MINING THE BEAUTY OF PENGUINS

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OUTLINE

- Introduction and motivation
- Illustrative Extensions of SM
- β OR χ_{BSM} from penguin dominated hadronic decays
- Mixing-Induced CP, RH currents and Exclusive radiative b decays
- Direct CP in radiative b decays
- Transverse polarization in B --> V V
- DIRCP & FSI
- Summary

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
- Since there is acute lack of tests that are 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

Illustrative Models of NP

- Two higgs doublet model for the top quark:

(T2HDM) 2nd higgs doublet couples only to the t , LEET that incorporates key features of EWSB.

- LRSM : few TeV scale no longer as imposing as in the early 80's..Also non-vanishing neutrino mass suggests re-examination of LRSM.
- Warped extra dimensions (WED), one of the most interesting ways to solve the HP and possibly

also the Flavor Problem (Randall-Sundrum)

Introduction and Motivation

- Testing the EWSM at distances shorter than 10^{-15} cm is an urgent task.
- Penguin dominated B-decays provide a promising avenue to stringently test flavor physics to one loop order
- Since in general penguins in SM are suppressed, effects of NP have better chance of being exposed.
- Thus penguins are a wonderful gold mine for

stringently testing the SM and to search for NP.

Mostly focus on 3 types of penguins

- Hadronic
- Radiative
- Semi-leptonic

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

Specifically wrt radiative penguins

1) Rates …for the future most imp. Is b ->d
(esp. comparison with b ->s)
2)Direct CP (comparison of rates of b with anti-b).
3) Extremely important (relatively) new tool…….
Time dependent (mixing induced CP)
Atwood, Gronau and A.S'97. In addition will discuss new generalization of AGS by Atwood, Gershon, Hazumi and A.S (AGHS in prep.)

II. Mixing Induced CP in Radiative B-decays

[$W = C(5*) \times S(5*)$]

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

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 $\frac{F_R^q}{F_L^q}$

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 $\xi = \pm 1$:

$$
\begin{aligned}
A(\bar{B} \to M^0\gamma_L) &= A\cos\psi e^{i\phi_L} \; , \\
A(\bar{B} \to M^0\gamma_R) &= A\sin\psi e^{i\phi_R} \; , \\
A(B \to M^0\gamma_R) &= \xi A\cos\psi e^{-i\phi_L} \; , \\
A(B \to M^0\gamma_L) &= \xi A\sin\psi e^{-i\phi_R} \; .
\end{aligned} \tag{3}
$$

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,

$$A(t) \equiv \frac{\Gamma(t) - \bar{\Gamma}(t)}{\Gamma(t) + \bar{\Gamma}(t)} = \xi\sin(2\psi)\sin(\phi_M - \phi_L - \phi_R)\sin(\Delta m t) \; .$$

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

and

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

Thus as illustrative examples (in the SM):

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

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

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

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

ttractive features,e.g. ν mass arises naturally. Using $K_L - K_S$ iff one gets a rather imposing bound $m_R \geq 1.5 TeV$ [Beall, and A. S'82]. Given that $m_\nu \neq 0$ (and TeV no longer such osing scale) model ought to reconsidered as a nice effective ergy theory. Done recently [Kiers et al, hep-ph/0205082]

$< \Phi >= \begin{pmatrix} \kappa & 0 \\ 0 & \kappa' \end{pmatrix}$ and setting $|\kappa'/\kappa| = m_b/m_t$ leads to

simplification:

M angle hierarchy arises

$M)_R = (CKM)_L$

The $W_L - W_R$ mixing is described by

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

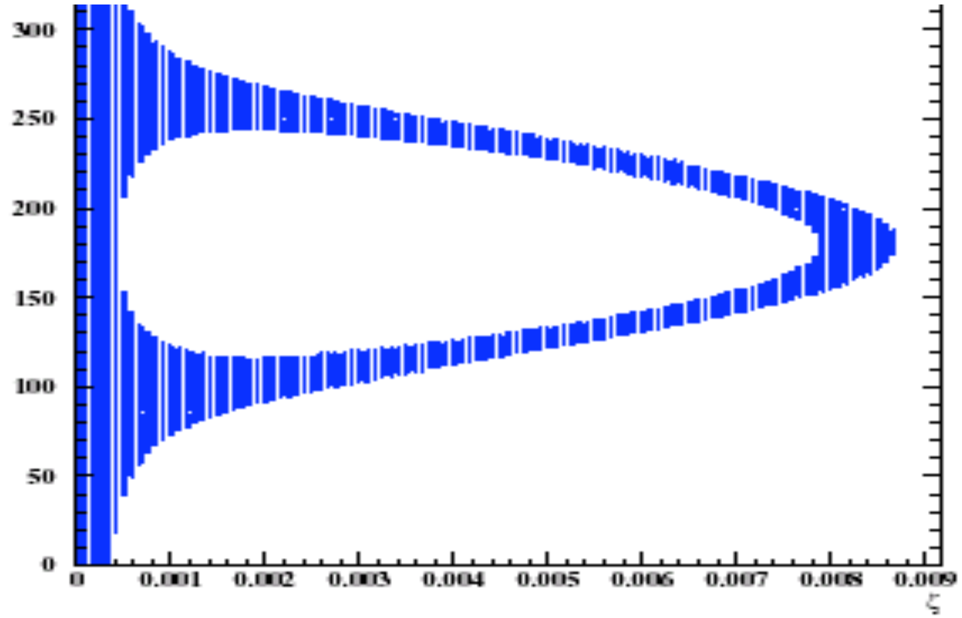
Although ζ is small, $\lesssim 3\times 10^{-3}$, [see Beall and A.S'81; Wolfenstein '84] that's considerably offset by helicity enhancement factor m_t/m_b

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	$\sin 2\omega\,\sin(\Delta m_t)$

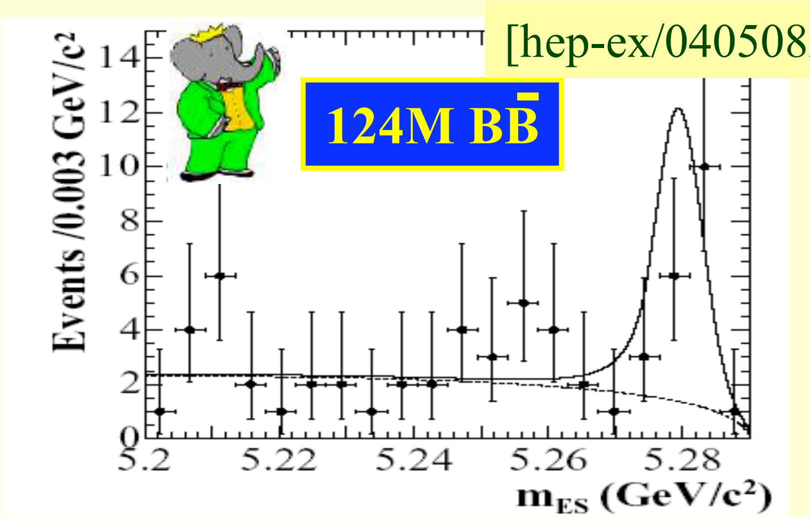
$\Rightarrow$ whereas in the SM negligible asymmetries, in the LRSM can be O(50%) even if $BR(B \to X_s\gamma)$ is in very good agreement with the SM.

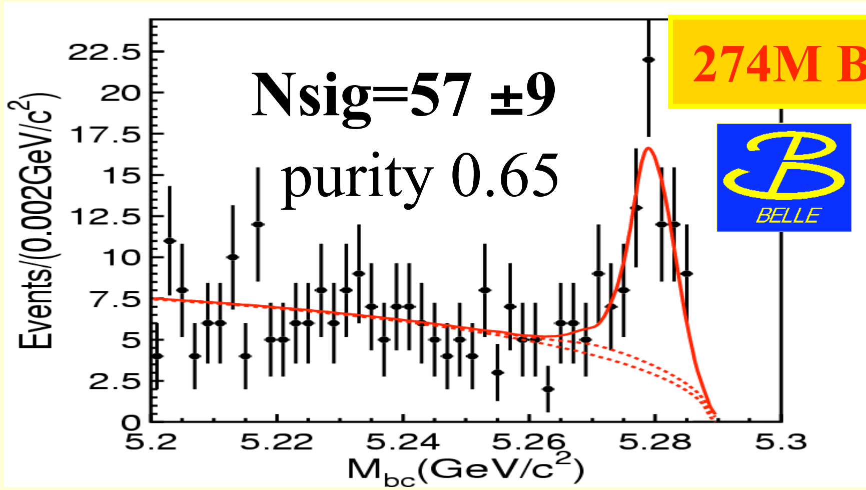


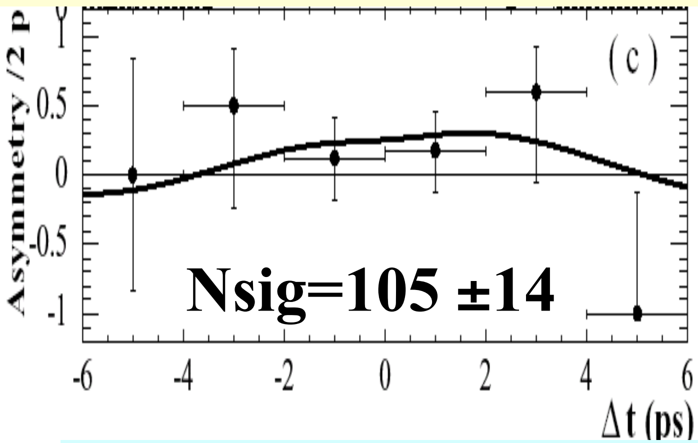
Large Presently allowed values of ζ and ω from $B(B \to X_s \gamma)$, deduced by setting EXP/SM $= 0.71 \pm 0.36$ (i.e. to 90% CL), are included in the shaded area and in the blank internal area. Only the shaded region would be allowed when a 10% agreement between the SM prediction and experiment is attained in the future.

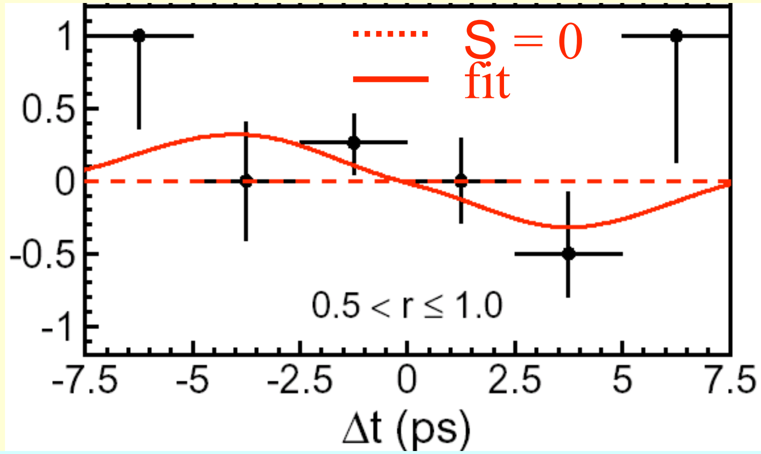
$B \to K^*[Ks p^0] g$ TCPV

[hep-ex/0405082]









S = +0.25 ±0.63 ±0.14 S = $-0.79\,^{+0.63}_{-0.50}$ ±
0.09

A = First step for new era of $b \to sg$! −0.00 ±0.38

$B \to \gamma P_1 P_2$

AGHS in prep.

• 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 CP 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 (see eq)

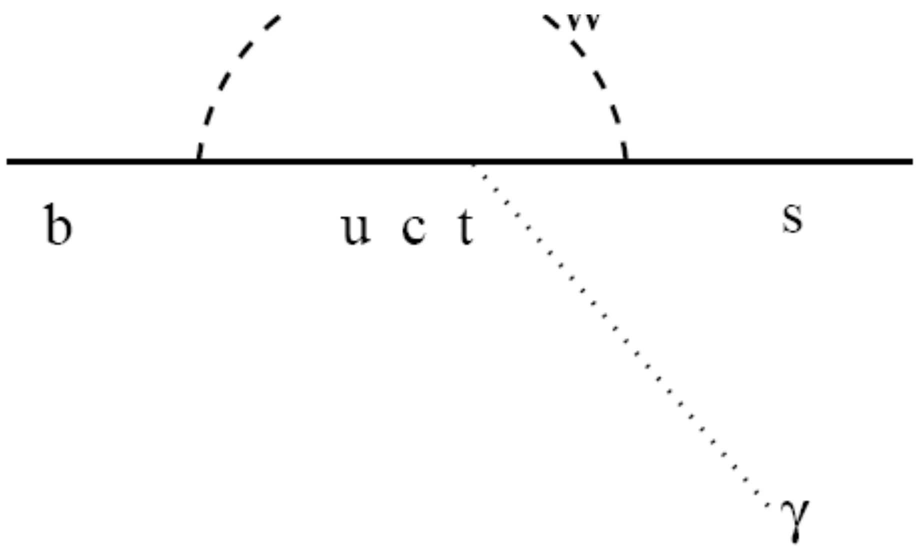


FIG. 1: The Caption

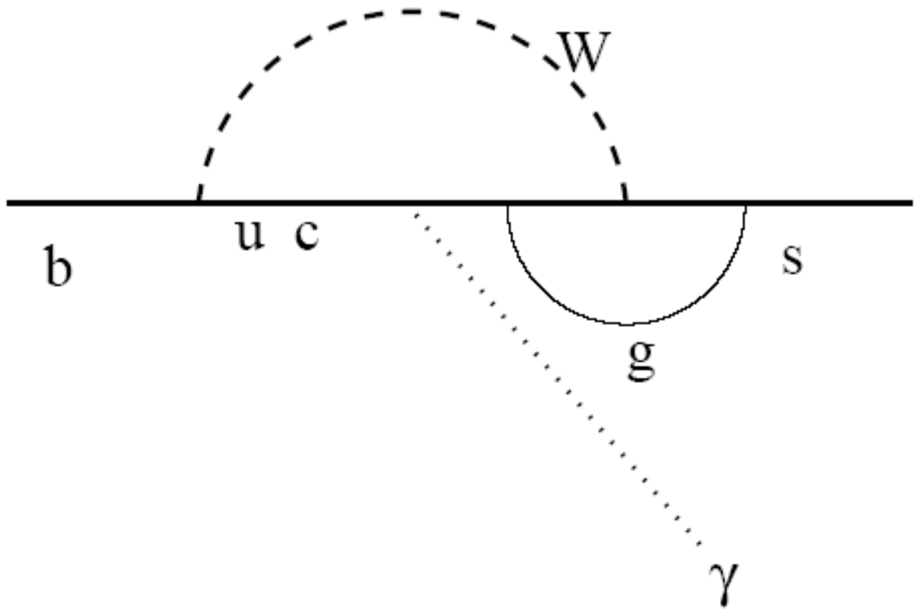


FIG. 2: The Caption

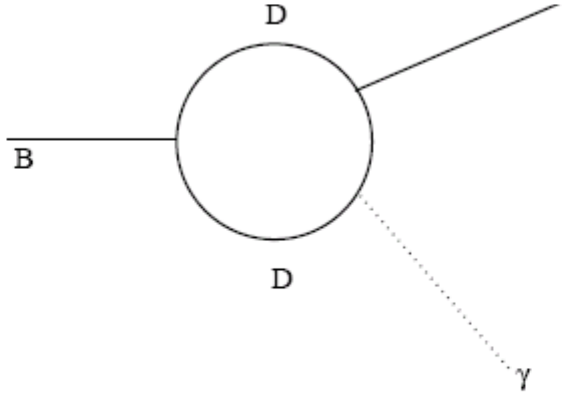


FIG. 3: The Caption

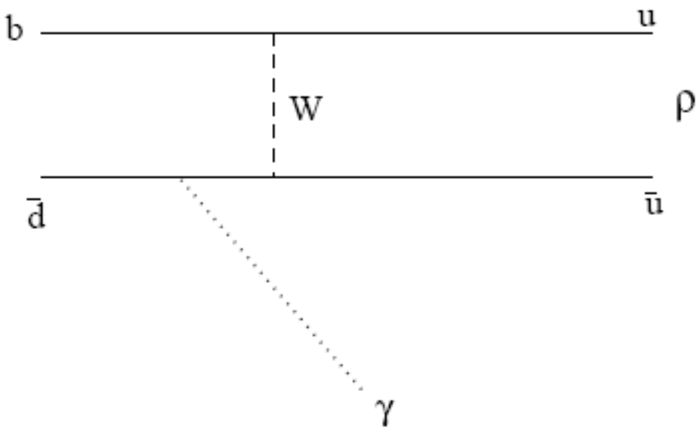


FIG. 4: The Caption

Intutive 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 $\cos\Theta = z$:

$S_1 = (p1 + p2)^2$; $S_2 = (p1 + k)^2$; $S_3 = (p2 + k)^2$

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

$\sin(\psi)\ \sin(\Phi)$ …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.

Once again, resonant and non-resonant info can be combined but now additional 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→s(d) + γ 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 have have same helicity as from the penguin. See AGHS for details.

Prospects

- Increased statistics obtained by going to $B^0 \rightarrow K_S \pi^0 \gamma$.
- Perform the oscillation measurement in $B^0 \rightarrow \rho^0 \gamma$.
- Generalize to $B^0 \rightarrow \pi^- \pi^+ \gamma$.

Search for χ_{BSM} via penguin dominated hadronic FS

[See Grossman and Worah (97); London and Soni (97)]

GW, PLB 97 suggested that the penguin dominated reaction $B \to \phi K_s$ can be used to test presence of BSM phase as in the SM TDCP asymmtery should give to a very good approximation $\sin(2\beta)$.

LS PLB '97 pointed that not only ϕK_s but also $K_s[\eta', \eta, \pi^0, \omega, \rho^0]$ should all be used by TDCPA measurments to test the SM in a similar fashion since $Tree/Penguin < 0.04$, according to their estimate.

(Recall tree is Cabibbo and color-suppressed)

Highlights of the current experimental status; adopted from T. Browder @ Lepton-Photon'03

Final State	BELLE	BABAR
ϕK_s^0	$-0.96 \pm 0.50^{+0.09}_{-0.11}$	$0.45 \pm 0.43 \pm 0.07$
$\eta' K_s^0$	$0.71 \pm 0.37^{+0.05}_{-0.06}$	$0.02 \pm 0.34 \pm 0.03$
KKK_s^0	$0.49 \pm 0.43^{+0.35}_{-0.11}$	

1. Recall (from $c\bar{c}$ modes) $\sin(2\phi_1) = 0.734 \pm 0.055$ (wt. av.)

2. For ϕK_s BELLE and BABAR differ significantly;overlooking that wt. av. is -0.15 ± 0.33

3. BABAR central value changed from -0.18 to $+$0.45 with increase of data from 81fb^{-1} to 110 fb^{-1}.

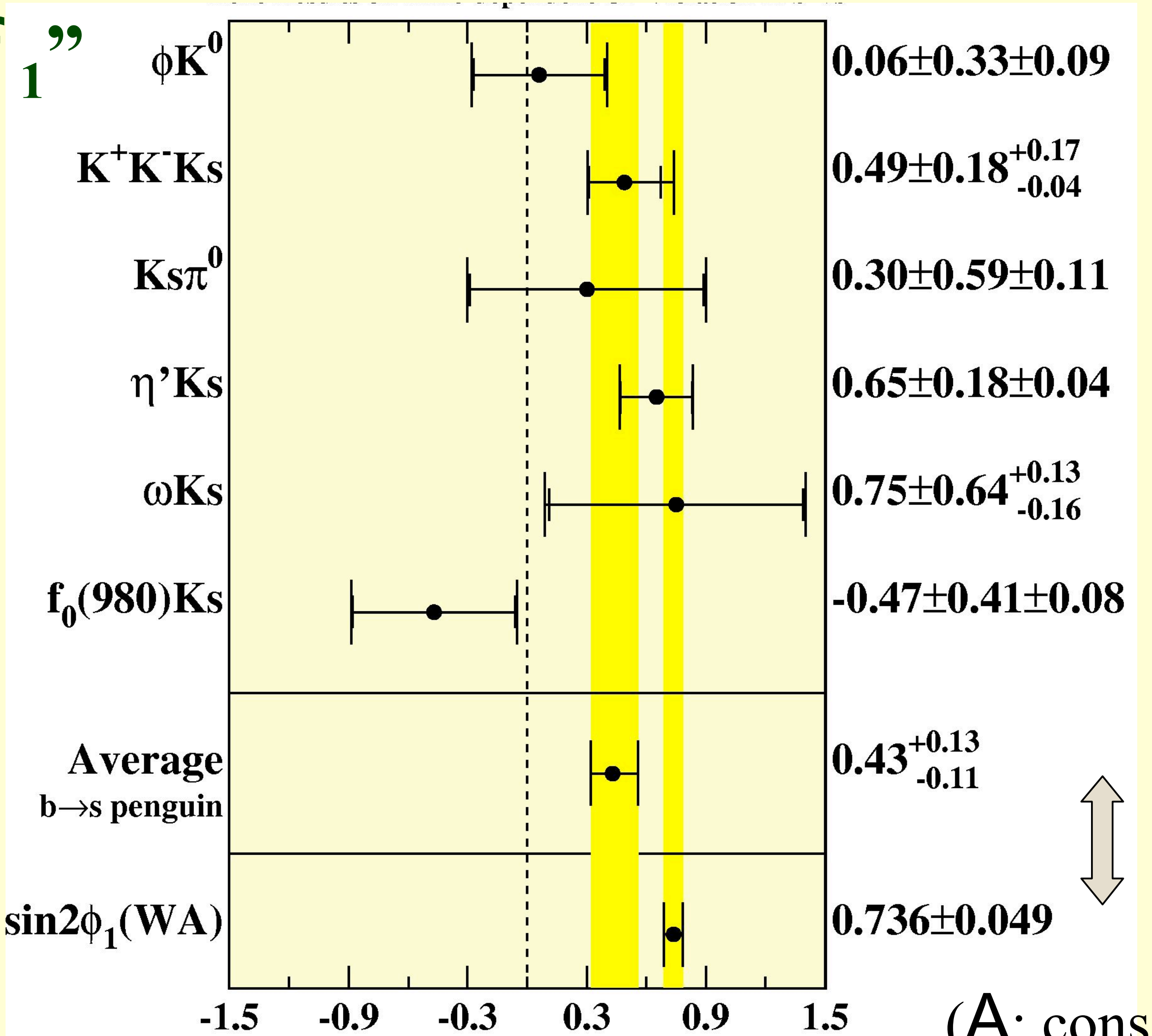
4. Combined result <u>disagrees</u> with SM at about 2.7 σ

Summary of $b \rightarrow sqq$ CPV

BELLE

274M $B\bar{B}$

"sin2f $_1$"



2.4σ

(A: consistent with 0)

Model Independent Remarks

Divide NP sources contributing to $B \to \phi K_s$ into 2 types:

I. NP leads to modification of $b \to s$ form-factor(s):

$\Lambda_\mu^{bs} = \bar{s}_i T_{ij}^a [-iF(q^2)(q^2\gamma_\mu - q_\mu \not{q})L + m_b q_\mu \varepsilon_\nu \sigma^{\mu\nu} G(q^2) R] b_j$

$F(q^2) = e^{i\delta_{st}} F_{SM} + e^{i\lambda_F} F_x$; $G(q^2) = G_{SM} + e^{i\lambda_G} G_x$ cBI where δ_{st} is the strong phase generated by the absorptive part resulting form the $c\bar{c}$ cut for $q^2 > 4m_c^2$; λ_F and λ_G are the CP-odd non-standard phases. For simplicity CKM phase in $b \to s$ is assumed negligibly small .$glu \to q\bar{q}$ interactions as dictated by QCD. So, $glu \to s\bar{s}$ leads to the ϕK_s anomally; but at the same time has serious ramifications for $\eta' K_s$. Infact recall that such a BSM modification was introduced to enahance rate for $B \to \eta' X_s(K)$ leading possibly to non-standard **direct CP** signals. [see Hou & Tseng PRL'98; Atwood & Soni PRL '97] Note $gluon \to c\bar{c}, \ldots$ is also inevitable. Should lead to deviations from SM in numerous channels, in particular, all FS with (net) $\Delta s = \pm 1$ are susceptible to effects of NP: RATES, DIRCP, TDCP, TCA should all be effected. NOT ONLY ϕK_s but also $\phi K^\pm$, ϕK^* (TCA), $K\bar{K}K(X)$;$pi^0 K_s$, $\eta' K_s$, $\eta' K^\pm$...; $\sin(2\beta)$ via $D_s D$ should NOT equal that from ψK_s; also DIRCP in $D_s D^-(D^0)$, TCA in $D_s^* D^*$...; Similarly in $\gamma X_s(K^*, K\pi ...)$; $l^+ l^- X_s(K, K^*, K\pi ...)$

II. NP as 4-fermi interaction in $b \to s\bar{s}s$ vertex:

$L_{4f}^{b3s} = G_{b3s} e^{i\chi_{b3s}} [\bar{s}\Gamma_\mu b][\bar{s}\Gamma'_\mu s]$

G_{b3s} is effective 4-fermi coupling, assumed real; χ_{b3s} is the associated non-standard CP-odd phase. This is much more restrictive and yet such a NP should effect not just TDCP in ϕK_s but also DIRCP in $\phi K_s(K^\pm, K^*...)$ also TCA in ϕK^*; Similarly $K\bar{K}K(X)$; $\eta' K_s(K^\pm, K^*)$

1. Its impossible to isolate NP only in TDCP in ϕK_s
2. All channels affected by II are also affected by I (but not the otherway around)
3. many NP effects in B_s as well; e.g. Δm_s, TDCP and TCA in $\phi(\phi, K\bar{K}(X))$, $\phi\eta'$

(Some) Implications of BSM_s invoked to explain ϕK_s

Illustrative Sample esp. to emphasize possible corroborative evidence **ASSUMING LARGISH SIGNAL FROM BELLE IS BASICALLY CORRECT**

I. Huang and Zhu (hep-ph/0307354) , 2HDM (Mod III)

$\Rightarrow$ TDCPA ($S_{\phi K}$) with either sign but DIRCPA $C_{\phi K} > 0$

Recall $C_{\phi K_s} = -0.38 \pm 0.37 \pm 0.12 (BABAR); +0.15 \pm 0.29 \pm 0.07$(BELLE)...see Browder @ Lep-ph'03

II. Raidal (hep-ph/0208091) LRSM; $\Rightarrow$ relatively low scale for m_{W_R}, with at least one new CP-odd phase $\Rightarrow$ Large TDCPA in $B \to K^*(\rho)\gamma$; $\not{C}P$ in $B_s \to \phi\phi$ (also $\eta\rho, \pi^0\rho$)

III.Hiller (hep-ph/0308180) and Atwood and Hiller (hep-ph/0307251) FC $sZ'b$ with complex coupling; $\Rightarrow$ large non-std. effects in Br, and A_{FB} of $b \to s l^+ l^-$; $B_s \to \mu\mu$; Δm_s

IV. Khalil and Kou (hep-ph/0307024) SUSY $\Rightarrow$ can (interestingly) account for different asymmetries in ϕK_s and $\eta' K_s$; $\Rightarrow$ DIRCP even in $B^{\pm}$; non std. helicity in $b \to s\gamma$ so (e.g.) TDCPA in $B \to K^*\gamma$

Summary on ϕK_s

- Many BSMs can accomodate (largish) asym. in ϕK_s.
- Virtually impossible to confine effects of a new phase just in ϕK_s, esp. if its large $\Rightarrow$ TDCPA, DIRCP, TCA should be seen in a multitude of channels. In particular, TCA and other anomalous effects in ϕK^*, $\pi^0 K_s$, $KKK(n\pi)$, $\eta' K(n\pi)$, $\gamma K^*(n\pi)$, $l^+ l^- K(n\pi)$ should be vigorously studied.
- Serious concern regarding somewhat conflicting results from the two experiments (both on ϕK_s and $\pi\pi$); its clearly important to resolve these.
- Future experimental effort should target definitive measurments of asymmetry of $O(\approx theo.errors) \approx \lambda^2$ i.e. about 5%..Given Br $\approx 10^{-5}$ and assuming 10% efficiency requires about $10^{10} B\bar{B}$ pairs for a convincing (5σ) signal i.e. a Super-B.

Radiative B-Decays.... Br and Dir CP

For DIRCP [[illegible])]

For rates [[illegible]

Recall (W.A) $Br(B \to X_s \gamma) = 3.34 \pm .38 \times 10^{-4}$... [Nakao@LP'03]

SM (NLO) predicts $3.57 \pm 0.30 \times 10^{-4}$ [see Misiak @ CKM'02]

Leads to important constraints on numerous extensions: 2HDM's, SUSY,XDM...(examples) [for recent rev.see Hurth hep-ph/021230

$\Rightarrow$ It will be very difficult to improve SM predictions for the Br

$\Rightarrow$ $a_{CP}^{B \to X_s \gamma}$, $Br(B \to X_d \gamma)$ and $a_{CP}^{B \to X_d \gamma}$ and exclusive counter parts deserve increased focus.

Note $a_{CP}^{B \to X_d \gamma} = -.004 \pm .051 \pm .038$ [BELLE; see Nakao @ LP'03]

- Current expt. limit on $A_{CP}^{B \to X_s \gamma}$ needs improvement by factor of 5-10 for sensitivity to SM (i.e. $A_{CP}^{B \to X_s \gamma} \approx 0.6\%$) ...
- Due accidental cancellations, in 2HDMs $A_{CP}^{B \to X_s \gamma}$ also $< 0.6\%$

– But can be a lot bigger in SUSY Models

– SM predicts $A_{CP}^{B\to X_d\gamma}$ a lot bigger ($\approx -16\%$)

[see Kiers,Soni,Wu hep-ph/0006280 (Table below)]

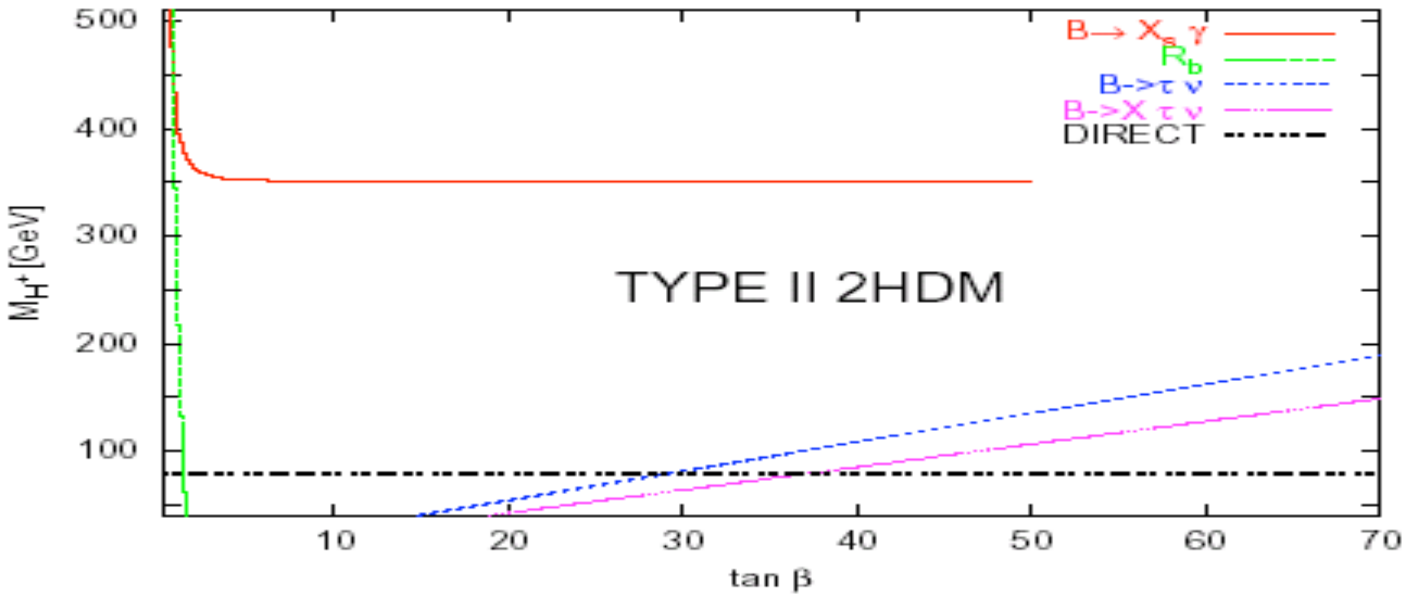
Direc CP violation in Radiative B decays in and beyond the SM

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

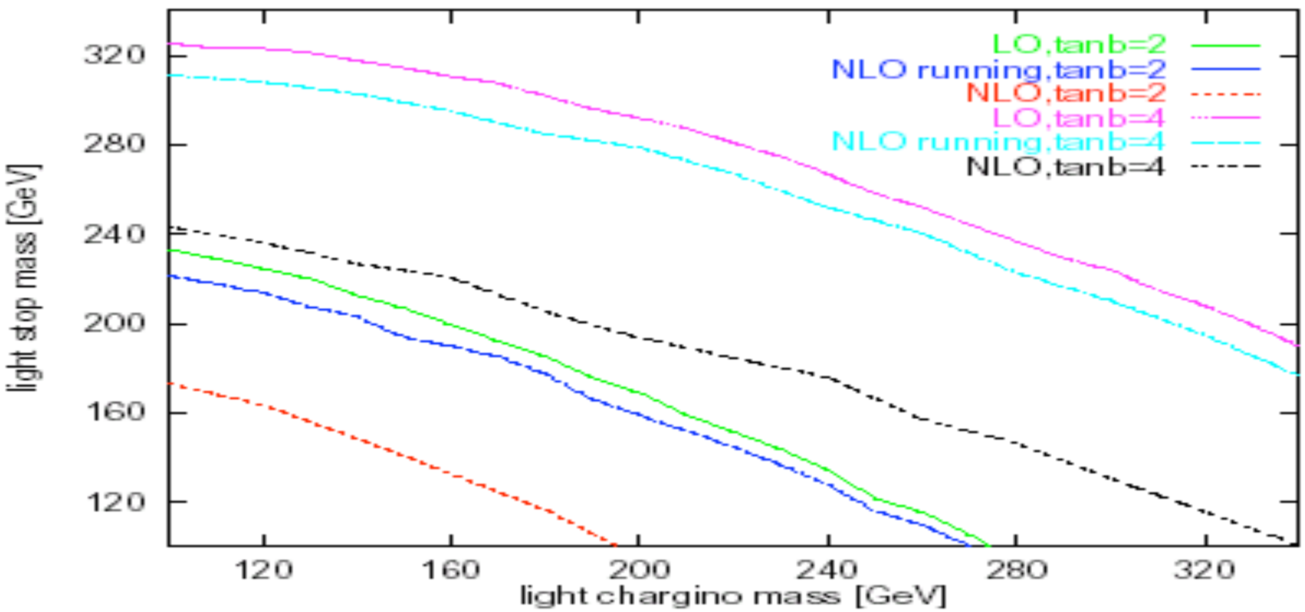
Model	$A_{CP}^{B\to X_s\gamma}(\%)$	$A_{CP}^{B\to X_d\gamma}(\%$
SM	0.6	-16
2HDM (Model II)	≈ 0.6	≈ -16
3HDM	-3 to +3	-20 to +2
T2HDM	$\approx$ 0 to +0.6	$\approx$ -16 to +
Supergravity[*]	$\approx$ -10 to +10	-(5 - 45) and (2
SUSY with squark mixing[+]	$\approx$ -15 to +15	
SUSY with R-parity violation[+*]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

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



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



Upper bounds on the lighter chargino and stop masses from $B \to X_s \gamma$ data in a scenario with a light charged Higgs mass; for $\tan\beta = 2$ (three lower curves) and 4 (three upper plots) the LL, NLL-running and NLL results (from the top to the bottom) are shown [see Hurth and see Ciuchini et al hep-ph/9806308]

B-Factory Signals for a WED
(Agashe,Perez,Soni,hep-ph/0406101)

- RS1 with a WARPED EXTRA DIMENSION (WED) provides an elegant solution to the problem
- 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.

NP Contributions due WED

There are essentially 3 types of top quark dominated FCNC contributions:

i) Contributions to FCNC processes arise from a relatively large dispersion in the doublets 5D masses, specifically large coupling of $(t,b)_L$ to gauge modes due to heaviness of the t.

ii) Contributions to FCNC processs (mostly semi-leptonic)

These arise from contribution of i) and mixing between the zero and KK states of the Z due to EWSB.

iii) Contribution to radiative B-decays via

dipole operators arise from large 5D Yukawa required to obtain m_t

Flavor	f_Q^{-1}	f_u^{-1}	f_d^{-1}
I	$\frac{\lambda^3}{f_{Q^3}} \sim 0.4 \times 10^{-2}$	$\frac{m_u}{m_t}\frac{f_{u^3}^{-1}}{\lambda^3} \sim 10^{-3}$	$\frac{m_d}{m_b}\frac{f_{d^3}^{-1}}{\lambda^3} \sim 10^{-3}$
II	$\frac{\lambda^2}{f_{Q^3}} \sim 2 \times 10^{-2}$	$\frac{m_c}{m_t}\frac{f_{u^3}^{-1}}{\lambda^2} \sim 10^{-1}$	$\frac{m_s}{m_b}\frac{f_{d^3}^{-1}}{\lambda^2} \sim 0.3 \times 10^{-2}$
III	$\frac{f_{u^3} m_t}{v\lambda_{5D} k} \sim \frac{1}{3}$	$\mathbf{O}\left(\frac{5}{6}\right)$	$\frac{m_b}{m_t} f_{u^3}^{-1} \sim 0.6 \times 10^{-2}$

Table 3: The known quark masses and CKM mixing implies relation between the model flavor parameters, f_{x^i}, (11,12). The value of f_{u^3}, λ_{5D} is determined by requiring the theory is perturbative (13,14).

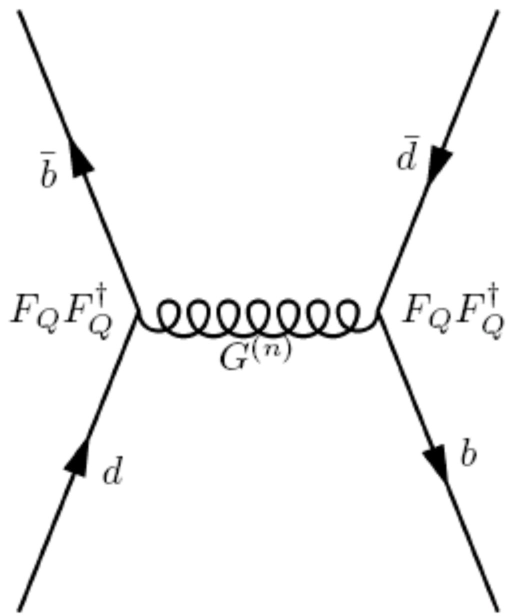


Fig. 1: Contributions to $\Delta F = 2$ processes from KK gluon exchange.

Contrasting B-Factory Signals from WED with those from the 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	$\Delta m^{SM}_{B_s}[1+O(1)]$	$O(1)$	$\sin 2\beta \pm O(.2)$	$Br^{SM}[1+O(1)]$	$O(1)$	$O(1)$
SM	$\Delta m^{SM}_{B_s}$	λ_c^2	$\sin 2\beta$	Br^{SM}	$\frac{m_s}{m_b}\left(\sin 2\beta, \lambda_c^2\right)$	$\frac{m_d}{m_b}\left(\lambda_c^2, \sin 2\beta\right)$

TABLE I: Contrasting signals from RS1 with the SM

Enhanced FSI in Color-Suppressed modes

- Hai-Yang Cheng,Chun-Khiang Chua & A.S (in prep.)

Numerous Indications:

- Measured Br of B^0 -> $D^{(*)0}\,\pi^0$ are all significantly larger than theoretical expectations.
- Measured Br of about $2X10^{-6}$ into 2 π^0's

is too high for expectations based on QCDF…

Additional indications of subtelities

- Similar to 2 pi0's, rho0 pi0 FS Br ($5X10^{-6}$) too high compared to QCDF
- Observed dir CP asymm in B^0-> K^+pi^- too high compared to (most) theoretical expectations. Indeed for both pi^+pi^- and K^+pi^- even the signs of observed asymm are opposite to QCDF!

-→ LD FS Rescattering in hadronic B decays are important

-→ e.g. low longitudinal pol. In VV modes NOT

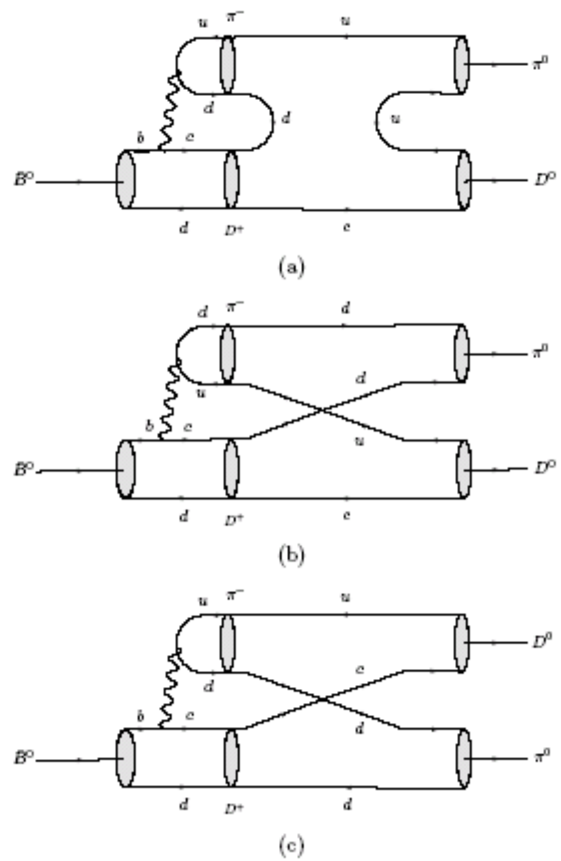
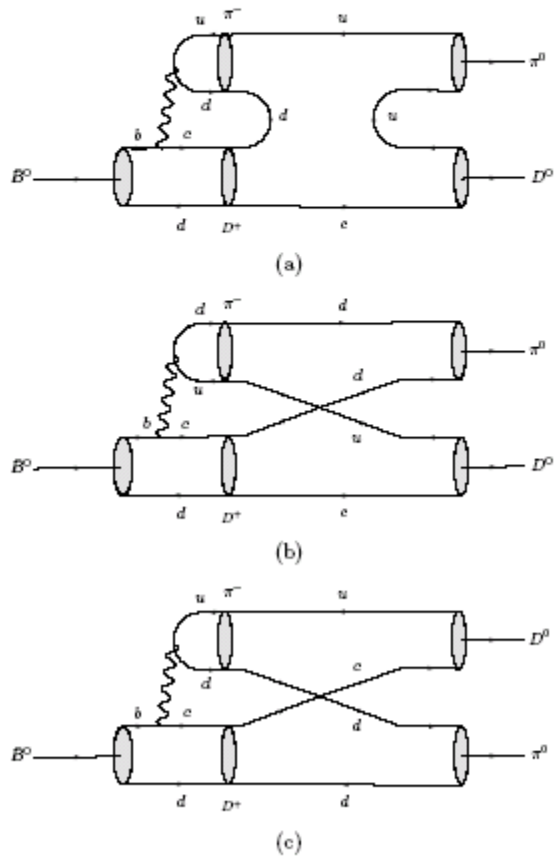


FIG. 1: Contributions to $\overline{B}^0 \to D^0\pi^0$ from the color-allowed weak decay $\overline{B}^0 \to D^+\pi^-$ followed by a resonant-like rescattering (a) and quark exchange (b) and (c). While (a) has the same topology as the W-exchange graph, (b) and (c) mimic the color-suppressed internal W-emission graph.

$D\pi$ states is unknown and the off-shell effects in the chiral loop should be properly addressed [41]. Nevertheless, as emphasized in [42, 43], most of the properties of resonances follow from unitarity alone, without regard to the dynamical mechanism that produces the resonance. Consequently, as shown in [42, 44], the effect of resonance-induced FSIs [Fig. 2(a)] can be described in a model-independent manner in terms of the mass and width of the nearby resonances. It is found that the $\mathcal{E}$ amplitude is modified by resonant FSIs by

$$\mathcal{E} = e + (e^{2i\delta_r} - 1)\left(e + \frac{\mathcal{T}}{3}\right), \tag{2.1}$$



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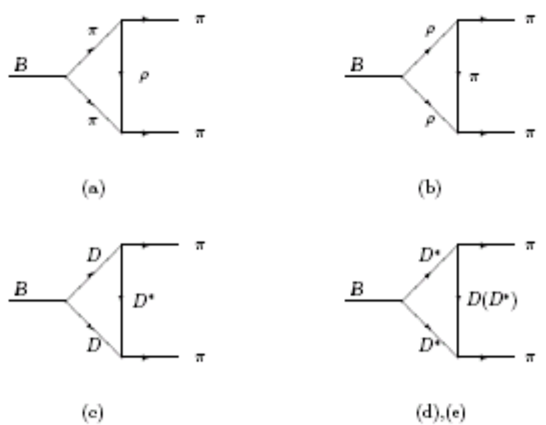

FIG. 5: Long-distance t-channel rescattering contributions to $B \to \pi\pi$. Graphs (d) and (e) correspond to the exchanged particles D and D^*, respectively.

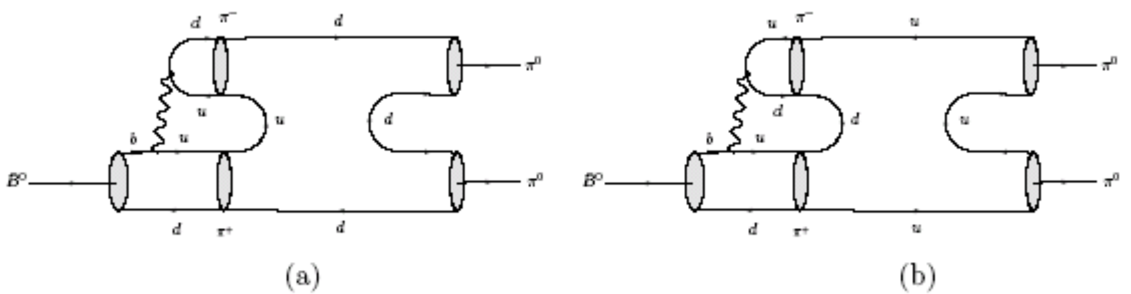

FIG. 6: Contributions to $\overline{B}^0 \to \pi^0\pi^0$ from the color-allowed weak decay $\overline{B}^0 \to \pi^+\pi^-$ followed by quark annihilation processes (a) and (b). They have the same topologies as the penguin and W-exchange graphs, respectively.

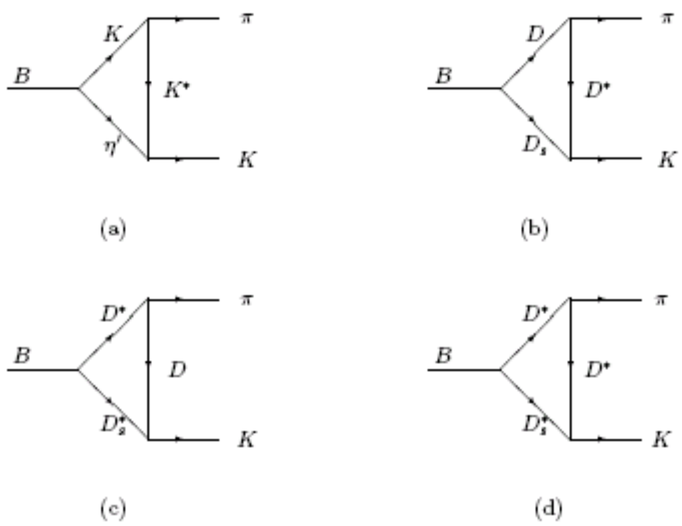

FIG. 7: Long-distance t-channel rescattering contributions to $B \to K\pi$.

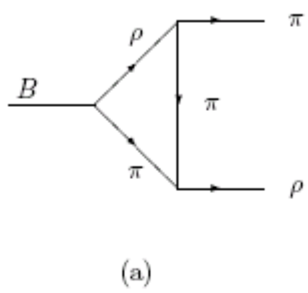

FIG. 8: Long-distance t-channel rescattering contributions to $B \to \rho\pi$.

Estimates of some FSI effects

Mode	Br /Asy	Experiment -	SD	LD
$\pi^+ \pi^-$	Br	4.6+-0.4	7	$11.5^{+8.1}_{-3.1}$
	Asy	0.46+-0.13	-0.05	$0.55^{+0.07}_{-.3}$
$\pi^0 \pi^0$	Br	1.9+-0.5	0.27	$1.5^{+3.1}_{-1.1}$
			0.61	$-0.63^{+.09}_{-.24}$
$\pi^- \pi^0$	Br	5.2+-.8	5.1	5.5+-.1
$\pi^- \pi^0$	Asy		$5X10^{-5}$	-.006+-.002

Dir CP in $B^+ \to \pi^+\pi^0$ an important `null' test

- $\pi^+\pi^0$ is I=2 final state so receives no contribution from QCDP and only from EWP + tree (of course)
- SM provides negligibly small (less than about 1%) asymmetry even after including rescattering effects

  →Especially sensitive to NP and should be exploited

→Similarly $\rho^+ \rho 0$

see CCS (in prep.) for details

FSI in K π Modes

Mode	Br/Asy	Expt	SD	L
+-	BR	18.2+-.8	13.9	$17.2^{+38.9}_{-3.6}$
	Asy	-11.2+-.02	0.04	$-.13^{+.01}_{-.15}$
00	Asy	-.40+-.29	-.04	$.02^{+.02}_{-.06}$

For other #s see CCS

A Rigorous Sum-Rule FOR EWP

- For π K modes:

$2\Delta(\pi^0 K^+) - \Delta(\pi^+ K^0) - \Delta(\pi^- K^+) + 2\Delta(\pi^0 K^0) = 0$

Δ=PARTIAL WIDTH DIFF.

Assumes only isospin; therefore, rigorously

measures EWP…see Atwood and A.S. hep-ph/9712287 (PRD). BTW the title of this paper is:`The possibilty of large direct CPV in π K modes due to long-distance rescattering effects and the implications for the angle gamma'

Note asymmetries in the range of 10-20% were discussed.

→ Not everyone is surprised by this much

DiRCP and FS phases..We should learn to use them

Summary and Outlook

- In a multitude of ways penguin loop offers enhanced chances for observing effects of NP

→Radiative Penguins…In addtion to rates,

and Dir CP mixing induced CP added ('97)

…a very powerful tool…Its practical viabilty

now demonstrated by both expts.

AGHS('04) offers a very important generalization that should help the experimentalists get a lot more

for their money….3-body non-resonant modes can be added to resonant ones to extract info on χ_{BSM}

and possibly also strong phase.

Penguin dominated hadronic modes ‘97

Intriguing 2-3 σ effect reported (see Sakai, Georgi

→ K_S [φ, π, ρ, ω, f_0 ….], T/P O(5%)

→ ICHEP’04) clearly very important to improve significance so that errors < than about O(λ^2)

→ Large dir CP in K …classic penguin- tree interference

→ LARGE FSI phases

→DIRCP should be explored/exploited more aggressively; in particular it is very important to study dirCP (including triple corr.)in charged counterparts of penguin-dominated hadronic modes wherein there is an indication of a possible anomally.It is exceedingly unlikely that NP can affect only neutral modes.

→ If the hadronic penguin anomally is due NP then it is highly likely if not virtually impossible that NP effects will not show up in dir and/or mixing induced CP in radiative B-decays

In the light of B-factory results

- HP and Coin-P suggest correction due to NP are likely to be small (have already been repeatedly emphasizing over the past few years)

→ SBF has an essential role to play. IT IS IMPERATIVE THAT WE GET SUCH A MACHINE.