations to AGS

- I. $B^0 \to \{K_S\pi^0(\eta',\eta),\pi\pi\ldots\}\gamma$; Atwood,Gershon,Hazumi &AS, PRD'05. Not on
  only this is a very important genralization to AGS,
  It also develops a DATA DRIVEN method for
  separating (unwanted) effects of higher order
  corrections ….thus their rendering their precise numerical value quite irrelevant

- II $B^{+-0},B_s \to \{K\varphi(\omega,\rho),\eta'(\pi)\ \varphi(\omega,\rho), \ldots.\}\gamma$; *Atwood,Gershon, Hazumi and AS…WIP*
- This generalization is now to FS that are VECTOR + Scalar (+photon)…Presence of the vector enhances the sensitivity to NP significantly and renders it essentially a PERFECT NULL TEST..(i.e. SM pollution virtually zero

NOW ALSO DIR. CP; OPENS up possibilities @
PROVIDES HIGHLY PRECISE TEST) LHCb!

Current experimental status & outlook for Super-B

- S ($K^*\gamma$) = -.32+-.36+-.05 Belle (535M B's)
- -.21+-.40+-.05 BaBar (232M B's)
- HFAG -0.28 +-.26

- SUPER-B Projections by BABAR & BELLE:
- Luminos. 10^{35} -> S ~0.07
- $5X10^{35}$ -> S~ 0.04

$B \to \gamma P_1 P_2$

- In this case there is potentially additional information from the angular distribution of the two mesons.
- There are two different cases of how the angular information enters

1) $P_1 = P_2$ e.g. $B^0 \to \pi^+\pi^-\gamma$. In this case the angular distribution gives you the information to calculate $\sin(2\psi)$ and $\sin(\varphi L + \varphi R + \varphi M)$ separately.

2) P_1 and P_2 are C eigenstates e.g. $B^0 \to K_s \pi^0 \gamma$. In this case you can obtain no additional informaton from angular distributions but you can add all the statistics (as unlike AGS K pi need not be resonant) and thereby it allows a more stringent test for NP, that is, a more accurate value of **the NP phase**

- ***In both cases the variation with E_γ tests whether dipole emission is an accurate model.***

For details see Atwood,Gershon,Hazumi & AS, PRD'05

Intuitive elaboration of why/how AGHS idea works

In AGS eq.3, strong interaction (meaning leaving out weak phase) info is in (A sin ψ).
For 3-body modes of AGHS interest, such quantities,
in general,
become functions of Dalitz variables, s_1 and cosΘ=z:
$S_1 = (p1 + p2)^2$; $S_2 = (p1 + k)^2$; $S_3 = (p2 + k)^2$
k is photon momentum, so $z = (S_2 - S_3)/ (S_2 + S_3)$.
Now for L,R helicities particle and antiparticle decays
we have 4 amplitudes so we have 4 such quantities now: f_L , f_R and similar 2 for anti-particle. Each is now a function of
s_1 and z. But QCD respects P, C and therefore for (I) the
case of $K_s \pi^0$ all 4 become identically the same upto a sign.
Thus time-dependent CP asymmetry A(t) becomes independent of Dalitz variables.
→ Expression for A(t) holds whether $K_s \pi^0$ are resonant or not or
from more than one resonance, in fact!
→ Since A(t) is independent of s1 all points in Dalitz plot can be added.
→ Significant improvement in statistics and in implementation.
Combining the data together one gets significantly improved info on
sin(ψ) sin(Φ) …the product of strong and weak phase which allows putting
lower bound on each.

AGHS for $\pi^+ \pi^- + \gamma$

This is the generalization for b -> d penguin of
the rho gamma case…Since pi+ pi- are now
antiparicles . Therefore, under C,
S2 and S3 get interchanged and as a result z->-z.
So angular distribution becomes non-trivial.
Once again, resonant and non-resonant info can
be combined but now additional angular info becomes
available to allow a separate determination of
the strong and the weak phase (up to dis. Ambig)!

Some Details

- Usual Expt. Cuts to ensure underlying 2 body $b \rightarrow s(d) + \gamma$ is necessary…that is, HARD PHOTON…in particular to discriminate against Brehmms
- Departure from that will show up as smears around a central value on the Dalitz plot
- In principle, annhilation graph is a dangerous contamination, due to enhanced emission of (LD) photons off of light (initial) quark leg (see Atwood,Blok and A.S). This is relevant only to b ->d case. Fortunately,can prove that these photons dominantly have same helicity as from the penguin. See AGHS for details.

Implications for B -> K $\acute{\eta}(\eta)\ \gamma$ of AG'HS

- AG'HS not only allows K $\pi\ \gamma$ from all

Kaonic resonances (irrespective of J^{CP}) as well as from non-resonant continuum to be included even a more important repercussion

of AG'HS is that K $\acute{\eta}(\eta)\ \gamma$ can be used.

For these reasons expect AG'HS to allow improvement over AGS (resonance only) by

factor O(2-5) so that with current O($10^{8.5}$) luminosities asymmetries O(0.20) may become accessible.

With a SBF may be able to get down to O(few%)

New physics signals in B->ΦKγ {Atwood,Gershon,Hazumi,AS;WIP}

- Presence of a Vector in the FS allows many useful observables to be constructed, in particular, triple correlations.

MAY BE Accessible to LHCb

- **A highly distinctive FS : $B^{+-} \to \Phi K^{+-} \gamma$;($\Phi \to K^+K^-$)**
- **Sizeable BR : (3.4+-0.9+-0.4)X10^{-6}**; see A.Drutskoy et al (Belle), PRL '04 {Used 90M B's}

  Babar {hep-ex/0607037; 207M B's} also finds:

I. **Br (B^{+-}) =[3.46+-.57+-.39] X10^{-6}**

II. A_{CP} (B^{+-}) =[-26.4+-14.3+-4.8]% ….**NEEDS ATTENTION**

III. Br(B^0) <2.71 X10^{-6}

Rich plethora of measureable observables in B->ΦKγ

$X_s \gamma$

$$F = |F_L|^2 + |F_R|^2 + |\overline{F}_L|^2 + |\overline{F}_R|^2$$

$$A_{CP} = \frac{|F_L|^2 + |F_R|^2 - |\overline{F}_L|^2 - |\overline{F}_R|^2}{|F_L|^2 + |F_R|^2 + |\overline{F}_L|^2 + |\overline{F}_R|^2}$$

$\phi K^{\pm} \gamma$

$$S_0 = \frac{1}{2} \frac{Im(F_L \overline{F}^*_R + F_R \overline{F}^*_L)}{|F_L|^2 + |F_R|^2 + |\overline{F}_L|^2 + |\overline{F}_R|^2}$$

$$A_{RL} = \frac{|F_R|^2 - |F_L|^2}{|F_R|^2 + |F_L|^2}$$

$$\overline{A}_{RL} = \frac{|\overline{F}_L|^2 - |\overline{F}_R|^2}{|\overline{F}_L|^2 + |\overline{F}_R|^2}$$

$$\zeta_{RL} = arg(F_R F^*_L)$$

$$\overline{\zeta}_{RL} = arg(\overline{F}^*_R \overline{F}_L)$$

$\phi K^{\pm} \gamma$

The general form of the angular disribution

$\sin\phi \propto (\vec{p}_\gamma \times \vec{p}_B) \cdot \vec{p}_K$

MONITORS TCA

$$\frac{d\Gamma(B^- \to \gamma K^- \phi)}{d\eta\, d\theta\, d\Phi} = \lambda_0 \sin^2\theta + \lambda_1 \sin^2\theta \cos^2\eta + \lambda_2 \sin^2\theta \cos\eta$$

$$+ \lambda_3 \sin^2\theta \cos(2\Phi) + \lambda_4 \sin^2\theta \sin(2\Phi) + \lambda_5 \sin^2\theta \cos\eta \cos(2\Phi)$$

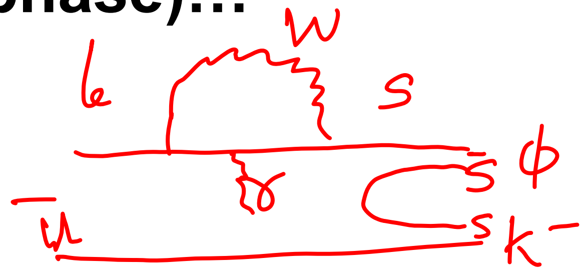
$$+ \lambda_6 \sin^2\theta \cos\eta \sin(2\Phi) + \lambda_7 \sin^2\theta \cos^2\eta \cos(2\Phi) + \lambda_8 \sin^2\theta \cos^2\eta \sin(2\Phi)$$

$$+ \lambda_9 \cos^2\theta \sin^2\eta + \lambda_{10} \sin 2\theta \sin\eta \cos\Phi + \lambda_{11} \sin 2\theta \sin\eta \sin\Phi$$

$$+ \lambda_{12} \sin 2\theta \sin 2\eta \cos\Phi + \lambda_{13} \sin 2\theta \sin 2\eta \sin\Phi \qquad (22)$$

Null tested perfected

- sinΦ terms in angular disribution are CP-odd,
  T_N odd (so don't require absorptive phase)…
  They go as ~ (CP-odd phase)XF_R /F_L
  SM…CP odd phase is in b ->s penguin ~O(λ)
  SM…. F_R /F_L ~{m_s/m_b + hoc}



- THUS dir CPV triple co-or is reduced to
  about 1/20 previous (already suppressed)!
  TDCP asy in K^* γ……..i.e. well below 1%
- *TRIPLE COR. Asy (TCA) in ΦKγ is an extremely clean null test of the SM*
- For more details see Atwood, Gershon,Hazumi&AS
  (to be published)

Summary & Outlook

- Radiative B-decays one of the most important FS for exploring new phenomena at the SBF
- Though Br($B \to X_s \gamma$) unlikely to payoff more, precise determination of CP-asy ($B \to X_s \gamma$), Br($B \to X_d \gamma$), CPA ($B \to X_d \gamma$),CPA ($B \to X_{s+d} \gamma$), are vitally important goals at a SBF
- TDCPA in $B \to \gamma(K^*, K_1, .., K_S \pi(\eta,\eta')..\rho,\rho'..\pi\pi..)$ &TCA in $\gamma\Phi(\omega,\rho)K$..and many other VPγ provide very clean null tests of the SM & verypowerful probes of NP at the SBF…
- In particular, now also use dir CP for extremely precise tests of SM
- MAY ALSO BE DOABLE at LHCb
- Synergy: Such precision flavor studies help discriminate amongst NP scenarios @ LHC