SM uncertainties in some CP asymmetries related to $\sin 2\beta$

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- Is the SM flavor sector confirmed? [ZL, hep-ph/0408267]

- Photon pol. in $B \to X\gamma$ [Grinstein, Grossman, ZL, Pirjol, PRD **71** (2005) 011504, hep-ph/0412019]
  ... Time dependent CPV significantly larger in SM than $(m_s/m_b)\sin 2\beta$

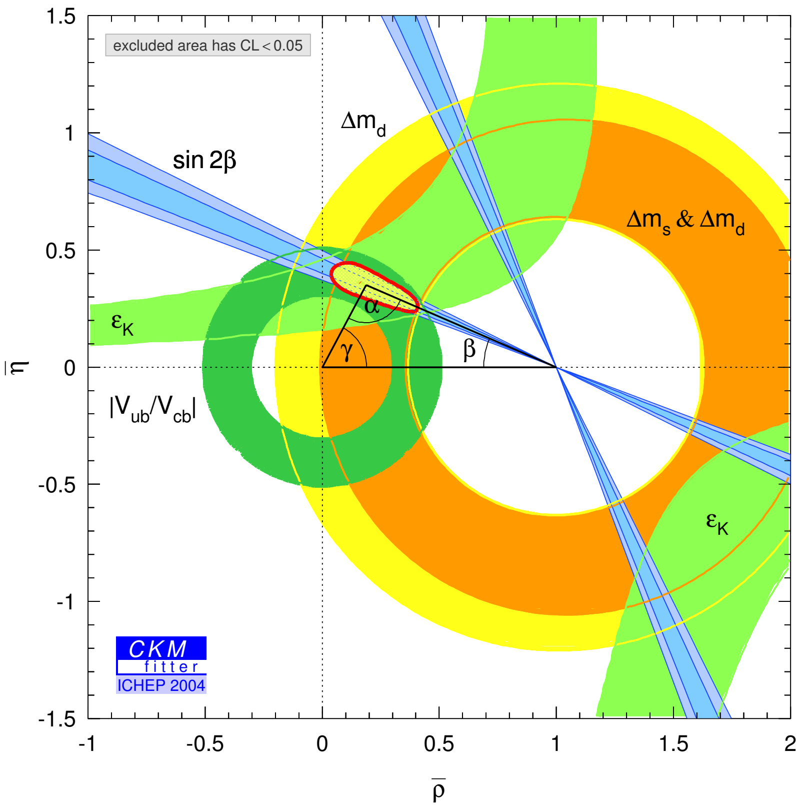
- Hadronic $b \to s$ decays [Grossman, ZL, Nir and Quinn, PRD **68** (2003) 015004, hep-ph/0303171]
  ... $SU(3)$ — how far can we get with minimal assumptions?
  ... 2-body: ϕK_S, $\eta' K_S$, $\ldots$

- Conclusions

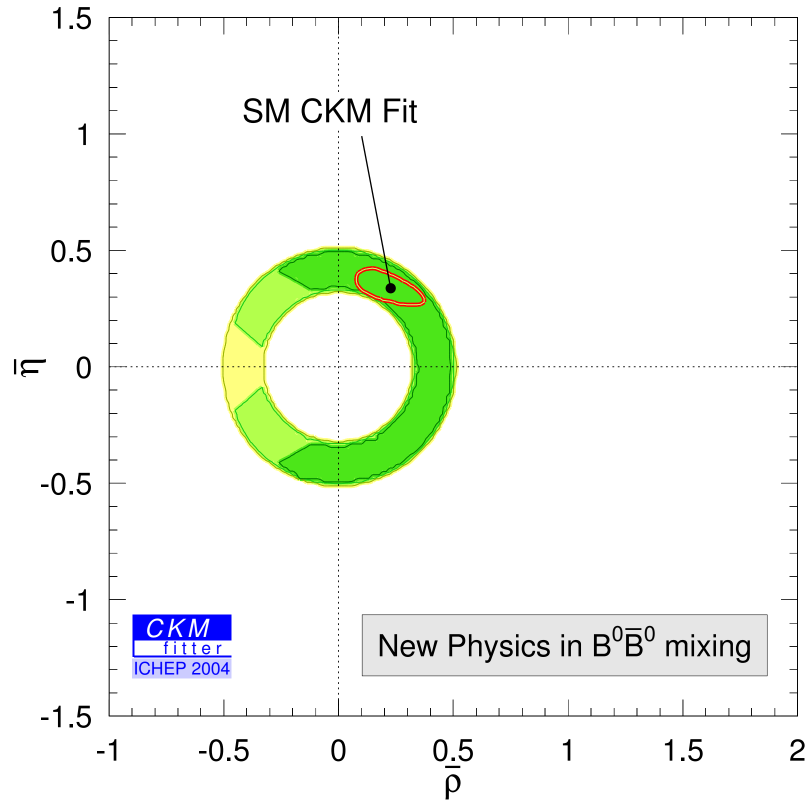
CKM fits with and without assuming SM

- Consistency of SM fit often said to imply tight constraints on NP — this is wrong

SM fit: impressive agreement



NP in loops: constraints relaxed



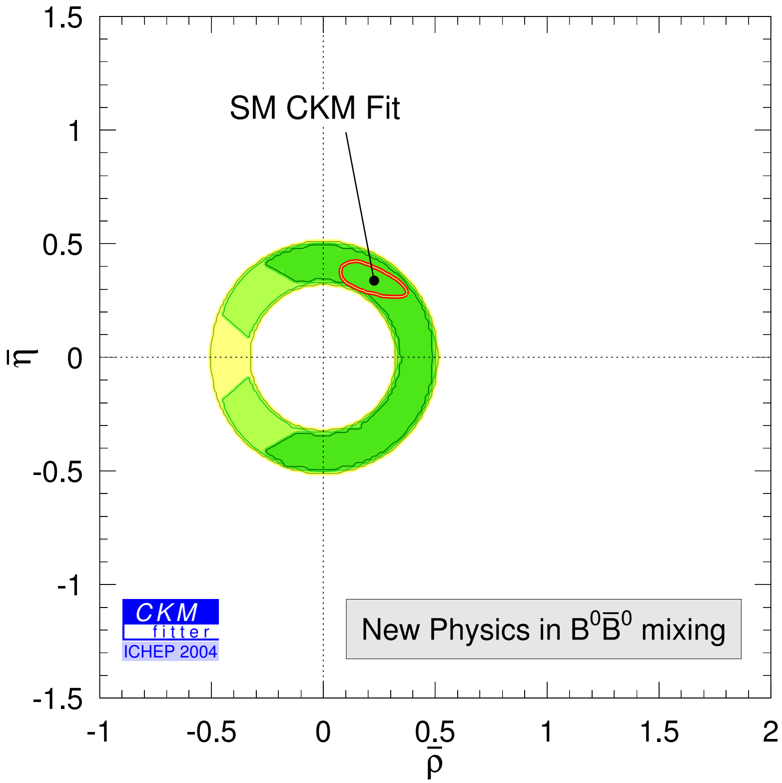
- These measurements alone cannot exclude NP in loop processes (coincidence)

Constraining NP in mixing: the '04 news

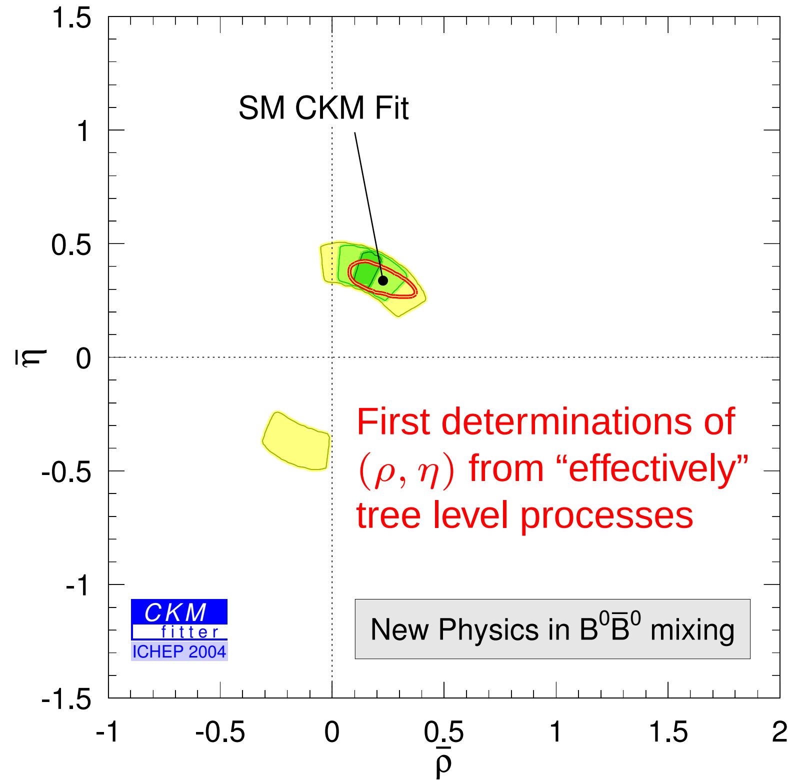
- NP in mixing amplitude only, 3×3 unitarity preserved: $M_{12} = M_{12}^{(\mathrm{SM})}\, r_d^2\, e^{2i\theta_d}$

$\Rightarrow \Delta m_B = r_d^2 \Delta m_B^{(\mathrm{SM})}$, $S_{\psi K} = \sin(2\beta + 2\theta_d)$, $S_{\rho\rho} = \sin(2\alpha - 2\theta_d)$, $\gamma(DK)$ unaffected

Constraints with $|V_{ub}|$, Δm_d, $S_{\psi K}$, A_{SL}



New in '04: α, γ, $2\beta + \gamma$, $\cos 2\beta$



- Similar to EW fit: $m_H <$ few $\times 100$ GeV in SM; model independently only $\lesssim 1$TeV

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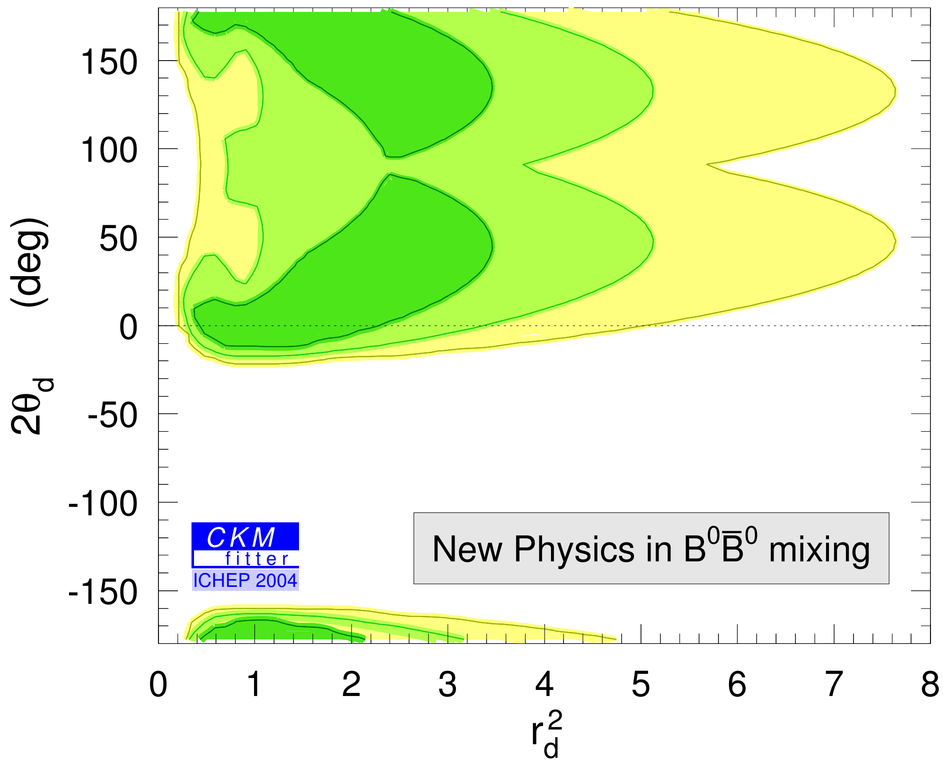

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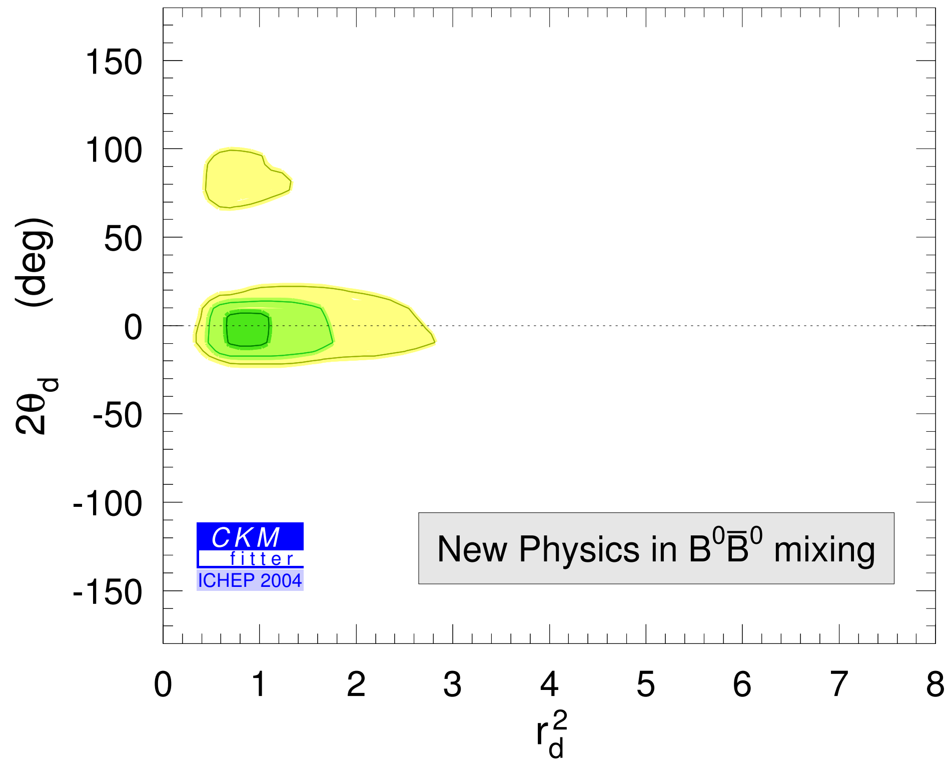


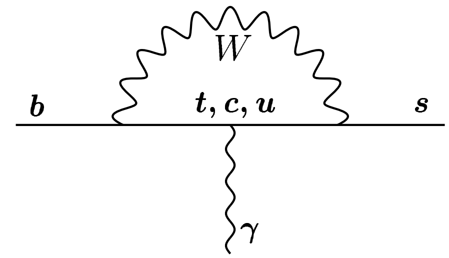
- New data restrict θ_d, r_d^2 significantly for the first time — still plenty of room left

Photon polarization in $B \longrightarrow X\gamma$

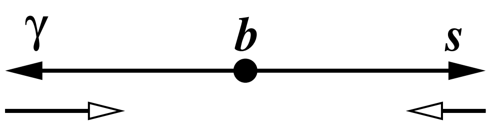
Source of photon polarization

- In the SM, charged current is left handed, so $b \to s_L$

  Photon must be left-handed to conserve J_z along decay axis



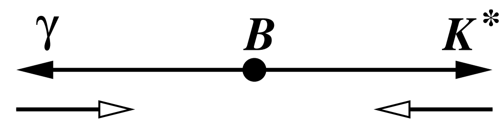
Inclusive $B \to X_s\gamma$



Assumption: 2-body decay

Does not apply for $b \to s\gamma g$

Exclusive $B \to K^*\gamma$



... quark model (s_L implies $J_z^{K^*} = -1$)

... higher K^* Fock states

BSM right handed interaction (motivated by ϕK_S, etc.) can give large $b \to s\gamma_R$

- What is the SM prediction? What limits the sensitivity to new physics?

Measuring the photon polarization

- Only measurement so far is time dependent CP asymmetry

$$\frac{\Gamma[\overline{B}^0(t) \to f\gamma] - \Gamma[B^0(t) \to f\gamma]}{\Gamma[\overline{B}^0(t) \to f\gamma] + \Gamma[B^0(t) \to f\gamma]} = S_{f\gamma} \sin(\Delta m\, t) - C_{f\gamma} \cos(\Delta m\, t)$$

No $\gamma_L - \gamma_R$ interference $\Rightarrow$ the lore has been: $S_{K^*\gamma} = -2\,(m_s/m_b) \sin 2\beta$

[Atwood, Gronau, Soni, PRL **79** (1997) 185]

- Babar [incl. Moriond'05] & Belle data:

$S_{K^*\gamma} = -0.38 \pm 0.34$ (my average, no correlation)

$$S_{K_S\pi^0\gamma} = \begin{cases} -0.58^{+0.46}_{-0.38} \pm 0.11 & \text{(Belle, } 0.6\,\text{GeV} < m_{K_S\pi^0} < 1.8\,\text{GeV)} \\ 0.9 \pm 1.0 \pm 0.2 & \text{(Babar, } 1.1\,\text{GeV} < m_{K_S\pi^0} < 1.8\,\text{GeV)} \end{cases}$$

Need $\sim 50\,\text{ab}^{-1}$ to get $\delta(S_{K^*\gamma}) = 0.04$ experimental error

- Few other proposals, all very hard to measure:
  - photon conversion off detector, study $\gamma \to e^+e^-$ and $K^* \to K\pi$ distributions
  - $B \to K_1\gamma$, measure up-down asymmetry of γ's relative to $K_1 \to K\pi\pi$ plane
  - $\Lambda_b \to \Lambda\gamma$ decay...

Right-handed photons

- Considering dominant operator in SM, γ_R suppressed by m_s/m_b to all orders in α_s

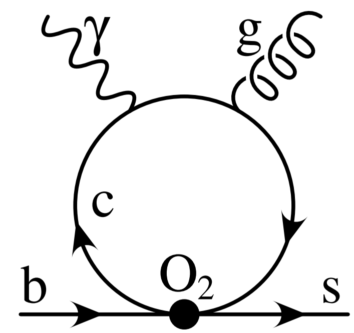
  Can decouple γ_L and γ_R at the level of the Hamiltonian

$$O_7 = \bar{s}\,\sigma^{\mu\nu}F_{\mu\nu}(m_b P_R + m_s P_L)b = \bar{s}\,\sigma^{\mu\nu}(m_b F^L_{\mu\nu} + m_s F^R_{\mu\nu})b \qquad F^{L,R}_{\mu\nu}=\tfrac{1}{2}(F_{\mu\nu}\pm i\widetilde{F}_{\mu\nu})$$

- Dominant source of “wrong-helicity” photons in the SM is O_2:

  Equal $b \to s\gamma_L,\ s\gamma_R$ rates at $\mathcal{O}(\alpha_s)$; calculated to $\mathcal{O}(\alpha_s^2\beta_0)$

  Inclusively only rates are calculable, get: $\Gamma_{22}^{(\mathrm{brem})}/\Gamma_0 \simeq 0.025$



- Suggests: $A(b \to s\gamma_R)/A(b \to s\gamma_L) \sim \sqrt{\Gamma_{22}^{(\mathrm{brem})}/(2\Gamma_0)} \simeq 0.11$

- Expect similar magnitude for $A(b \to d\gamma_R)/A(b \to d\gamma_L)$ due to imperfect cancellation between (strong phases of) c & u loops

Exclusive $B \to K^*\gamma$

- Can be analyzed using SCET methods, similar to heavy to light form factors

  Technically complicated: in "factorizable" part there is an operator that could contribute at leading order in $\Lambda_{\rm QCD}/m_b$, but its $B \to K^*\gamma$ matrix element vanishes

  NB: $\overline{B}^* \to \overline{K}^{(*)}\gamma_R$ occurs at leading order; yields $\overline{B}^0 \to \overline{B}^{0*}\pi_{\rm (soft)} \to K_S\pi^0_{\rm (soft)}\gamma_R$ with modest $m_{K\pi}$, w/o formal $\Lambda_{\rm QCD}/m$ suppression (probably small numerically)

  Subleading order: several contributions to $\overline{B}^0 \to \overline{K}^{0*}\gamma_R$, no complete study yet

- Our estimate:

$$\frac{A(\overline{B}^0 \to \overline{K}^{0*}\gamma_R)}{A(\overline{B}^0 \to \overline{K}^{0*}\gamma_L)} = \mathcal{O}\left(\frac{C_2}{3C_7}\,\frac{\Lambda_{\rm QCD}}{m_b}\right) \sim 0.1$$

- We do not expect $S_{\rho\gamma} \ll S_{K^*\gamma}$ in SM (contrary to AGS prediction: m_d/m_s)

Conclusions from our analysis

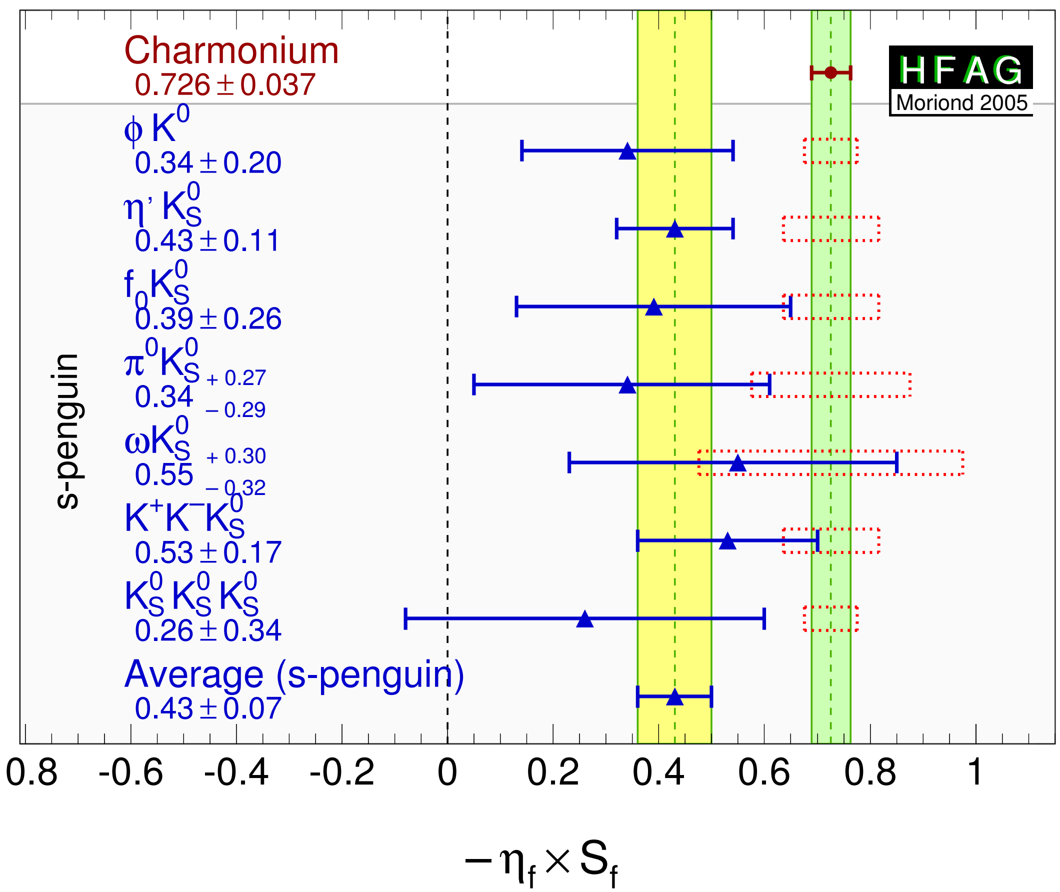
- Lots of room for NP, but SM prediction is not as small and pristine as it was thought
  - Inclusive: $\Gamma(b \to s\gamma_R)/\Gamma(b \to s\gamma_L) = \mathcal{O}(\alpha_s)$
  - Exclusive: $A(\overline{B} \to K^*\gamma_R)/A(\overline{B} \to K^*\gamma_L) = \mathcal{O}(\Lambda_{\rm QCD}/m_b)$
  - $S_{f_s\gamma} \sim \mathcal{O}(0.1)$ is possible
  - $S_{f_s\gamma}$ has significant uncertainties in SM (e.g., it depends on strong phases)
  - The suppression of A_R/A_L is not much stronger in $b \to d\gamma$ than it is in $b \to s\gamma$

- Comments:

– I would not average $S_{K^*\gamma}$ and semi-inclusive $S_{K_S\pi^0\gamma}$

– Not clear if A_R/A_L should increase for higher mass states; may have cancellations between different states decaying to $K(n\,\pi)$ with same invariant mass

S_{f_s} in hadronic $b \to s$ modes



The question

- How large should $S_{f_s} - S_{\psi K}$ be, so that it is definitively due to new physics?

Disclaimers: (i) The following bounds are NOT my best estimates of $|S_{f_s} - S_{\psi K}|$
(That is not the question we were interested in)

(ii) Theory errors have no statistical interpretations; we want several times smaller experimental errors to maximize sensitivity to NP

The successes of the SM are impressive:

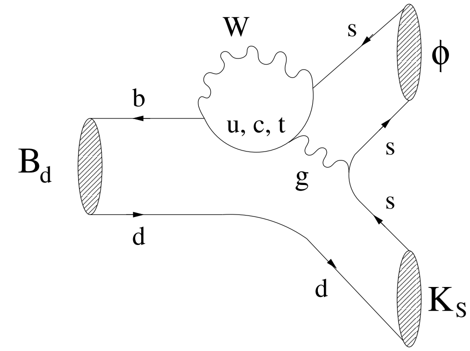
– Any of Δm_K, $\epsilon_K^{(\prime)}$, $\sin 2\beta$, Δm_B, $B \to X_s\gamma$, $X_s\ell^+\ell^-$ could have shown NP

$\Rightarrow$ Only truly convincing deviations are likely to be interesting

CP asymmetry in $B^0 \to f_s$

- Measuring the same angle (β) in different decays may be the best way to find NP

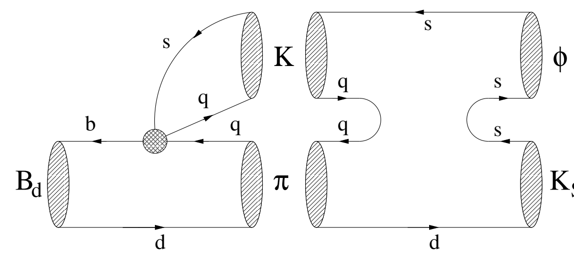
  Amplitudes with one weak phase expected to dominate:

$$A = \underbrace{\overset{[\lambda^2]}{V_{cb}^* V_{cs}}}_{\text{dominant contribution}} [P_c - P_t + T_{c\bar{c}s}] + \underbrace{\overset{[\lambda^4]}{V_{ub}^* V_{us}}}_{\text{suppressed by } \lambda^2} [P_u - P_t + T_{u\bar{u}s}]$$

  In SM: expect $S_{f_s} \approx S_{\psi K}$ and $C_{f_s} \approx 0$ at $\mathcal{O}(\lambda^2) \sim 5\%$ level

  With NP: $S_{f_s} \neq S_{\psi K}$ and $C_{f_s} \neq 0$ possible

  ψK_S: NP could enter through $B - \bar{B}$ mixing

  ϕK_S: NP could enter through both mixing and decay

- Main concern in SM: how to bound $|\bar{A}/A| - 1$, i.e., possible enhancement of $T_{u\bar{u}s}$?

What we are after?

- Bound CKM suppressed (second) term's contribution:

$$A_f \equiv A(B^0 \to f) = V_{cb}^* V_{cs}\, a_f^c + V_{ub}^* V_{us}\, a_f^u = V_{cb}^* V_{cs}\, a_f^c\,(1 + \xi_f)$$

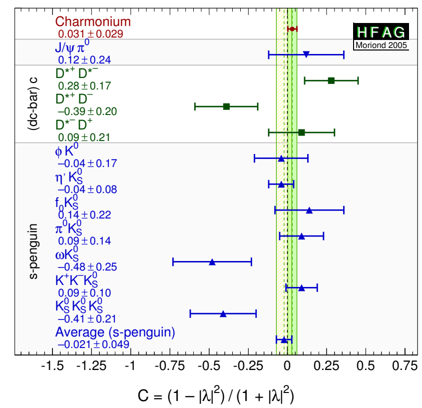
$$\xi_f \equiv \frac{V_{ub}^* V_{us}}{V_{cb}^* V_{cs}}\, \frac{a_f^u}{a_f^c}\,, \qquad \delta_f = \arg \frac{a_f^u}{a_f^c}$$

$$\Rightarrow \quad -\eta_f S_f - \sin 2\beta = 2 \cos 2\beta\, \sin\gamma\, \cos\delta_f\, |\xi_f|$$

$$C_f = -2 \sin\gamma\, \sin\delta_f\, |\xi_f|$$

$$C_f^2 + [(\eta_f S_f + \sin 2\beta)/\cos 2\beta]^2 = 4 \sin^2\gamma\, |\xi_f|^2$$

Bounds are ellipses in $S_f - C_f$ plane; C's near 0



- Bounds on ξ_f depend on amount of hadronic physics one is willing to use
  - $\mathcal{O}(0.04)$ [CKM suppression]
  - $SU(3)$ relations [this talk]
  - Quark model [London & Soni, hep-ph/9704277: ~ 0.02]
  - QCDF [Beneke & Neubert, hep-ph/0210085: ~ 0.07]

Simplest example

- Compare: $B_d^0 \to \pi^0 K^0 \quad (\bar{b} \to q\bar{q}\bar{s})$ vs. $B_s^0 \to \pi^0 \overline{K}^0 \quad (\bar{b} \to q\bar{q}\bar{d})$

  $SU(3)$ flavor symmetry (in this case U-spin) implies amplitude relations:

$$A(B_d^0 \to \pi^0 K^0) = V_{cb}^* V_{cs} \,(P_c - P_t + T_{c\bar{c}s}) + V_{ub}^* V_{us} \,(P_u - P_t + T_{u\bar{u}s}) \equiv P + T$$

$$A(B_s^0 \to \pi^0 \overline{K}^0) = V_{cb}^* V_{cd} \,(P_c - P_t + T_{c\bar{c}s}) + V_{ub}^* V_{ud} \,(P_u - P_t + T_{u\bar{u}s}) = \lambda\, P + \lambda^{-1}\, T$$

- 0'th approx.: assume B_d decay dominated by P, while B_s by T

$$|\xi| \equiv \left|\frac{T}{P}\right| = \lambda \sqrt{\frac{\Gamma(B_s^0 \to \pi^0 \overline{K}^0)}{\Gamma(B_d^0 \to \pi^0 K^0)}}$$

- 1'st approx.: without assumptions

$$\left|\frac{\xi + \lambda^2}{1 + \xi}\right| = \lambda \sqrt{\frac{\Gamma(B_s^0 \to \pi^0 \overline{K}^0)}{\Gamma(B_d^0 \to \pi^0 K^0)}}$$

hard for $|\xi|_{\rm max}$ to approach λ^2
(would need info on phases)

Next complications: no B_s data, octet-singlet mixing, messy amplitude relations

General case

- For $\bar{b} \to q\bar{q}\bar{s}$ transitions:

  $$A_f = V_{cb}^* V_{cs}\, a_f^c + V_{ub}^* V_{us}\, a_f^u = V_{cb}^* V_{cs}\, a_f^c\, (1 + \xi_f)$$

  For $\bar{b} \to q\bar{q}\bar{d}$ transitions:

  $$A_{f'} = V_{cb}^* V_{cd}\, b_{f'}^c + V_{ub}^* V_{ud}\, b_{f'}^u = V_{ub}^* V_{ud}\, b_{f'}^u\, (1 + \lambda^2 \xi_{f'}^{-1})$$

- $SU(3)$ gives relations among a_f^q and $b_{f'}^q$: $a_f^u = \sum_{f'} x_{f'}\, b_{f'}^u$

  The branching ratios $\mathcal{B}(f)$ constrain a_f^c and $b_{f'}^u$: $\left| \frac{V_{ub}^* V_{ud}}{V_{cb}^* V_{cs}} \frac{b_{f'}^u}{a_f^c} \right| \sim \sqrt{\frac{\mathcal{B}(f')}{\mathcal{B}(f)}}$

- Combining $SU(3)$ and experimental data gives, conservatively:

  $$|\xi_f| \equiv \left| \frac{V_{ub}^* V_{us}}{V_{cb}^* V_{cs}} \frac{a_f^u}{a_f^c} \right| < \left| \frac{V_{us}}{V_{ud}} \right| \sum_{f'} |x_{f'}| \sqrt{\frac{\mathcal{B}(f')}{\mathcal{B}(f)}}$$

  As explained, the bound is on $\left| \frac{\xi_f + (V_{us}V_{cd})/(V_{ud}V_{cs})}{1+\xi_f} \right|$, small difference if $\lambda^2 \ll \xi_f < 1$

$SU(3)$ relations for $B \to P_8 P_8$

- $H \sim (\bar{b}\, q_i)(\bar{q}_j q_k)$ transforms as

  $3 \times 3 \times \bar{3} = 15 + \bar{6} + 3 + 3$

  $8 \times 8 = 27 + 10 + \overline{10} + 8_S + 8_A + 1$

  5 amplitudes describe 15 final states when $SU(3)$ breaking is neglected

  For $\eta^{(\prime)}$ (singlet part), 3 more $B \to P_8 P_1$ matrix elements

  $\Rightarrow$ Relations among the matrix elements

$f^{(\prime)}$	A_{15}^{27}	A_{15}^{8}	$A_{\bar{6}}^{8}$	A_{3}^{8}	A_{3}^{1}
$\eta_8 K^0$	$4\sqrt{6}/5$	$1/\sqrt{6}$	$-1/\sqrt{6}$	$-1/\sqrt{6}$	0
$K^0 \pi^0$	$12\sqrt{2}/5$	$1/\sqrt{2}$	$-1/\sqrt{2}$	$-1/\sqrt{2}$	0
$K^+ \pi^-$	$16/5$	-1	1	1	0
$\eta_8 K^+$	$8\sqrt{6}/5$	$-\sqrt{3/2}$	$1/\sqrt{6}$	$-1/\sqrt{6}$	0
$K^+ \pi^0$	$16\sqrt{2}/5$	$3/\sqrt{2}$	$-1/\sqrt{2}$	$1/\sqrt{2}$	0
$K^0 \pi^+$	$-8/5$	3	-1	1	0
$\eta_8 \pi^0$	0	$5/\sqrt{3}$	$1/\sqrt{3}$	$-1/\sqrt{3}$	0
$\pi^0 \pi^0$	$-13\sqrt{2}/5$	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/(3\sqrt{2})$	$\sqrt{2}$
$\eta_8 \eta_8$	$3\sqrt{2}/5$	$-1/\sqrt{2}$	$-1/\sqrt{2}$	$-1/(3\sqrt{2})$	$\sqrt{2}$
$\pi^- \pi^+$	$14/5$	1	1	$1/3$	2
$K^- K^+$	$-2/5$	2	0	$-2/3$	2
$K^0 \overline{K^0}$	$-2/5$	-3	-1	$1/3$	2
$\eta_8 \pi^+$	$4\sqrt{6}/5$	$\sqrt{6}$	$-\sqrt{2/3}$	$\sqrt{2/3}$	0
$\pi^+ \pi^0$	$4\sqrt{2}$	0	0	0	0
$K^+ \overline{K^0}$	$-8/5$	3	-1	1	0

- Decomposition of a_f^u and $b_{f'}^u$ identical with that of a_f^c and $b_{f'}^c$, although the matrix elements are independent $\Rightarrow$ use: $a(f) \equiv a_f^{u,c}$ and $b(f') \equiv b_{f'}^{u,c}$

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$\eta' K_S$: the answer

- Best bound at present comes from: $(s \equiv \sin\theta_{\eta\eta'},\, c \equiv \cos\theta_{\eta\eta'})$

$$a(\eta' K^0) = \frac{s^2 - 2c^2}{2\sqrt{2}} b(\eta'\pi^0) - \frac{3sc}{2\sqrt{2}} b(\eta\pi^0) + \frac{\sqrt{3}s}{4} b(\pi^0\pi^0)$$
$$- \frac{\sqrt{3}s(s^2+4c^2)}{4} b(\eta'\eta') + \frac{3\sqrt{3}sc^2}{4} b(\eta\eta) + \frac{\sqrt{3}c(2c^2-s^2)}{2\sqrt{2}} b(\eta\eta')$$

$$|\xi_{\eta' K_S}| < \left|\frac{V_{us}}{V_{ud}}\right| \left(0.59\sqrt{\frac{\mathcal{B}(\eta'\pi^0)}{\mathcal{B}(\eta' K^0)}} + 0.33\sqrt{\frac{\mathcal{B}(\eta\pi^0)}{\mathcal{B}(\eta' K^0)}} + 0.14\sqrt{\frac{\mathcal{B}(\pi^0\pi^0)}{\mathcal{B}(\eta' K^0)}} \right.$$
$$\left. + 0.53\sqrt{\frac{\mathcal{B}(\eta'\eta')}{\mathcal{B}(\eta' K^0)}} + 0.38\sqrt{\frac{\mathcal{B}(\eta\eta)}{\mathcal{B}(\eta' K^0)}} + 0.96\sqrt{\frac{\mathcal{B}(\eta\eta')}{\mathcal{B}(\eta' K^0)}} \right)$$

- Yields: $|\xi_{\eta' K_S}| < 0.17$

Using the $\eta' K^+$ mode

- Similar relations hold for charged B decays ($x =$ free param.)

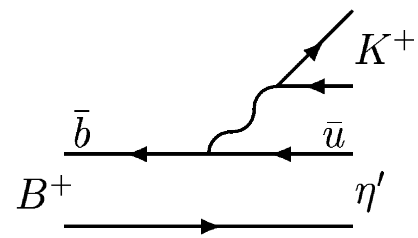
$$a(\eta' K^+) = \frac{(3-x)cs}{2}\, b(\eta\pi^+) + \frac{(x-1)s^2 + 2c^2}{2}\, b(\eta'\pi^+) + \frac{(x-3)s}{2\sqrt{3}}\, b(\pi^+\pi^0) + \frac{xs}{\sqrt{6}}\, b(\overline{K^0} K^+)$$

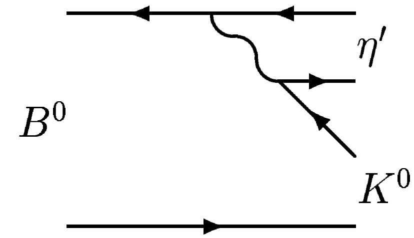
Experimental data $\Rightarrow$ $|\xi_{\eta' K^+}| < 0.08$

- We have $a^c_{\eta' K^0} = a^c_{\eta' K^+}$, but $a^u_{\eta' K^0} \neq a^u_{\eta' K^+}$

$a^u_{\eta' K^+}$ has a color-allowed tree contribution

$a^u_{\eta' K^0}$ only arises from a color-suppressed tree diagram or penguins





- Assumption: $|a^u_{\eta' K^+}| \not< |a^u_{\eta' K^0}|$ (l.h.s. larger in large-N_c; comparable in SCET)

$\Rightarrow$ $|\xi_{\eta' K_S}| < 0.08$

Bounds for $B \to \phi K_S$

- For PV final state, more matrix elements... more complicated relations:

$$a(\phi K^0) = \frac{1}{2}\left[b(\overline{K^{*0}}K^0) - b(K^{*0}\overline{K^0})\right] + \frac{1}{2}\sqrt{\frac{3}{2}}\left[cb(\phi\eta) - sb(\phi\eta')\right]$$
$$+ \frac{\sqrt{3}}{4}\left[cb(\omega\eta) - sb(\omega\eta')\right] - \frac{\sqrt{3}}{4}\left[cb(\rho^0\eta) - sb(\rho^0\eta')\right]$$
$$+ \frac{1}{4}\,b(\rho^0\pi^0) - \frac{1}{4}b(\omega\pi^0) - \frac{1}{2\sqrt{2}}\,b(\phi\pi^0)$$

$\Rightarrow$ No bound on $\xi_{\phi K_S}$ using only $SU(3)$ at present (because of $\overline{K^{*0}}K^0$ and $K^{*0}\overline{K^0}$)

- Charged modes: $a(\phi K^+) = b(\phi\pi^+) + b(\overline{K^{*0}}K^+)$ (Grossman, Isidori, Worah)

Contrary to $\eta' K_S$, $a^u_{\phi K^0}$ and $a^u_{\phi K^+}$ are of same order in N_c ($u\bar{u} \to \phi$ is suppressed)

Dynamical assumption: $|a^u_{\phi K^+}| \not< |a^u_{\phi K^0}|$ $\Rightarrow$ $|\xi_{\phi K_S}| < 0.23$

A plea...

- Progress since CKM '03:

$\xi_{\eta' K_S}$ bound: 0.36 in '03 $\to 0.17$ now [$\eta' K^+$ bound: $0.09 \to 0.08$]

[Due to new data: hep-ex/0403046, hep-ex/0412043]

$\xi_{\phi K^+}$ bound: 0.25 in '03 $\to 0.23$ now [still no ϕK_S bound based only on $SU(3)$]

- HFAG $\to$ Rare Decays $\to$ Charmless Mesonic $\to$ B^+ table: $\overline{K}^{*0} K^+$ is one of 7 modes where CLEO rules [no Babar / Belle data; all are $K\pi h(h)$ type final states]

ϕK_S: No bound yet on $\overline{K}^{*0} K^0$ and $K^{*0} \overline{K}^0$

A plea...

- Progress since CKM '03:

$\xi_{\eta' K_S}$ bound: 0.36 in '03 $\to$ 0.17 now [$\eta' K^+$ bound: $0.09 \to 0.08$]

[Due to new data: hep-ex/0403046, hep-ex/0412043]

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Someone, please, look at these!

Other interesting modes

- 3-body modes: No time for $K^+K^-K_S$ and $K_SK_SK_S$ [Engelhard, Nir, Raz, ZL, to appear]

- We missed: $B \to \pi^0 K_S$ — simple amplitude relation:

$$a(\pi^0 K_S) = \frac{1}{\sqrt{2}}\, b(K^+K^-) - b(\pi^0\pi^0)$$

  Follows from table shown 5 pages earlier... not noticed until asked by Babarians

  $\Rightarrow \ |\xi_{\pi^0 K_S}| < 0.15$ [Gronau, Grossman, Rosner, PLB 579 (2004) 331]

- Other 2-body modes:

  E.g.: could $B \to \rho^0 K_S$ have much larger rate than $B \to \pi^0 K_S$?

  Amplitude relations involve: $B \to \rho^0\pi^0,\ \rho^0 K^0,\ K^{*0}\pi^0,\ K^{*\pm}K^{\mp}$

Summary for $S_{\eta' K_S}$ and $S_{\phi K}$

- $S_{\eta' K_S} = 0.43 \pm 0.11:$ largest single deviation from $S_{\psi K}$ at present (2.5σ)

  Conservative SM bound: $|\xi_{\eta' K_S}| < 0.17$ (< 0.08 using $\eta' K^+$ and large N_c)

  $S_{\eta' K_S}$ at its present central value with $<$ half the error would signal NP

  Would not only exclude SM, but MFV and universal SUSY models such as GMSB

- $S_{\phi K} = 0.34 \pm 0.20:$ significant effect still possible, need to further decrease errors

  No bound yet based only on $SU(3)$; w/ some dynamical assumption, $|\xi_{\phi K_S}| < 0.23$

  $S_{\phi K_S}$ at its present central value with smaller error would be a sign of NP

- There is a lot to learn from more precise measurements

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Conclusions

- Consistency of SM fit does not imply similarly tight constraints on NP
- Right-handed photon polarization in $B \to X\gamma$ is only suppressed by α_s and $\Lambda_{\rm QCD}/m_b$; $S_{K^*\gamma}$, $S_{K_S\pi^0\gamma} \sim 0.1$ possible in SM, significantly larger implies NP
- Our bounds on $|\sin 2\beta - S_{f_s}|$ are weaker than estimates based on explicit calculations, but have the advantage of being model independent
- $SU(3)$ breaking effects could be significant, but the bounds are probably still very conservative — with more data the bounds will improve
- Present $S_{\eta' K_S}$ and $S_{\phi K_S}$ central values with 5σ significance would be convincing signals of NP