GOLDEN Channels

for New Physics searches in $b \to s$ penguins

Javier Virto

CKM Workshop Sept'08

Sponsor: FlaviA net

some GOLDEN Channels

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some GOLDEN Channels for New Physics searches in $b \to s$ penguins

which you already know about

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Hadronic b->s decays: Generalities

$$A(B \to f) = \langle f|\mathcal{H}_{eff}^{SM}|B\rangle + A^{NP}$$

$$\mathcal{H}_{eff}^{SM} = \frac{G_F}{\sqrt{2}} \left\{ V_{ub}V_{us}^* \left[C_1 Q_1^u + C_2 Q_2^u + \sum_{i=3..12} C_i Q_i \right] + V_{cb}V_{cs}^* \left[C_1 Q_1^c + C_2 Q_2^c + \sum_{i=3..12} C_i Q_i \right] \right\}$$

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$$\begin{aligned} A(B \to f) &= V_{ub} V_{us}^* \; P_u \; + \; V_{cb} V_{cs}^* \; P_c \; + \; A^{NP} \\ &= V_{cb} V_{cs}^* \; P_c \left[1 + \; \mathcal{O}(\lambda^2) \; + \; \mathcal{O}\left(\frac{M_W^2}{{\Lambda_{NP}^{\Delta S=1}}^2} \right) \right] \end{aligned}$$

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Bad :(

Good! :)

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$$= V_{cb}V_{cs}^*\ P_c\left[1 + \mathcal{O}(\lambda^2)\ +\ \mathcal{O}\left(\frac{M_W^2}{{\Lambda_{NP}^{\Delta S=1}}^2}\right)\right]$$

Approximation (too naive, wait a minute):

$$S_f = -\eta_{CP}\ sin\phi_M + \mathcal{O}(\lambda^2)$$

$$C_f = 0\ +\ \mathcal{O}(\lambda^2)$$

Hadronic b->s decays: Generalities

- For tree (b->suū) decays $P_u \gg P_c$

so $O(\lambda^2)$ could mean ~ 20% !!

- For pure penguins (e.g. b->sdd̄) in principle

$P_u \sim P_c$, so $O(\lambda^2)$ ~ few % "really".

BUT could there be enhancements

making $P_u \gg P_c$??!

Hadronic b->s decays: Generalities

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  $P_u \sim P_c$, so $\mathcal{O}(\lambda^2)$ ~ few % "really".

  BUT could there be enhancements

  making $P_u \gg P_c$??!

$\mathcal{O}(\lambda^2)$ doesn't let us see $\mathcal{O}\left(\frac{M_W^2}{\Lambda_{NP}^{b \to s\,2}}\right)$

-> MUST compute hadronic corrcts.

Some b->s's I will comment on:

- $B_d \to \phi K_S, \pi^0 K_S, \eta' K_S,$ e.t.c...

  --> for sin(2β)

- $B_s \to K^{0*} \bar{K}^{0*}, \phi K^{0*}, \phi\phi$

  --> for sin(2β_s)

- $B_s \to KK, B_d \to \pi K$

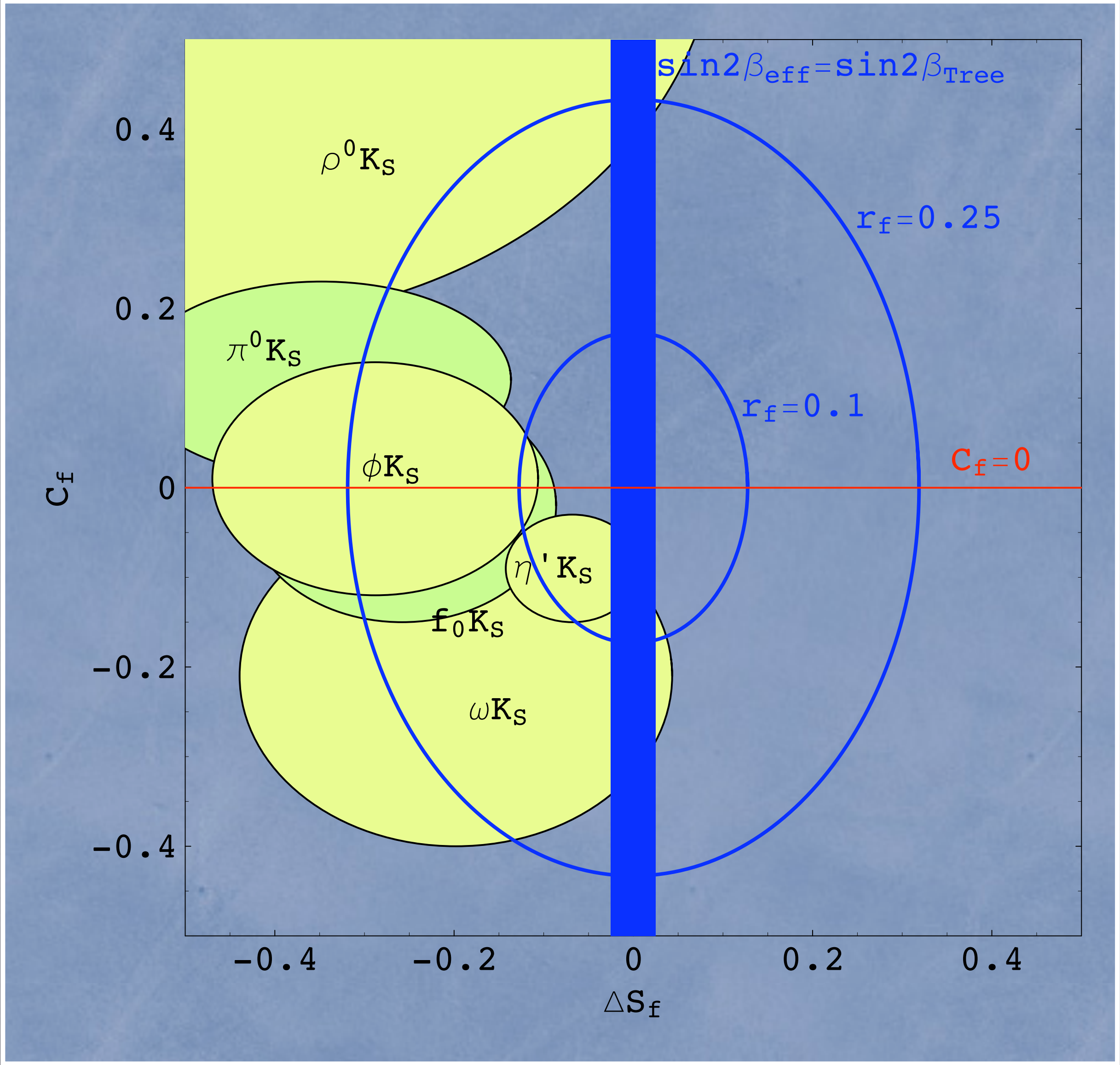
  --> for γ and other NP CPV issues

The $\sin(2\beta)_{penguin}$ Situation

-We write: $\epsilon_f e^{i\delta_f} = \left|\frac{V_{ub}V_{us}^*}{V_{cb}V_{cs}^*}\right|\frac{P_u}{P_c}$; $-\eta_f^{CP} S_f = \sin 2\beta + \Delta S_f$

so that: $\Delta S_f = 2\epsilon_f \cos\delta_f \sin\gamma \cos 2\beta$

$$C_f = -2\epsilon_f \sin\delta_f \sin\gamma$$



- General trend for negative ΔS_f
- C_f consitent with zero gives no info on the size of ϵ_f .

The $\sin(2\beta)_{penguin}$ Situation

- $B_d \to \phi K_S$ (Theory)

– SU(3): [Grossman,Isidori,Worah'98 , Grossman,Ligeti,Nir,Quinn'03, ...]

$$|\Delta S_{\phi K_S}| < \sqrt{2}\,\lambda \left(\sqrt{\frac{BR(B^+ \to \phi\pi^+)}{BR(B_d \to \phi K_S)}} + \sqrt{\frac{BR(B^+ \to K^* K^+)}{BR(B_d \to \phi K_S)}} \right) + \mathcal{O}(\lambda^2) \lesssim 0.3$$

– QCDF: $0.01 < \Delta S_{\phi K_S} < 0.05$ [Beneke'05]

(safe minimal QCDF input + BR : $0.03 < \Delta S_{\phi K_S} < 0.06$ [Virto'07])

QCDF + FSI : $\Delta S_{\phi K_S} = 0.03^{+0.01}_{-0.04}$ [Cheng,Chua,Soni'05]

– GP: $\Delta S_{\phi K_S} = 0 \pm 0.09$ [Silvestrini'07]

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$B_d \to \phi K_S$ (Experiment)

- Current (*) : $\Delta S^{exp}_{\phi K_S} = -0.29 \pm 0.18$ [HFAG,BaBar,Belle'07]

- LHC: $2fb^{-1} : N \sim 920,\ 0.3 < B/S < 1.1,\ \sigma_S \sim 0.23$

  $10fb^{-1} : \sigma_S \sim 0.10$ [Xie, LHCb-2007-130]

- SuperB: $75ab^{-1} : \sigma_S \sim 0.02$!! [SuperB CDR '07]

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The sin (2β)$_{penguin}$ Situation

- $B_d \to \eta' K_S,\ \pi^0 K_S$ (Theory)

	QCDF	SCET	GP
$\Delta S_{\eta' K_s}$	[0.00-0.03]	-0.019±0.008 -0.010±0.010	-0.007±0.054
$\Delta S_{\pi^0 K_s}$	[0.02-0.015]	0.077±0.030	0.024±0.059

[Beneke'05 , Williamson,Zupan'06 , Silvestrini'07]

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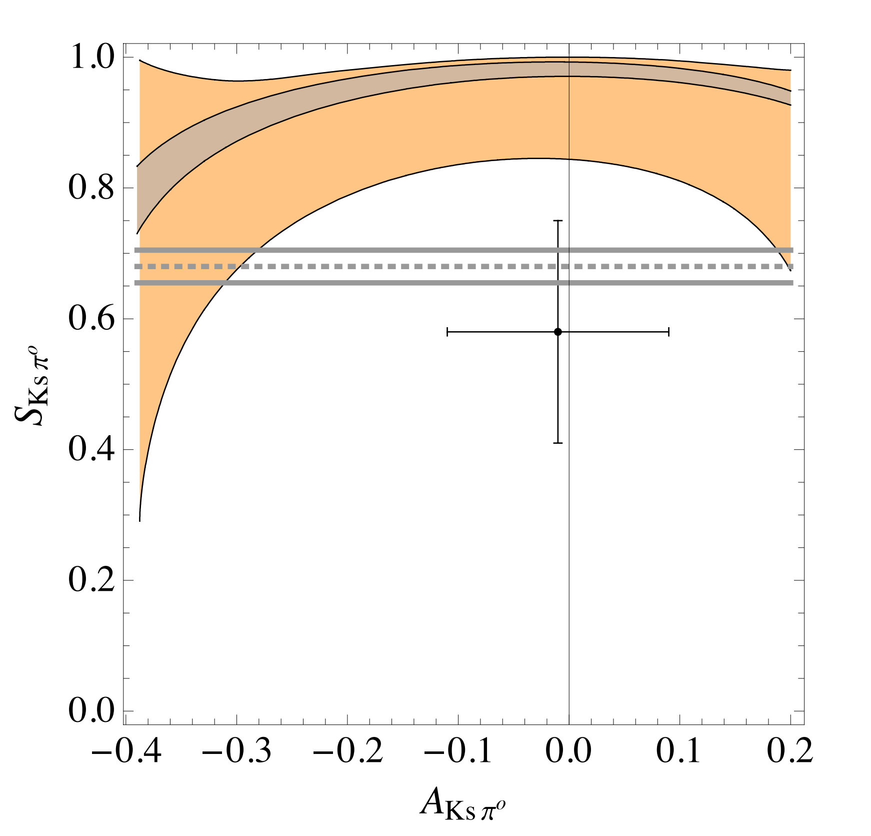
[Fleischer,Jäger,Pirjol,Zupan '08]



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	Current	LHC	SuperB (75at^{-1})
$\Delta S_{\eta' K_s}$	-0.11±0.08	?	$\sigma_S \sim 0.01$
$\Delta S_{\pi^0 K_s}$	-0.13±0.21	?	$\sigma_S \sim 0.02$

[BaBar'08 , SuperB CDR'07]

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[BaBar'08 , SuperB CDR'07]

Interesting B_s->VV modes

- The polarization issue

- Naive factorization: $1 - f_0 = \mathcal{O}(1/m_b^2)\ , \quad \frac{f_\perp}{f_\parallel} = 1 + \mathcal{O}(1/m_b^2)$

$$B \to \rho\rho \quad \to \quad \begin{cases} f_0 &= 0.941^{+0.034}_{-0.040} \pm 0.030 \\ f_0 &= 0.997 \pm 0.024^{+0.015}_{-0.013} \end{cases} \quad \surd$$

[Belle'03]

[BaBar'06]

$$B \to \phi K^{o*} \quad \to \quad \begin{cases} f_0 &= 0.45 \pm 0.05 \pm 0.02 \\ f_0 &= 0.506 \pm 0.004 \pm 0.015 \end{cases} \quad \times$$

[Belle'05]

[BaBar'04]

-> Leading order Non-fact. corrections to transverse amps [Kagan'04, Beneke,Rohrer,Yang'06]

- But more suited for hadronic machines
- Time-dep angular analysis -> long obs.

Interesting B_s->VV modes

- $B_s \to K^{o*}\bar{K}^{o*}$ (Theory)

- QCDF: [Beneke,Rohrer,Yang'06]

BR (10^{-6})	A_{CP} (%)	$\phi_{\parallel}$ (deg)	f_L	A^0_{CP} (%)
$9.1^{+0.5\ +11.3}_{-0.4\ -6.8}$	1^{+2}_{-1}	-34^{+110}_{-62}	63^{+42}_{-29}	$11^{+3\ +7}_{-3\ -17}$

- Similar results from pQCD [Ali et.al.'07]

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- From $BR(B_s \to K^{o*}\bar{K}^{o*})$ and QCDF input:

$$BR_s^L \gtrsim 3 \cdot 10^{-5} \quad \Rightarrow \quad (S^L_{K^*K^*} - 0.051) < \sin 2\beta_s < (S^L_{K^*K^*} - 0.037)$$

also in SM: $C^L_{K^*K^*} = 0.000 \pm 0.014$, $S^L_{K^*K^*} = 0.004 \pm 0.018$

[Descotes-Genon,Matias,Virto'07]

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[Descotes-Genon,Matias,Virto'07]

- Null tests:

writing $A(B_s- > f) = V_{tb}V_{ts}P_t + V_{ub}V_{us}P_u$

we have: $S_f = \sin(2\beta_s - 2\beta_s) + \mathcal{O}(\lambda^2) = 0 + \mathcal{O}(\lambda^2)$

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SU(3) analysis $B_d \to K^{o*}\bar{K}^{o*} \leftrightarrow B_s \to K^{o*}\bar{K}^{o*}$

Estimate: $\sigma(S_{K^*K^*}) \sim 0.013$!! [Ciuchini,Pierini,Silvestrini'07]

100% SU(3) breaking, model independent

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Interesting B_s->VV modes

- Other decays of similar application:

$$B_s \to \phi K^* \qquad B_s \to \phi\phi$$

- LHC sensitivity:

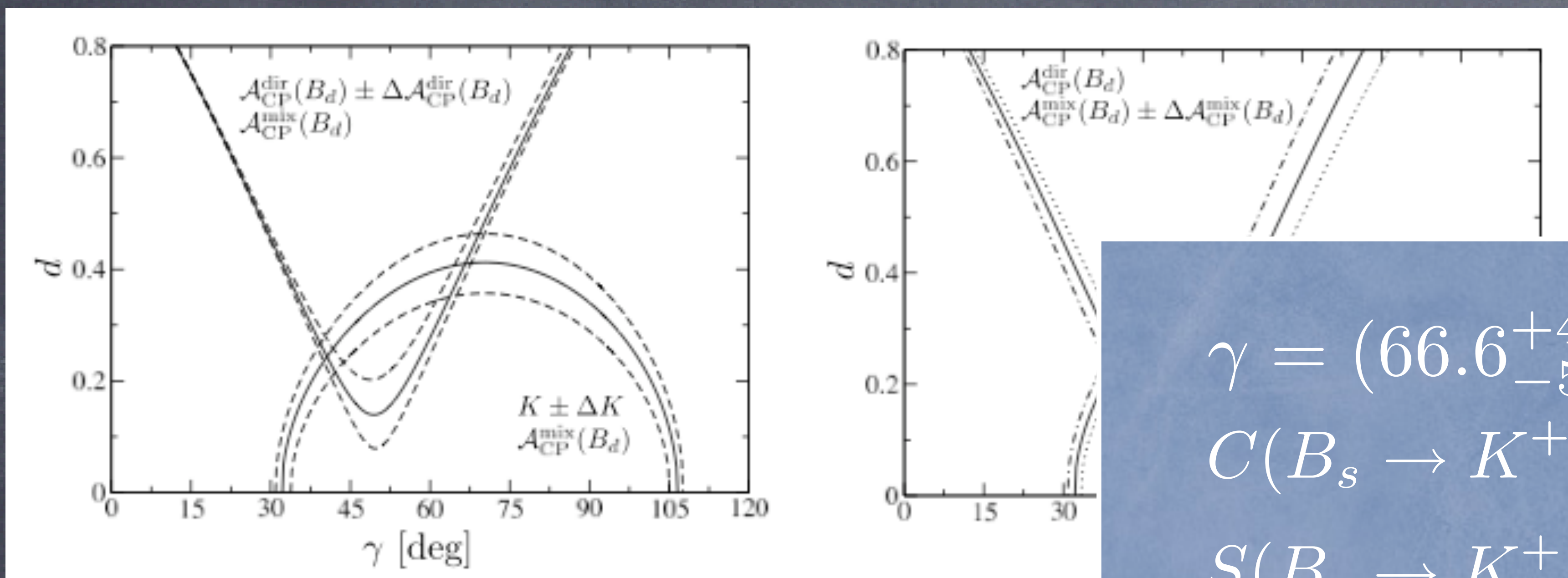
$$2fb^{-1} \quad \to \quad 3100 \text{ events}, \ B/S < 0.8, \ \sigma(S_{\phi\phi}) = 0.11$$

$$10fb^{-1} \quad \to \quad \sigma(S_{\phi\phi}) = 0.05$$

[Amato et.al. LHC-2007-047]

The two $B_s \to KK$ channels

- The $B_d \to \pi^+\pi^-$ vs $B_s \to K^+K^-$ strategy:



[Fleischer'99, Fleischer'07]

$$\gamma = (66.6^{+4.3+4.0+0.1}_{-5.0-3.0-0.2})^{\circ}$$

$$C(B_s \to K^+K^-) = 0.101^{+0.055}_{-0.047}$$

$$S(B_s \to K^+K^-) = -0.246^{+0.036}_{-0.030}$$

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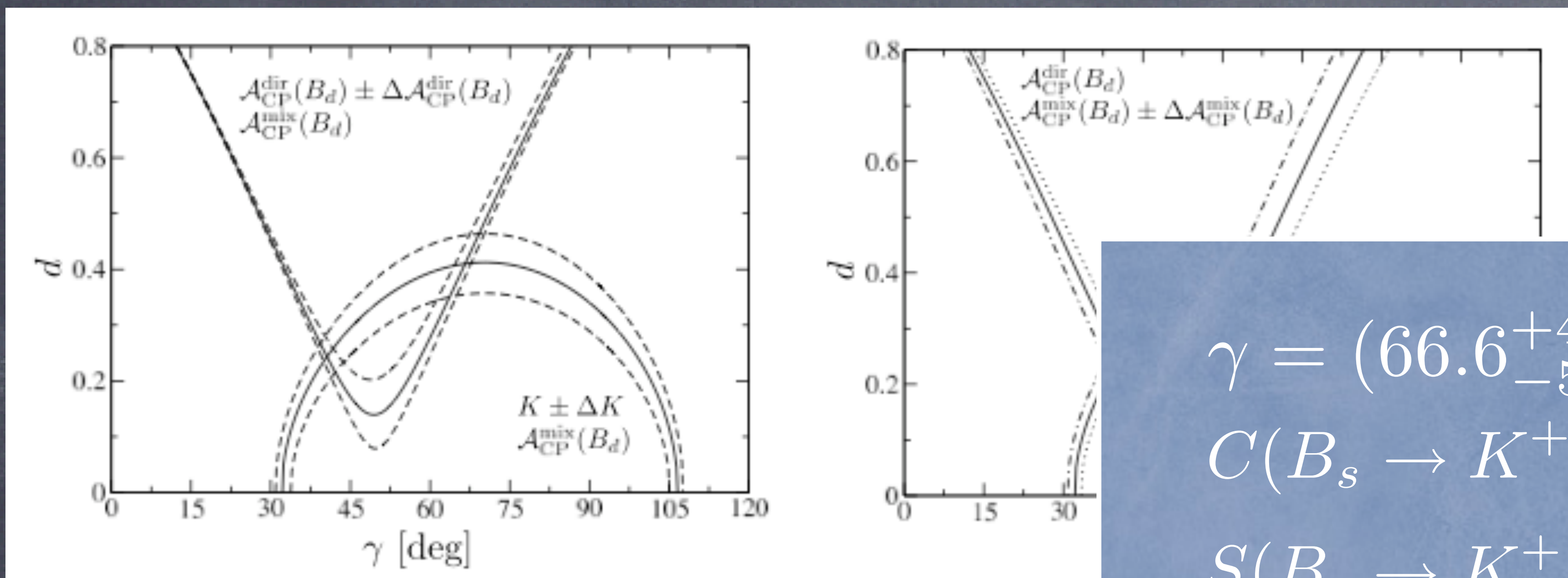

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+ Sensitivity @LHCb with $2fb^{-1}$:

Channel	B/S	N/yr	$\sigma(C)$	$\sigma(S)$
$B_d \to \pi^+\pi^-$	< 0.8	27k	0.054	0.054
$B_s \to K^+K^-$	< 0.55	35k	0.043	0.043

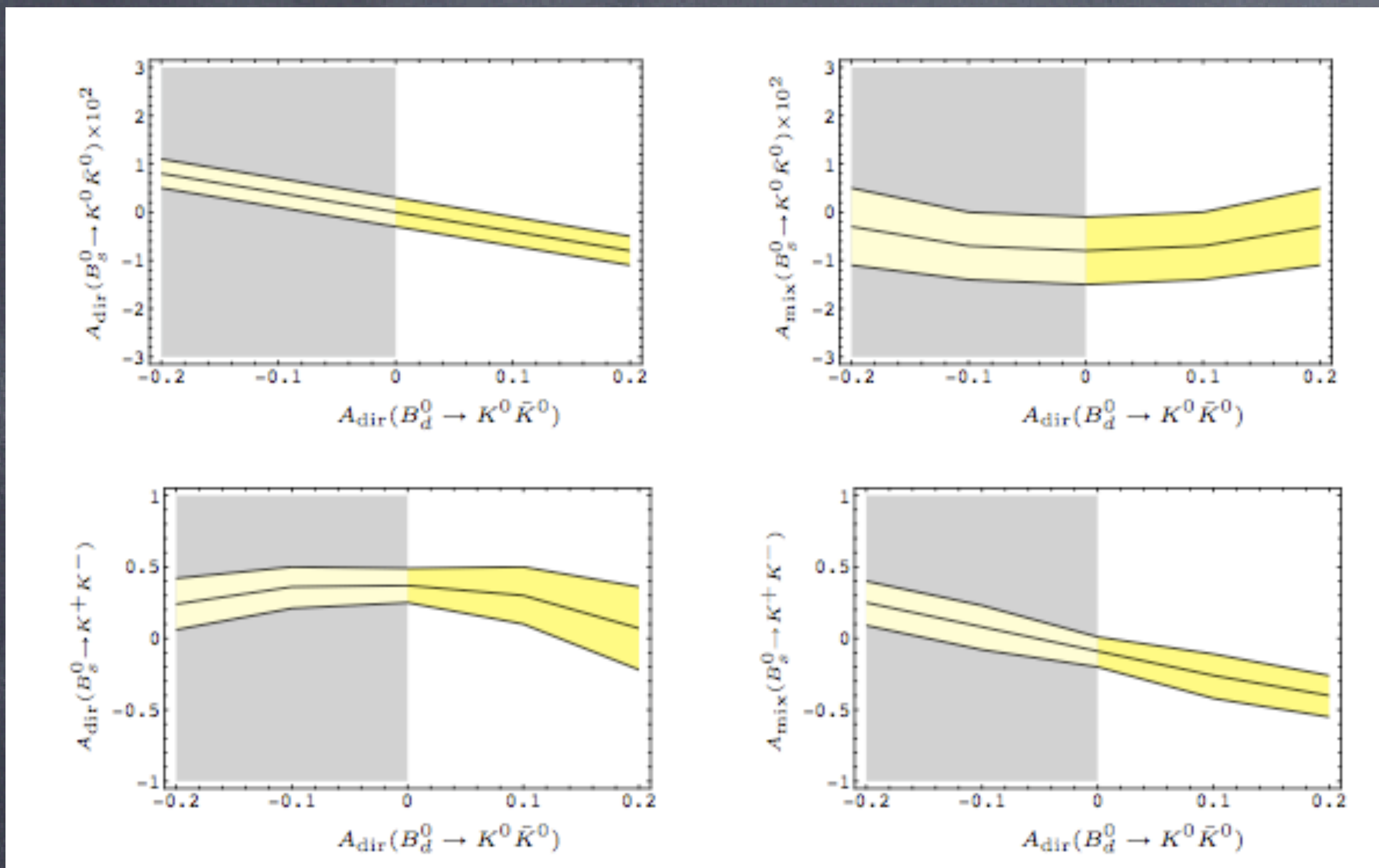
[Vagnoni'03]

and $\sigma(\gamma) \sim 10^{\circ}$

[Gibson , LHCb-2007-100]

The two B_s->KK channels

- $B_s \to K^+K^-$ and $B_s \to K^0\bar{K}^0$ from $B_d \to K^0\bar{K}^0$:



[Descotes-Genon,Matias,Virto'06]
[Baek,London,Matias,Virto'06]

$$BR(B_s^0 \to K^0\bar{K}^0) = (18 \pm 7 \pm 4 \pm 2) \times 10^{-6}\,,$$
$$BR(B_s^0 \to K^+K^-) = (17 \pm 6 \pm 3 \pm 2) \times 10^{-6}\,.$$

Improvable by better measurements of Bd->KK

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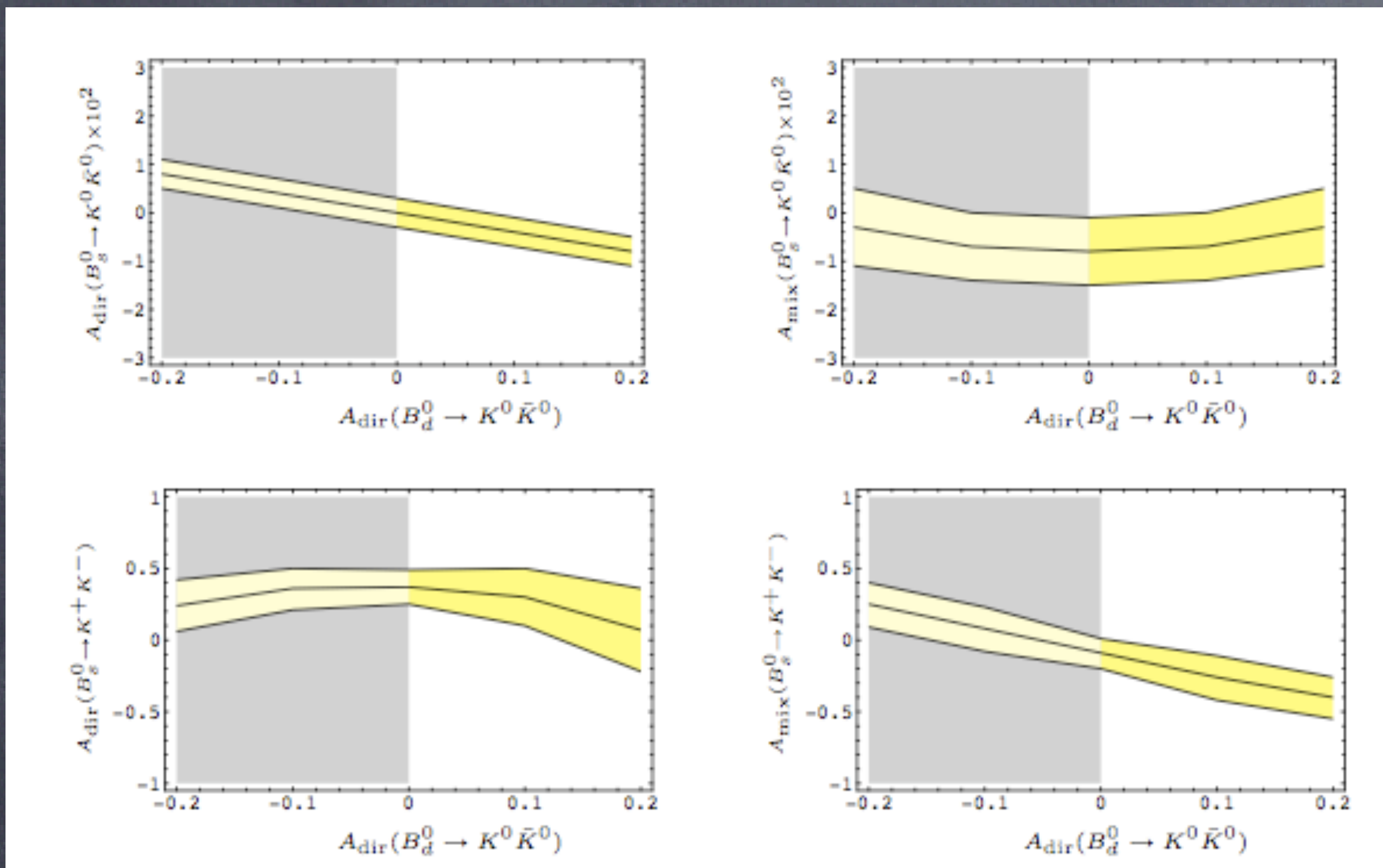

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Improvable by better measurements of Bd->KK

-Experiment:

$$BR(B_s^0 \to K^+K^-)_{\rm exp} = (24.4 \pm 1.4 \pm 3.5) \times 10^{-6} \,.$$

[CDF'08]

* CP A's @ LHC, ~5% error for charged mode.
* Neutral mode NOT good for LHC. Maybe SuperB?

A comment on B->πK

Isospin:

$$A(B_d \to K^+\pi^-) = -Te^{i\gamma} - P$$

$$\sqrt{2}A(B^+ \to K^+\pi^0) = -(T + C + A)e^{i\gamma} - P - P_{EW}$$

Expected Hierarchies:

$$|P| : |T|, |P_{EW}| : |C| \sim 1 : \lambda : \lambda^2$$ [Gronau et.al.'95]

$$|A/T| \lesssim 0.1$$ [Beneke,Neubert'04]

$$\Rightarrow \quad A_{CP}(B_d \to K^+\pi^-) - A_{CP}(B^+ \to K^+\pi^0) \sim 0$$

Experiment:

$$A_{CP}(B_d \to K^+\pi^-) = -0.097 \pm 0.012$$

$$A_{CP}(B^+ \to K^+\pi^0) = 0.050 \pm 0.025$$ [BaBar'08 , Belle'08]

Some final comments

- Any of these modes could establish a non-zero NP contribution in b->s in next few years
- LHCb and SFF are complementary. We need SFF for many golden B->PP.
- Comparison with tree-decays and mixing determinations to pin down the important NP ops.
- Analyses of different correlations in NP models will help to figure out what kind of NP is.
- Of course if direct NP searches are successfull, even better!