CP Violation & New Physics in B_s Decays

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- Setting the Stage

- $B_s \to J/\psi\phi$:

  - B_s counterpart of $B_d \to J/\psi K_S \Rightarrow \boxed{\phi_s}$
  - Sensitive to new-physics effects in B^0_s–$\overline{B^0_s}$ mixing.

- $B_s \to K^+K^-$:

  - Complements $B_d \to \pi^+\pi^- \Rightarrow \boxed{\gamma}$
  - Sensitive to new-physics effects in the penguin sector.

- $B_s \to D_s^{(*)\pm}K^{\mp}$:

  - Complements nicely $B_d \to D^{(*)\pm}\pi^{\mp} \Rightarrow \boxed{\gamma}$
  - Tree decays, i.e. small sensitivity on new-physics effects.

- Conclusions and Outlook

Setting the Stage

Basic Features

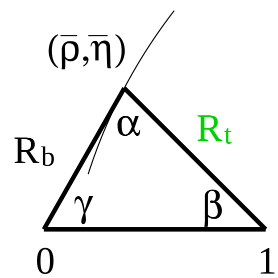
- At the e^+e^- B factories operating at the $\Upsilon(4S)$ resonance, no B_s mesons are accessible!

- Plenty of B_s mesons will be produced at hadron colliders:

$\Rightarrow$ "El Dorado" for B studies @ Tevatron-II and LHC!

- Mass difference ΔM_s:

  - $\Delta M_s/\Delta M_d \Rightarrow R_t$ from $\xi \equiv \sqrt{\hat{B}_{B_s}} f_{B_s}/(\sqrt{\hat{B}_{B_d}} f_{B_d})$:



  - $\Delta M_s|_{\rm exp} > 14.4\text{ps}^{-1} \Rightarrow \gamma \lesssim 90^\circ$!
  - Controversy concerning theoretical uncertainties of ξ...

[Kronfeld & Ryan; see talk by Becirevic]

- Decay width difference $\Delta\Gamma_s$:

  - $\Delta\Gamma_s/\Gamma_s = \mathcal{O}(-10\%)$, while $\Delta\Gamma_d/\Gamma_d$ is negligible!
  - Interesting studies with "untagged" B_s-decay rates:

$$\langle\Gamma(B_q(t) \to f)\rangle \equiv \Gamma(B_q^0(t) \to f) + \Gamma(\overline{B_q^0}(t) \to f).$$

[Dunietz (1995); R.F. & Dunietz (1996–97)]

Our Focus: CP Violation

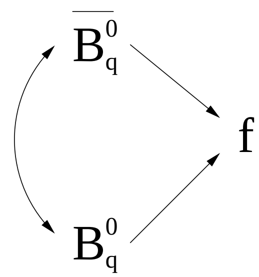
- Time-dependent CP asymmetry for $(\mathcal{CP})|f\rangle = \pm|f\rangle$:

$$\frac{\Gamma(B^0_q(t)\to f)-\Gamma(\overline{B^0_q}(t)\to f)}{\Gamma(B^0_q(t)\to f)+\Gamma(\overline{B^0_q}(t)\to f)}$$
$$= \left[\frac{\mathcal{A}_{\rm CP}^{\rm dir}\cos(\Delta M_q t)+\mathcal{A}_{\rm CP}^{\rm mix}\sin(\Delta M_q t)}{\cosh(\Delta\Gamma_q t/2)-\mathcal{A}_{\Delta\Gamma}\sinh(\Delta\Gamma_q t/2)}\right]$$

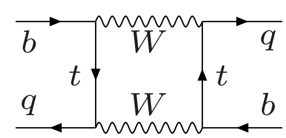
- Observables:

$$\mathcal{A}_{\rm CP}^{\rm dir}\equiv\frac{1-\left|\xi_f^{(q)}\right|^2}{1+\left|\xi_f^{(q)}\right|^2},\quad \mathcal{A}_{\rm CP}^{\rm mix}\equiv\frac{2\,{\rm Im}\,\xi_f^{(q)}}{1+\left|\xi_f^{(q)}\right|^2}$$

$$\xi_f^{(q)}=-e^{-i\phi_q}\left[\frac{A(\overline{B^0_q}\to f)}{A(B^0_q\to f)}\right]$$



$$\phi_q \stackrel{\rm SM}{=} 2\arg(V_{tq}^*V_{tb}) = \left\{\begin{array}{cc} +2\beta & (q=d)\\ -2\lambda^2\eta & (q=s)\end{array}\right.$$



- $\Delta\Gamma_s$ provides $\mathcal{A}_{\Delta\Gamma}$: $\quad\left[\mathcal{A}_{\rm CP}^{\rm dir}\right]^2+\left[\mathcal{A}_{\rm CP}^{\rm mix}\right]^2+\left[\mathcal{A}_{\Delta\Gamma}\right]^2=1$

$$\langle\Gamma(B_q(t)\to f)\rangle\propto\left[\cosh(\Delta\Gamma_q t/2)-\mathcal{A}_{\Delta\Gamma}\sinh(\Delta\Gamma_q t/2)\right]e^{-\Gamma_q t}$$

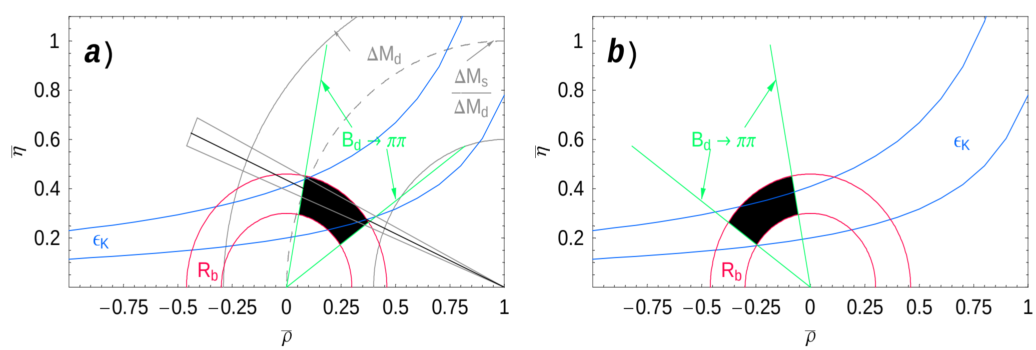
$\Rightarrow$ $\mathcal{A}_{\Delta\Gamma}$ from untagged measurements!

Impact of New Physics

- Preferred Mechanism: B_q^0–$\overline{B_q^0}$ Mixing
  - Highly CKM suppressed, loop-induced, fourth order weak interaction process in the SM!
  - Simple dimensional arguments suggest that new physics in the TeV regime may well manifest itself as follows:
    - $\Delta M_q \longrightarrow$ impact on R_t, if different NP in $\Delta M_{d,s}$.
    - $\phi_q \longrightarrow$ Impact on CP Violation!

[Nir & Silverman; Grossman, Nir & Worah; R.F. & Mannel; ...]

- $\sin\phi_d \sim 0.734$: $\Rightarrow \phi_d \sim \underbrace{47^\circ\,(\mathrm{a})}_{\mathrm{SM}} \vee \underbrace{133^\circ\,(\mathrm{b})}_{\mathrm{NP!?}}$
  - Analysis of CP violation in $B_d \to \pi^+\pi^-$ suggests:



  - Interestingly, $B \longrightarrow \pi K$, $B \longrightarrow \pi\pi$ branching ratios seem to favour $\gamma \gtrsim 90^\circ$, as well as $K^+ \to \pi^+\nu\overline{\nu}$...

[R.F., Isidori & Matias, hep-ph/0302229, to appear in *JHEP*]

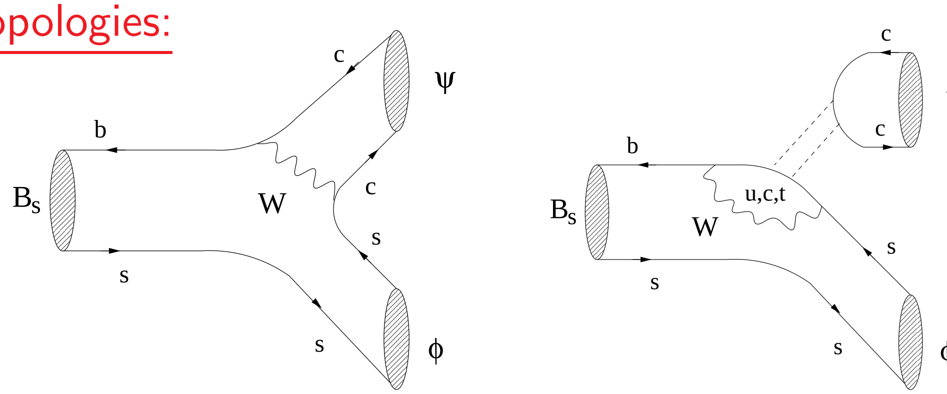
Burning Question:

Is ϕ_s Sizeable?

$$\longrightarrow \quad \boxed{B_s \to J/\psi\phi}$$

... B_s-meson counterpart of $B_d \to J/\psi K_S$

- Topologies:



  - Amplitude structure: $A(B_s \to J/\psi\, \phi) \propto \left[1 + \lambda^2 a e^{i\vartheta} e^{i\gamma}\right]$
  - Plausible assumption: [$\overline{\lambda}$: generic "expansion" parameter]

$$a e^{i\vartheta} = \frac{\text{"Penguin"}}{\text{"Tree"}} = \mathcal{O}(0.2) = \mathcal{O}(\overline{\lambda}) \equiv \mathcal{O}(\lambda).$$

Final state is admixture of different CP eigenstates ...

- Angular distribution of $J/\psi[\to \ell^+\ell^-]\phi[\to K^+K^-]$: $\Rightarrow$
  - Direct CP-violating effects: $0 + \mathcal{O}(\overline{\lambda}^3)$
  - Mixing-induced CP-violating effects:

$$\boxed{\sin\phi_s + \mathcal{O}(\overline{\lambda}^3) = \sin\phi_s + \mathcal{O}(10^{-3})}$$

[Dighe, Dunietz & R.F. (1999)]

- Standard Model: $\phi_s = -2\lambda^2\eta = \mathcal{O}(10^{-2}) \;\Rightarrow$

Hadronic uncertainties of O(10%)!

[In contrast to the $B_d \to J/\psi K_S$ case!]

  - Can be controlled through $B_d \to J/\psi \rho^0$ [R.F. (1999)]

- Another interesting aspect:

  – $B_s \to J/\psi[\to \ell^+\ell^-]\phi[\to K^+K^-]$ angular distribution:

$$\Rightarrow \boxed{\cos\delta_f \cos\phi_s}$$

  * Fixing the sign of $\cos\delta_f$ through factorization:

$$\Rightarrow \text{sgn}(\cos\phi_s) \Rightarrow \boxed{\textit{unambiguous}\text{ value of } \phi_s!}$$

  – Important question, also if $\sin\phi_s \approx 0$ should be found...

    [Dunietz, R.F. & Nierste, *Phys. Rev.* **D63** (2001) 114015]

  – Also recently addressed with $B_s \to D_\pm \eta^{(\prime)}$, $D_\pm \phi$, ...

    [R.F., hep-ph/0301255, to appear in *Phys. Lett.* **B**, see below]

- Big Hope: **Experiments will find *sizeable* value of $\sin\phi_s$**

  ... immediate signal for NP because of tiny SM "background"!

  – Specific recent NP analyses with large impact on $\sin\phi_s$:

    * SUSY: Ciuchini *et al.*, *Phys. Rev.* **D67** (2003) 075016
    * Left-right symmetric model: Silverman *et al.*, hep-ph/0305013
    * ...

$$\boxed{B_s \to K^+K^-}$$

- Dominated by QCD penguin processes!

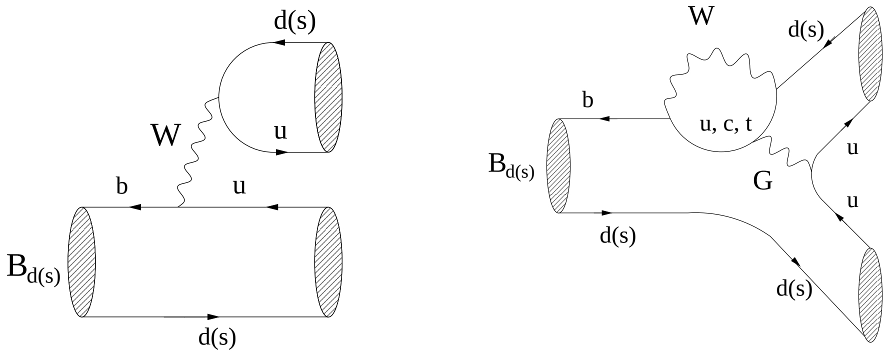
- Complements nicely $B_d \to \pi^+\pi^-$:

  U-spin symmetry $\Rightarrow$ $\boxed{\gamma}$ [R.F. ('99)]

- Other U-spin strategies to extract γ:

  - $B_{s(d)} \to J/\psi K$; $B_{d(s)} \to D^+_{d(s)} D^-_{d(s)}$ [R.F. ('99)]
  - $B_{(s)} \to \pi K$ [Gronau & Rosner (2000)]
  - $B_{s(d)} \to J/\psi \eta$ [Skands (2000)]

Amplitudes & Observables



- Structure of decay amplitudes:

$$A(B_d^0 \to \pi^+\pi^-) \quad \propto \quad \left[e^{i\gamma} - de^{i\theta}\right]$$

$$A(B_s^0 \to K^+K^-) \quad \propto \quad \left[e^{i\gamma} + \left(\frac{1-\lambda^2}{\lambda^2}\right) d'e^{i\theta'}\right]$$

$$de^{i\theta} = \left.\frac{\text{“Pen”}}{\text{“Tree”}}\right|_{B_d\to\pi^+\pi^-}, \quad d'e^{i\theta'} = \left.\frac{\text{“Pen”}}{\text{“Tree”}}\right|_{B_s\to K^+K^-}$$

- CP-violating observables:

$$\mathcal{A}_{\rm CP}^{\rm dir}(B_d \to \pi^+\pi^-) \quad = \quad \text{function}(d, \theta, \gamma)$$

$$\mathcal{A}_{\rm CP}^{\rm mix}(B_d \to \pi^+\pi^-) \quad = \quad \text{function}(d, \theta, \gamma, \phi_d)$$

$$\mathcal{A}_{\rm CP}^{\rm dir}(B_s \to K^+K^-) \quad = \quad \text{function}(d', \theta', \gamma)$$

$$\mathcal{A}_{\rm CP}^{\rm mix}(B_s \to K^+K^-) \quad = \quad \text{function}(d', \theta', \gamma, \phi_s)$$

Extracting γ & Strong Parameters

- As we have seen, ϕ_d and ϕ_s can "straightforwardly" be fixed, also if NP should contribute to B_q^0–$\overline{B_q^0}$ mixing:

  – $\mathcal{A}_{\rm CP}^{\rm dir}(B_d \to \pi^+\pi^-)$ & $\mathcal{A}_{\rm CP}^{\rm mix}(B_d \to \pi^+\pi^-)$:

  $\Rightarrow$ $d = d(\gamma)$, in a *theoretically clean* way!

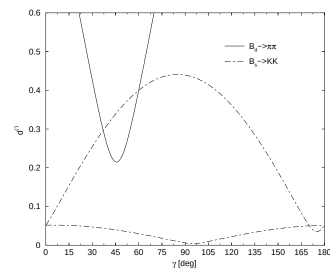
  – $\mathcal{A}_{\rm CP}^{\rm dir}(B_s \to K^+K^-)$ & $\mathcal{A}_{\rm CP}^{\rm mix}(B_s \to K^+K^-)$:

  $\Rightarrow$ $d' = d'(\gamma)$, in a *theoretically clean* way!

- U-spin symmetry $\Rightarrow$ $d = d', \quad \theta = \theta'$

  – $d = d'$ $\Rightarrow$ extraction of γ, d, θ, θ'

  – $\theta = \theta'$ provides interesting U-spin check!



[R.F., *Phys. Lett.* **B459** (1999) 306]

- Experimental accuracy of $\mathcal{O}(10^\circ)$ and $\mathcal{O}(1^\circ)$ for γ may be achieved at Tevatron-II and LHCb/BTeV, respectively:

$\Rightarrow$ very promising!

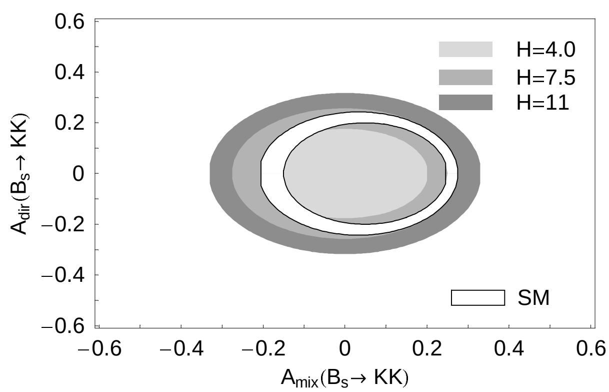
[Report of B-Decay Working Group, LHC Workshop, hep-ph/0003238; B Physics at the Tevatron: Run II and beyond, hep-ph/0201071]

Waiting for $B_s \to K^+K^-$ ...

- BR($B_s \to K^+K^-$) $\approx$ BR($B_d \to \pi^\mp K^\pm$): $\Rightarrow$ estimate for

$$H = \left(\frac{1-\lambda^2}{\lambda^2}\right)\left[\frac{\text{BR}(B_d \to \pi^+\pi^-)}{\text{BR}(B_s \to K^+K^-)}\right] \sim 7.5.$$

- Using $d = d'$ *and* $\theta = \theta'$: $\Rightarrow$ $\boxed{H = \text{function}(d, \theta, \gamma)}$ $\Rightarrow$
  - γ, d, θ from CP violation in $B_d \to \pi^+\pi^-$! [see above]
  - Allowed region in $B_s \to K^+K^-$ observable space:



[$\phi_s = 0^\circ$; SM: $50^\circ \leq \gamma \leq 70^\circ$]

$\Rightarrow$ **Very narrow target range for CDF-II & LHCb!**

[R.F. & J. Matias, *Phys. Rev.* **D66** (2002) 054009]

- Already the measurement of BR($B_s \to K^+K^-$) by CDF-II will be an important and exciting achievement...

$$B_s \to D_s^{(*)\pm} K^{\mp}, \ldots$$

- Pure "tree" decays!
- Complement nicely $B_d \to D^{(*)\pm}\pi^{\mp}, \ldots$:
  - Same theoretical basis!
  - New strategies...

R.F., hep-ph/0304027

- History & alternative strategies:

Aleksan, Dunietz & Kayser, *Z. Phys.* **C54** (1992) 653

R.F. & Dunietz, *Phys. Lett.* **B387** (1996) 361

Dunietz, *Phys. Lett.* **B427** (1998) 179

London, Sinha & Sinha, *Phys. Rev. Lett.* **85** (2000) 1807

Diehl & Hiller, *Phys. Lett.* **B517** (2001) 125

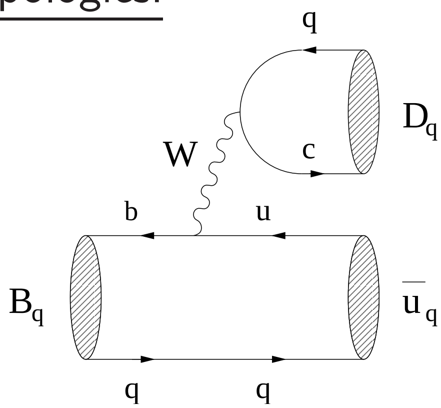
Suprun, Chiang & Rosner, *Phys. Rev.* **D65** (2002) 054025

Gronau, Pirjol & Wyler, *Phys. Rev. Lett.* **90** (2003) 051801

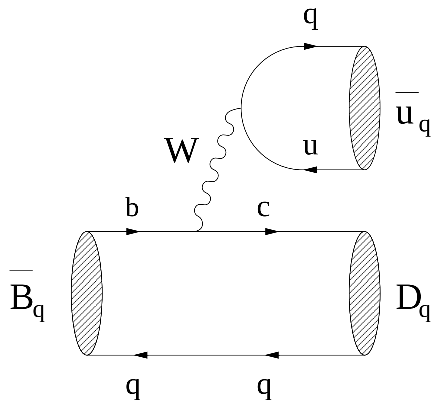
...

Basic Features

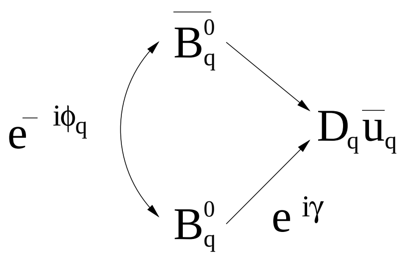
- Topologies:



$\propto e^{i\gamma}$



no weak phase



$$\boxed{\phi_q + \gamma}$$

- Distinguish between the following cases:

  - $q = s$: $D_s \in \{D_s^+, D_s^{*+}, \ldots\}$, $u_s \in \{K^+, K^{*+}, \ldots\}$:

    $\longrightarrow$ hadronic parameter $x_s e^{i\delta_s} \propto R_b \Rightarrow$ *large* effects!

  - $q = d$: $D_d \in \{D^+, D^{*+}, \ldots\}$, $u_d \in \{\pi^+, \rho^+, \ldots\}$:

    $\longrightarrow$ hadronic parameter $x_d e^{i\delta_d} \propto -\lambda^2 R_b \Rightarrow$ *tiny* effects!

[For simplicity, we require that at least one of the D_q, $\overline{u}_q$ states is a pseudoscalar meson. Otherwise, an angular analysis is needed!]

Conventional Extraction of $\phi_q + \gamma$

- Observables provided by $\cos(\Delta M_q t)$ terms:

$$\left.\begin{array}{l} C(B_q \to D_q \overline{u}_q) \equiv C_q \\ C(B_q \to \overline{D}_q u_q) \equiv \overline{C}_q \end{array}\right\} \Rightarrow \langle C_q \rangle_{\pm} \equiv \frac{\overline{C}_q \pm C_q}{2}:$$

$$\boxed{\langle C_q \rangle_- = (1 - x_q^2)/(1 + x_q^2) \quad \Rightarrow \quad x_q \text{ from } \mathcal{O}(x_q^2) \text{ terms!}}$$

  - $q = s$: $x_s = \mathcal{O}(R_b) \approx 0.4 \;\Rightarrow\; x_s^2 = \mathcal{O}(0.16)$
  - $q = d$: $x_d = \mathcal{O}(-\lambda^2 R_b) \approx -0.02 \;\Rightarrow\; x_d^2 = \mathcal{O}(0.0004)$!!!

- Observables provided by $\sin(\Delta M_q t)$ terms:

$$\left.\begin{array}{l} S(B_q \to D_q \overline{u}_q) \equiv S_q \\ S(B_q \to \overline{D}_q u_q) \equiv \overline{S}_q \end{array}\right\} \Rightarrow \langle S_q \rangle_{\pm} \equiv \frac{\overline{S}_q \pm S_q}{2}:$$

$$s_+ \equiv (-1)^L \left[\frac{1 + x_q^2}{2\, x_q}\right] \langle S_q \rangle_+ = +\cos\delta_q \sin(\phi_q + \gamma)$$

$$s_- \equiv (-1)^L \left[\frac{1 + x_q^2}{2\, x_q}\right] \langle S_q \rangle_- = -\sin\delta_q \cos(\phi_q + \gamma)$$

[Note the $(-1)^L$ factors, where L is the $D_q \overline{u}_q$ angular momentum!]

$$\boxed{\sin^2(\phi_q + \gamma) = \frac{1}{2}\left[(1 + s_+^2 - s_-^2) \pm \sqrt{(1 + s_+^2 - s_-^2)^2 - 4 s_+^2}\right]}$$

$\Rightarrow$ Eightfold solution for $\phi_q + \gamma$!

[sgn$(\cos\delta_q) > 0$, as suggested by factorization $\Rightarrow$ fourfold solution]

Closer Look at "Untagged" Rates

- New strategy employing $\Delta\Gamma_s$:
  - If the width difference $\Delta\Gamma_s$ is sizeable, time-dependent untagged rates provide observables $\overline{\mathcal{A}}_{\Delta\Gamma_s}$ and $\mathcal{A}_{\Delta\Gamma_s}$:

$$\Rightarrow \boxed{\tan(\phi_s+\gamma) = -\left[\frac{\langle S_s\rangle_+}{\langle \mathcal{A}_{\Delta\Gamma_s}\rangle_+}\right] = +\left[\frac{\langle \mathcal{A}_{\Delta\Gamma_s}\rangle_-}{\langle S_s\rangle_-}\right]}$$

... essentially *unambiguous* value of $\phi_s+\gamma$, i.e. of γ!

  - Because of $\langle S_s\rangle_\pm \propto x_s$ and $\langle \mathcal{A}_{\Delta\Gamma_s}\rangle_\pm \propto x_s$, we have *not* to rely on $\mathcal{O}(x_s^2)$ terms, but need sizeable $\Delta\Gamma_s$...

- Untagged rates are also very useful in the case of small $\Delta\Gamma_q$:

$\Rightarrow$ Extraction of "unevolved" untagged rates

... various strategies to determine x_q from the ratio of

$$\langle \Gamma(B_q\to D_q\overline{u}_q)\rangle + \langle \Gamma(B_q\to \overline{D}_q u_q)\rangle$$

and CP-averaged rates of $B^\pm$ or flavour-specific B_q decays:

- $B_d^0\to D^{(*)+}\pi^-$: $B^+\to D^{(*)+}\pi^0$ or $B_d^0\to D_s^+\pi^-$
- $B_s^0\to D_s^{(*)+}K^-$: $B^+\to D_s^{(*)+}\pi^0$ or $B_s^0\to D_s^{(*)-}\pi^+$

Bounds on $\phi_q + \gamma$

- Keeping δ_q and x_q as "unknown", free parameters yields

$$\boxed{|\sin(\phi_q+\gamma)| \geq |\langle S_q\rangle_+|, \quad |\cos(\phi_q+\gamma)| \geq |\langle S_q\rangle_-|} \qquad (1)$$

- If x_q has been measured, *stronger* constraints arise from

$$\boxed{|\sin(\phi_q+\gamma)| \geq |s_+|, \quad |\cos(\phi_q+\gamma)| \geq |s_-|} \qquad (2)$$

- Once s_+ and s_- are known, we may of course determine $\phi_q + \gamma$ through the "conventional" approach...

- However, the bounds in (2) provide essentially the same information and are much simpler to implement:

$$\gamma = 60^\circ,\ \phi_d = 47^\circ,\ \phi_s = 0^\circ,\ x_d = -0.02,\ x_s = 0.4 \ \longrightarrow$$

  - $\delta_d = \delta_s = 0^\circ$:
    - B_d: $26^\circ \leq \gamma \leq 60^\circ$ $\quad [\gamma|_{\rm conv.} = 26^\circ \vee 43^\circ \vee 60^\circ]$
    - B_s: $60^\circ \leq \gamma \leq 120^\circ$ $\quad [\gamma|_{\rm conv.} = 60^\circ \vee 90^\circ \vee 120^\circ]$

    $\Rightarrow$ overlap of $\gamma = 60^\circ$!
  - $\delta_d = \delta_s = 40^\circ$:
    - B_d: $(0^\circ \leq \gamma \leq 32^\circ) \vee (54^\circ \leq \gamma \leq 86^\circ)$

      $[\gamma|_{\rm conv.} = 3^\circ \vee 26^\circ \vee 60^\circ \vee 83^\circ]$
    - B_s: $(42^\circ \leq \gamma \leq 71^\circ) \vee (109^\circ \leq \gamma \leq 138^\circ)$

      $[\gamma|_{\rm conv.} = 50^\circ \vee 60^\circ \vee 120^\circ \vee 130^\circ]$

    $\Rightarrow$ overlap of $54^\circ \leq \gamma \leq 71^\circ$!

Combined Analysis of $B_{s,d} \to D_{s,d}\overline{u}_{s,d}$ Modes

- $B_s^0 \to D_s^{(*)+}K^-$, $B_d^0 \to D^{(*)+}\pi^-$ related through $s \leftrightarrow d$:

$$U\text{-spin symmetry} \quad \Rightarrow \quad \boxed{a_s = a_d \quad \text{and} \quad \delta_s = \delta_d}$$

$$a_s = \frac{x_s}{R_b}, \quad a_d = -\left(\frac{1-\lambda^2}{\lambda^2}\right)\frac{x_d}{R_b} \quad \to \quad \left|\frac{\text{Hadr. ME}}{\text{Hadr. ME}}\right|$$

- Various possibilities to implement these relations:
  - For example, assume that $a_s = a_d$ *and* $\delta_s = \delta_d$:

$$\boxed{\tan\gamma = -\left[\frac{\sin\phi_d - S\sin\phi_s}{\cos\phi_d - S\cos\phi_s}\right]}$$

$$S = -R\left[\frac{\langle S_d\rangle_+}{\langle S_s\rangle_+}\right] \quad \text{with} \quad R = \left(\frac{1-\lambda^2}{\lambda^2}\right)\left[\frac{1}{1+x_s^2}\right]$$

$$R = \left(\frac{f_K}{f_\pi}\right)^2\left[\frac{\Gamma(\overline{B^0_s} \to D_s^{(*)+}\pi^-) + \Gamma(B^0_s \to D_s^{(*)-}\pi^+)}{\langle\Gamma(B_s \to D_s^{(*)+}K^-)\rangle + \langle\Gamma(B_s \to D_s^{(*)-}K^+)\rangle}\right]$$

  - Alternatively, we may *only* assume that $\delta_s = \delta_d$ *or* $a_s = a_d$ ...

- Important advantages, apart from features related to ambiguities:
  - x_d has *not* to be fixed, and x_s may *only* enter through $1 + x_s^2$ correction, determined from *untagged* B_s rates!
  - Measurement of x_s/x_d would *only* be interesting for the inclusion of U-spin-breaking effects in a_s/a_d!

Colour-Suppressed $B_q \to D^0 f_r, \overline{D^0} f_r$ Modes

- $B_d \to D K_{\mathrm{S(L)}}$, $B_s \to D\eta^{(\prime)}, D\phi, \ldots$: $x_{f_s} e^{i\delta_{f_s}} \propto R_b$

CP eigenstates $D_\pm$: $\Rightarrow$ additional interference effects:

$$\Gamma^{f_s}_{+-} \equiv \frac{\langle \Gamma(B_q \to D_+ f_s)\rangle - \langle \Gamma(B_q \to D_- f_s)\rangle}{\langle \Gamma(B_q \to D_+ f_s)\rangle + \langle \Gamma(B_q \to D_- f_s)\rangle}$$

$$\Rightarrow \quad \boxed{|\cos\gamma| \geq |\Gamma^{f_s}_{+-}|}$$

$$\langle S_{f_s}\rangle_\pm \equiv \frac{S^{f_s}_+ \pm S^{f_s}_-}{2} \quad \text{with} \quad S^{f_s}_\pm \equiv \mathcal{A}^{\mathrm{mix}}_{\mathrm{CP}}(B_q \to D_\pm f_s) \quad \Rightarrow$$

$$\boxed{\tan\gamma \cos\phi_q = \left[\frac{\eta_{f_s}\langle S_{f_s}\rangle_+}{\Gamma^{f_s}_{+-}}\right] + \left[\eta_{f_s}\langle S_{f_s}\rangle_- - \sin\phi_q\right]}$$

[$\eta_{f_s} \equiv (-1)^L \eta^{f_s}_{\mathrm{CP}}$, where L is angular momentum of Df_s]

- $B_s \to D_\pm K_{\mathrm{S(L)}}$, $B_d \to D_\pm \pi^0, D_\pm \rho^0, \ldots$: $x_{f_d} e^{i\delta_{f_d}} \propto -\lambda^2 R_b$

$$\boxed{\eta_{f_d}\langle S_{f_d}\rangle_- = \sin\phi_q + \mathcal{O}(x^2_{f_d}) = \sin\phi_q + \mathcal{O}(4\times 10^{-4})}$$

... theoretical accuracy is one order of magnitude better than in $B_s \to J/\psi\phi$, i.e. ϕ_s^{SM} with $\mathcal{O}(1\%)$ uncertainty!

[R.F., hep-ph/0301255 ($\to$ PLB) & hep-ph/0301256 ($\to$ NPB)]

Conclusions and Outlook

- Will $B_s \to \psi\phi$ show sizeable mixing-induced CP-violating effects, thereby indicating NP effects in B_s^0–$\overline{B_s^0}$ mixing?

- B_s decays offer interesting avenues to extract γ, e.g.,:

  - $B_s \to K^+K^-$ & $B_d \to \pi^+\pi^-$:

    * Governed by QCD penguin processes!

  - $B_s \to D_s^{(*)\pm}K^\mp$ & $B_d \to D^{(*)\pm}\pi^\mp$:

    * Pure "tree" decays!

Will discrepancies show up?

... could indicate NP effects in the penguin sector!

- B_s decays are the "El Dorado" for B-physics studies at hadron colliders:

  - Important first steps at run II of the Tevatron.

  - Physics potential can be fully exploited by LHCb & BTeV.