B-Physics Probes for New Physics in the LHC Era

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Portorož 2011: The Role of Heavy Fermions in Fundamental Physics
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- Setting the Stage
- B Physics in the LHC Era: $\rightarrow$ Promising Channels for NP Signals:
  - $B_s^0 \to J/\psi\phi$: critical look at hadronic corrections.
  - $B_s^0 \to K^+K^-$, $B_d^0 \to \pi^+\pi^-$: picture from current data.
  - $B_s^0 \to \mu^+\mu^-$: fragmentation functions are crucial for measurement.
- Concluding Remarks

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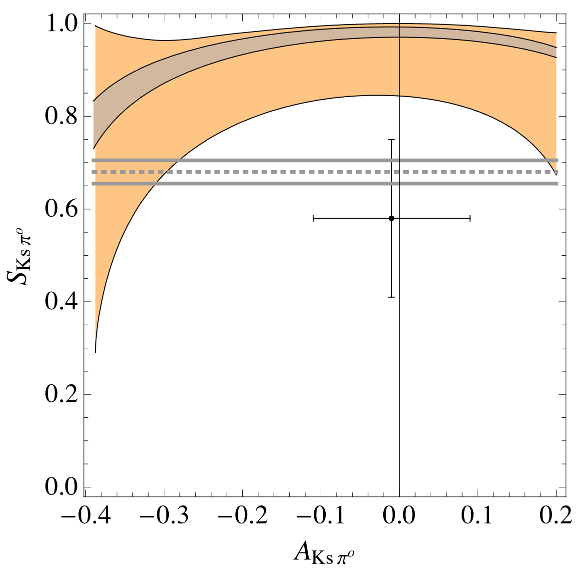
Setting the Stage

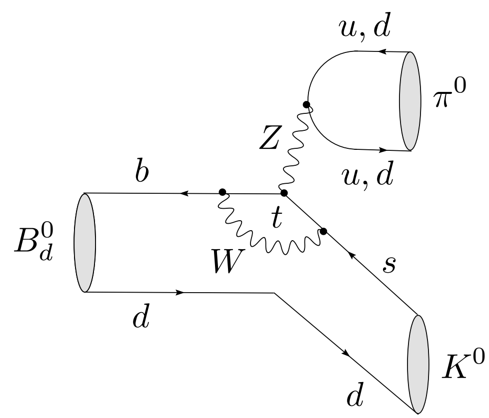
(New) Flavour Physics: Where Do We Stand?

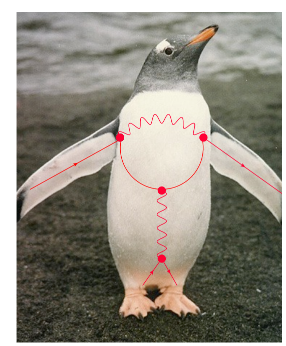
- Lessons from the B, D, K, ... data collected so far:
  - CKM matrix is the dominant source of flavour and CP violation.
  - New effects not yet established, although there are potential signals:
    - $*$ *Example:* CP violation in $B^0 \to \pi^0 K_S$

$$\frac{\Gamma(\bar{B}^0(t) \to \pi^0 K_S) - \Gamma(B^0(t) \to \pi^0 K_S)}{\Gamma(\bar{B}^0(t) \to \pi^0 K_S) + \Gamma(B^0(t) \to \pi^0 K_S)}$$

$$= A_{\pi^0 K_S} \cos(\Delta M_d t) + S_{\pi^0 K_S} \sin(\Delta M_d t)$$







Electroweak "penguin" contribution $\to$ NP?

[R.F., S. Jäger, D. Pirjol & J. Zupan ('08); update: Jure Zupan @ Beauty 2011]

- Implications for the structure of New Physics (NP):

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \mathcal{L}_{\rm NP}(\varphi_{\rm NP}, g_{\rm NP}, m_{\rm NP}, ...)$$

  – Large characteristic NP scale $\Lambda_{\rm NP}$, i.e. not just $\sim$ TeV, which would be bad news for the direct searches at ATLAS and CMS, or (and?) ...

  – Symmetries prevent large NP effects in FCNCs and the flavour sector; most prominent example: *Minimal Flavour Violation (MFV):*

    $\rightarrow$ essentially the same CP & flavour violation as in the SM.

- Comments:

  – MFV is still far from being experimentally established!

  – There are various non-MFV scenarios with room for sizeable effects: *SUSY, warped extra dimensions, little Higgs, 4th generation,* Z', ...

  – Nevertheless, we have to be prepared to deal with "smallish" NP effects.

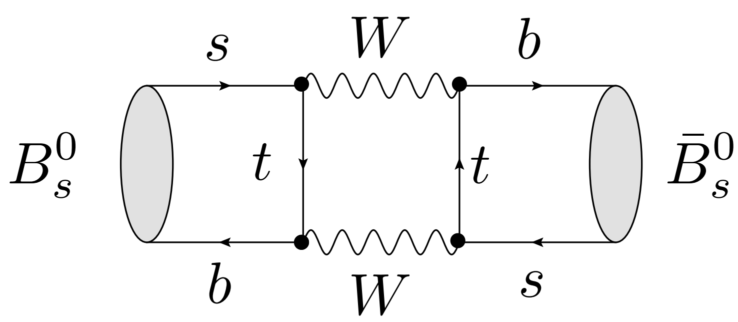
- Excellent news:

  – We are at the beginning of a new era in particle physics: $\rightarrow$ LHC era

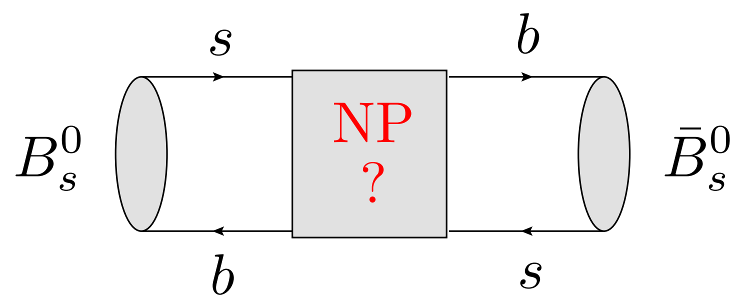
B Physics in the LHC Era:

$\longrightarrow$ promising probes for New Physics ...

$\star$ Search for NP in B_s^0–$\bar{B}_s^0$ mixing:



Standard Model



New Physics (e.g. SUSY, Z' models)

$\diamond$ FCNC process: $\Rightarrow$ strongly suppressed in the SM ("box" diagrams)

$\star$ involves a CP-violating phase $\phi_s = \phi_s^{\rm SM} + \phi_s^{\rm NP}$

$\rightarrow$ SM piece is *tiny*: $\phi_s^{\rm SM} \approx -2^\circ$

$\Rightarrow$ sensitive probe for NP

[$\rightarrow$ also the talks by Fulvia De Fazio & Alexander Lenz]

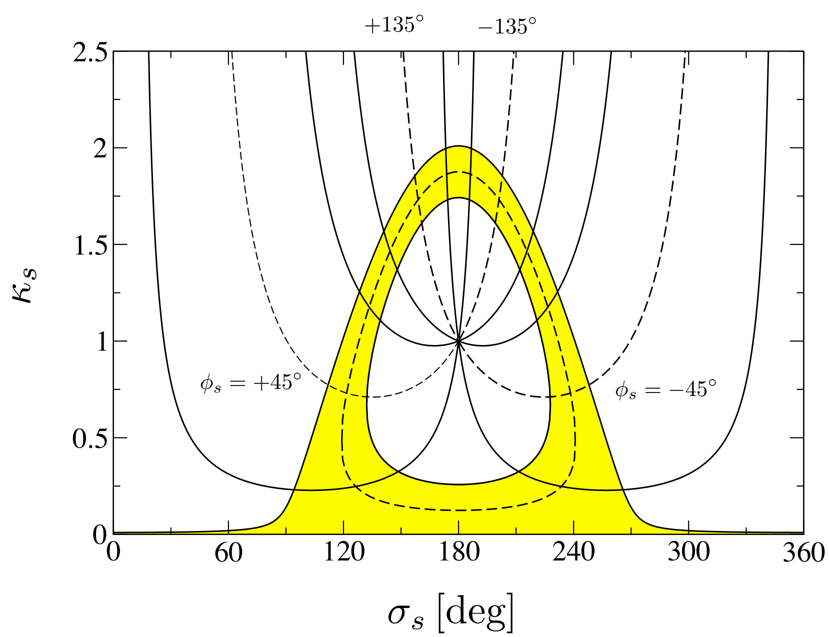
Constraints on NP Parameter Space

- Parameter (complex number) to characterize NP in B_s^0 – $\bar{B}_s^0$ mixing:

$$\boxed{\kappa_s e^{i\sigma_s} \equiv \text{“NP”} / \text{“SM”}} \Rightarrow$$

  - Mass difference: $\Delta M_s = \Delta M_s^{\mathrm{SM}} \left|1 + \kappa_s e^{i\sigma_s}\right|$
  - Mixing phase: $\phi_s = \phi_s^{\mathrm{SM}} + \phi_s^{\mathrm{NP}} = \phi_s^{\mathrm{SM}} + \arg(1 + \kappa_s e^{i\sigma_s})$

- Allowed region in the σ_s–κ_s plane:

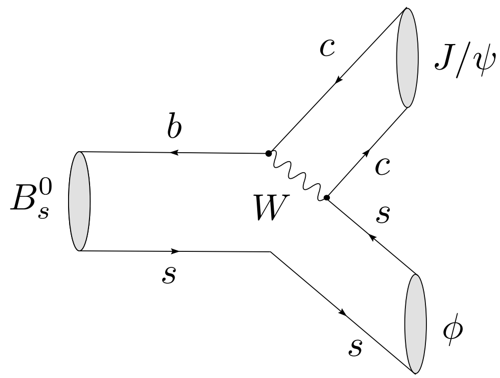


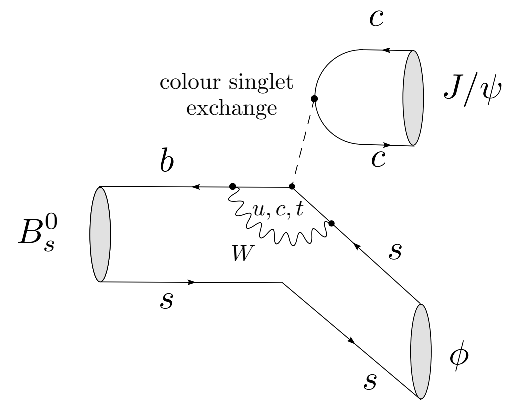
$\Delta M_s \Rightarrow$ yellow band;

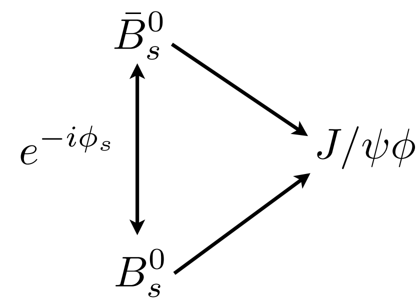
$\phi_s \Rightarrow$ contours ...

[Details: Patricia Ball & R.F. (2006)]

CP Violation in $B_s^0 \to J/\psi\phi$

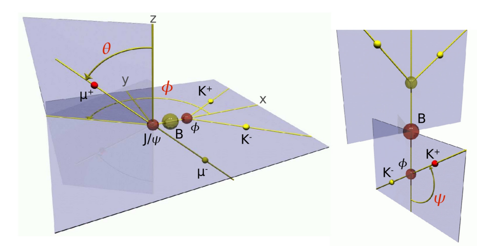






- Interference effects through B_s^0–$\bar{B}_s^0$ mixing:
  - *Mixing-induced* CP violation in time-dependent rates.
  - Hadronic parameters cancel to good approximation:

$$\Rightarrow \boxed{\text{CP asymmetries} \sim \sin\phi_s}$$



- Final state is mixture of CP-odd and -even eigenstates:

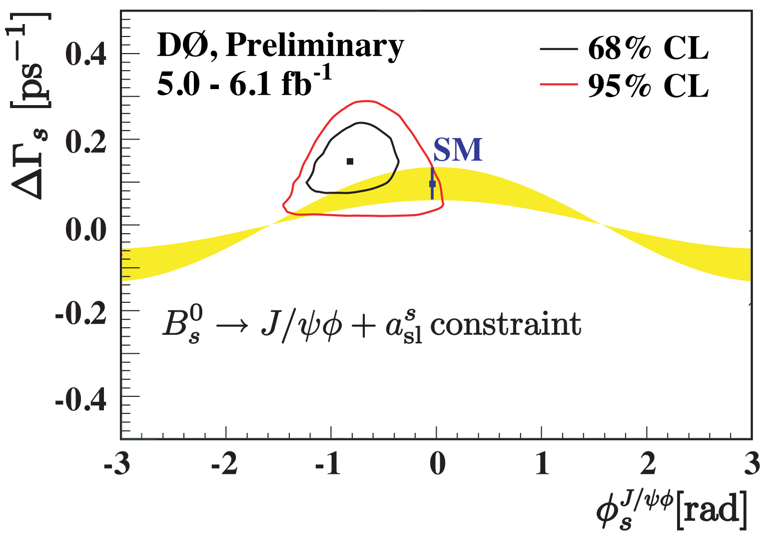
  $\to$ disentangle through $J/\psi[\to \mu^+\mu^-]\phi[\to\ K^+K^-]$ angular distribution.

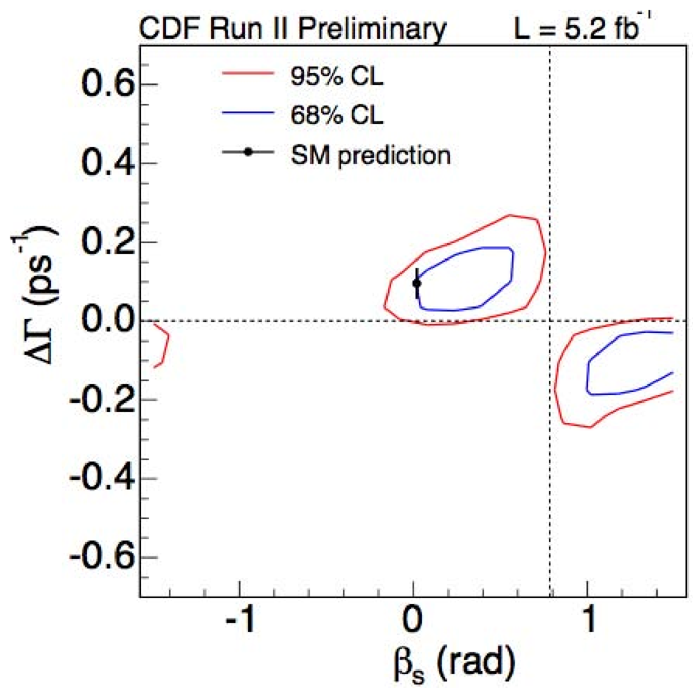
- *Smallish* CPV in the SM: $\Rightarrow$ sensitive probe for NP in B_s^0–$\bar{B}_s^0$ mixing

[Dighe, Dunietz & R.F. ('99); Dunietz, R.F. & Nierste ('01); Faller, R.F. & Mannel ('08)]

Tevatron $B_s^0 \to J/\psi\phi$ Results

- Current picture (early '11 and Summer '10): [Dictionary: $\phi_s = -2\beta_s$]



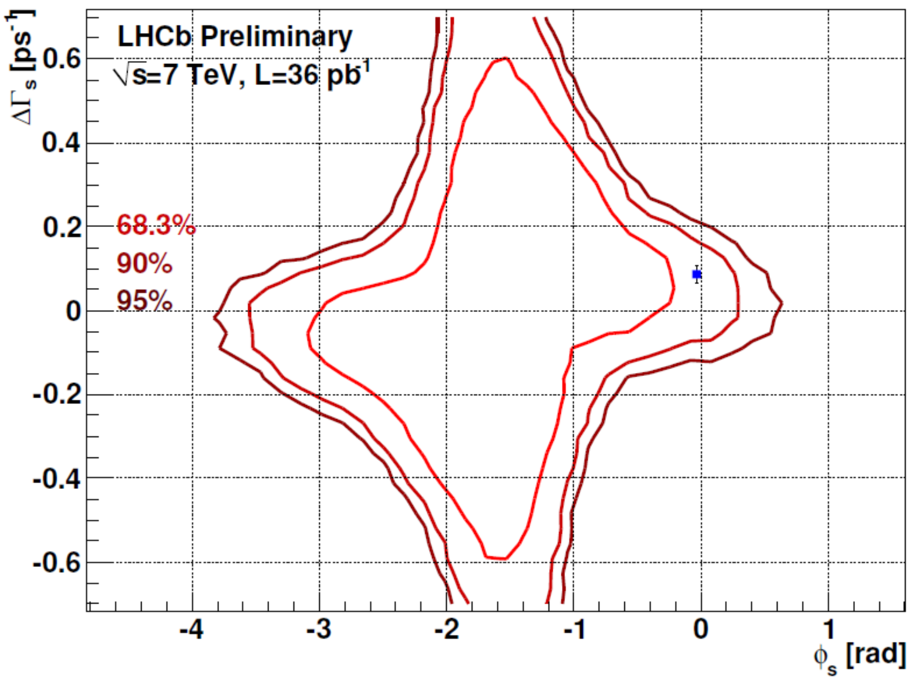


  – DØ includes also the anomalous like-sign dimuon charge asymmetry;
  – CDF plot uses only $B_s \to J/\psi\phi$ data. [→ talk by Michal Kreps]

- Bad news: situation is (still...) not conclusive (?)

LHCb $B_s^0 \to J/\psi\phi$ Results

$\rightarrow$ first constraints in the ϕ_s–$\Delta\gamma_s$ plane form a *tagged* analysis:



$\phi_s \in$ [-2.7, -0.5] rad at 68% CL
$\phi_s \in$ [-3.5, 0.2] rad at 95% CL

$\Rightarrow$ consistent with the Tevatron results $\rightarrow$ stay tuned ...

[Uli Uwer @ Beauty 2011, LHCb-Conf-2011-006]

Prospects for $B_s \to J/\psi\phi$ @ LHCb

- Experimental reach @ LHCb: *very impressive ...*
  - 2011 LHCb data should allow world's best ϕ_s measurement.
  - One nominal year of operation, i.e. $2\,\mathrm{fb}^{-1}$: $\sigma(\phi_s)_{\rm exp} \sim 1^\circ$
  - LHCb upgrade with integrated lumi of $100\,\mathrm{fb}^{-1}$: $\sigma(\phi_s)_{\rm exp} \sim 0.2^\circ$

- However: *SM penguin effects were so far fully neglected:*[1]

$$A(B_s^0 \to J/\psi\phi) \propto \mathcal{A}_f \left[1 + \lambda^2(ae^{i\theta})e^{i\gamma}\right]$$

  - Impact of these corrections: $\mathcal{A}_{\rm CP}^{\rm mix} = \sin\phi_s \;\to\; \sin(\phi_s + \Delta\phi_s)$.
  - Hadronic shift $\Delta\phi_s$ can be controlled through $B_s^0 \to J/\psi\bar{K}^{*0}$.
    [CDF reported observation of this channel @ ICHEP 2010; LHCb @ Beauty 2011]

- Two scenarios: [$\Delta\phi_s$ must in any case be controlled to match LHCb accuracy]
  - *Optimistic:* $\mathcal{A}_{\rm CP}^{\rm mix} \sim -40\%$ would be an unambiguous signal of NP!
  - *Pessimistic:* $\mathcal{A}_{\rm CP}^{\rm mix} \sim -(5...10)\%$ would require more work from theorists and experimentalists to clarify the picture ...

[S. Faller, R.F. & T. Mannel, Phys. Rev. **D79** ('09) 014005 [arXiv:0810.4248 [hep-ph]]]

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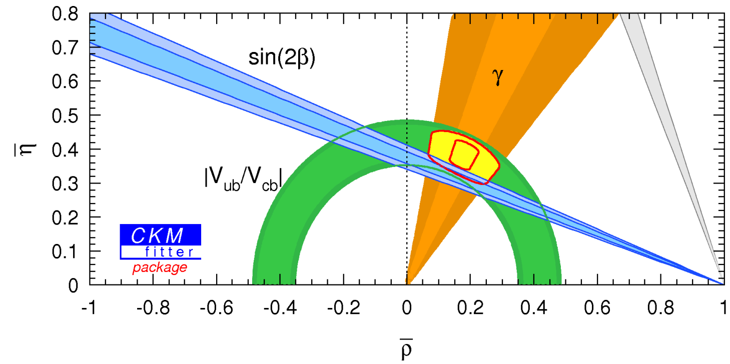
[1] $\lambda \equiv |V_{us}| = 0.22$ is the Wolfenstein parameter.

Implications of the Data for the B_d^0 System

- Tension in fit of UT: $(\phi_d)_{J/\psi K^0} - 2\beta_{\rm true} = -(8.7^{+2.6}_{-3.6} \pm 3.8)^\circ \rightarrow$ NP!?



- SM corrections: doubly Cabibbo-suppressed penguins $(\lambda \equiv |V_{us}| = 0.22) \rightarrow$

$$A(B_d^0 \rightarrow J/\psi\, K_{\rm S}) \propto \left[1 + \epsilon a e^{i\theta} e^{i\gamma}\right] \quad (\epsilon \equiv \lambda^2/(1-\lambda^2) \sim 0.05)$$

- Generalized expression for mixing-induced CP violation: $[\phi_d = 2\beta + \phi_d^{\rm NP}]$

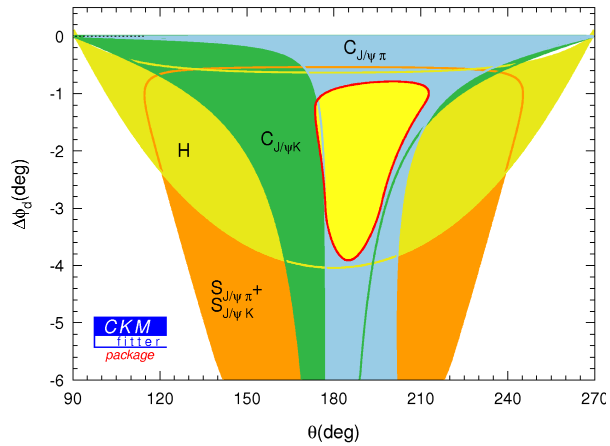
$$\frac{S(B_d \rightarrow J/\psi K_{\rm S})}{\sqrt{1 - C(B_d \rightarrow J/\psi K_{\rm S})^2}} = \sin(\phi_d + \Delta\phi_d)$$

$$\sin \Delta\phi_d \propto 2\epsilon a \cos\theta \sin\gamma + \epsilon^2 a^2 \sin 2\gamma$$

$$\cos \Delta\phi_d \propto 1 + 2\epsilon a \cos\theta \cos\gamma + \epsilon^2 a^2 \cos 2\gamma$$

- $\Delta\phi_d$ *cannot* be calculated: $\Rightarrow$ use $B_d^0 \to J/\psi\pi^0$ data & $SU(3)$

$$A(B_d^0 \to J/\psi\pi^0) \propto \left[1 - ae^{i\theta}e^{i\gamma}\right]$$



  - Fit to all current data, allowing also for $SU(3)$-breaking corrections:

    $\Rightarrow \Delta\phi_d \in [-6.7, 0.0]^\circ$, i.e. softens the tension in the fit of the UT.

  - NP mixing phase: $\phi_d^{\mathrm{NP}} \in [-14.9, 4.0]^\circ$, i.e. no significant effect.

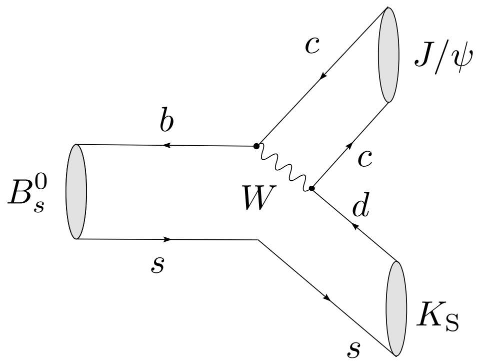
- Observation:

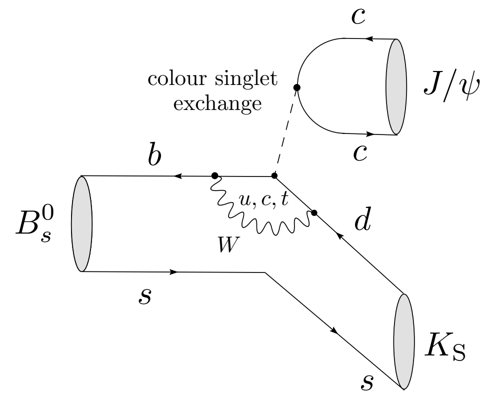
  - The quality of the B-factory data has essentially reached a level of precision where subleading SM effects have to be included!

  - This will be even much more relevant in the LHC era, but $B_d^0 \to J/\psi\pi^0$ is very challenging for this experiment (super-B factory could do) $\Rightarrow$

[S. Faller, R.F., M. Jung & T. Mannel (2008)]

A New Channel for LHCb: $B_s^0 \to J/\psi K_{\rm S}$





$$A(B_s^0 \to J/\psi K_{\rm S}) \propto \mathcal{A}\left[1 - a e^{i\theta} e^{i\gamma}\right]$$

- U-spin symmetry:[2] $\boxed{B_s^0 \to J/\psi K_{\rm S} \Leftrightarrow B_d^0 \to J/\psi K_{\rm S}}$ [R.F. (1999)]
  - Determination of the UT angle γ.
  - Control of penguins in the determination of ϕ_d from $B_d^0 \to J/\psi K_{\rm S}$.
- CDF reported observation @ ICHEP2010: $\to$ first BR measurement:

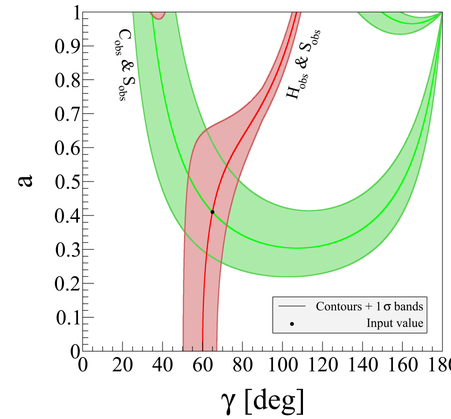
$$(3.53 \pm 0.61(\text{stat.}) \pm 0.35(\text{syst.}) \pm 0.43(\text{frag.}) \pm 0.13(\text{PDG})) \times 10^{-5}$$

  - $SU(3)$ flavour-symmetry test:

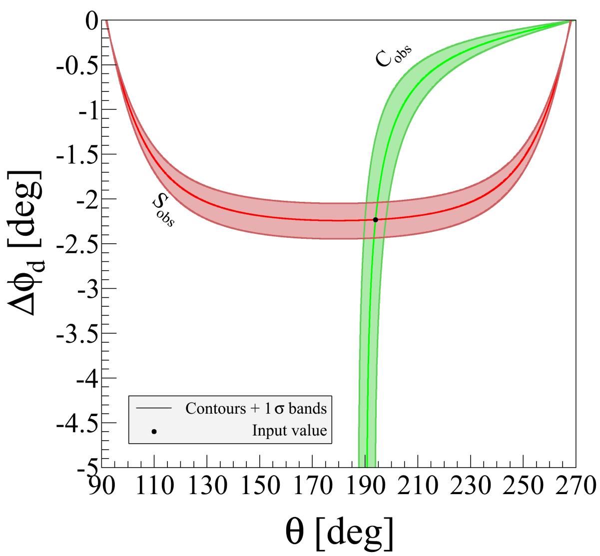
$$\Xi_{SU(3)} \equiv \frac{\text{BR}(B_s^0 \to J/\psi \bar{K}^0)}{2\text{BR}(B_d^0 \to J/\psi \pi^0)} \frac{\tau_{B_d}}{\tau_{B_s}} \frac{\Phi^d_{J/\psi\pi^0}}{\Phi^s_{J/\psi K_{\rm S}}} = 1.01 \pm 0.25 \stackrel{SU(3)}{\longrightarrow} 1$$

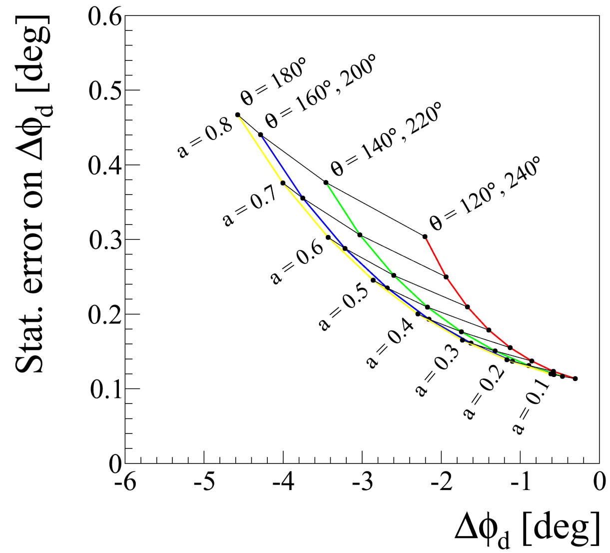
[2] U spin is an $SU(2)$ subgroup of strong $SU(3)_{\rm F}$ relating down and strange quarks to each other.

- Fresh look: [with Kristof De Bruyn & Patrick Koppenburg, arXiv:1010.0089 [hep-ph]]



  - First LHCb (toy) feasibility study: $\rightarrow \gamma$ extraction;
  - *Main application:* control of the penguin effects in $(\phi_d)_{J/\psi K_S}$:





$\Rightarrow$ interesting study for the LHCb upgrade $[100\,\text{fb}^{-1}]$

The

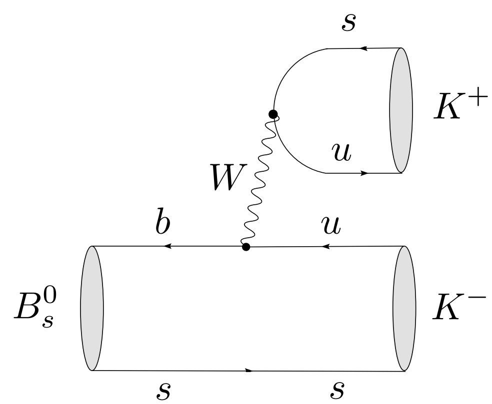
$$B_s \to K^+K^-, \; B_d \to \pi^+\pi^-$$

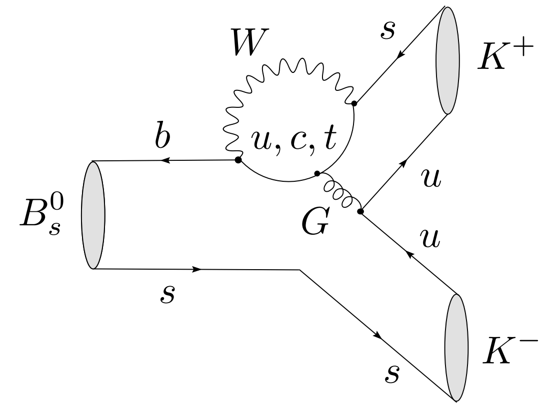
System

Decay Topologies & Amplitudes

- $B_s^0 \to K^+K^-$:

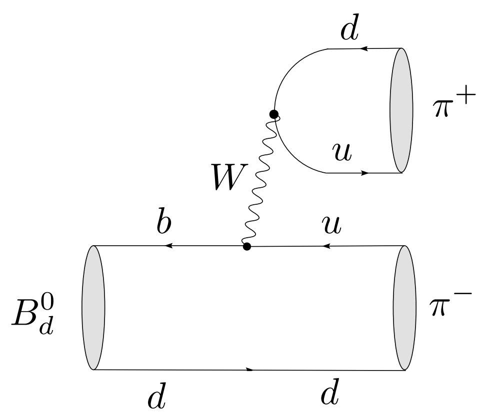
$$A(B_s^0 \to K^+K^-) \propto \mathcal{C}' \left[e^{i\gamma} + \left(\frac{1-\lambda^2}{\lambda^2}\right) d' e^{i\theta'}\right]$$

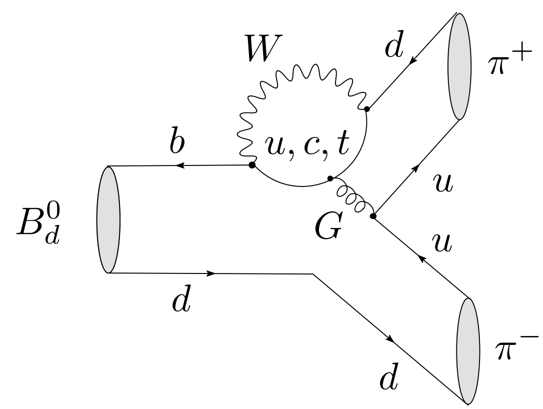




- $B_d^0 \to \pi^+\pi^-$:

$$A(B_d^0 \to \pi^+\pi^-) \propto \mathcal{C} \left[e^{i\gamma} - d\, e^{i\theta}\right]$$





$$\Rightarrow \quad \boxed{s \leftrightarrow d}$$

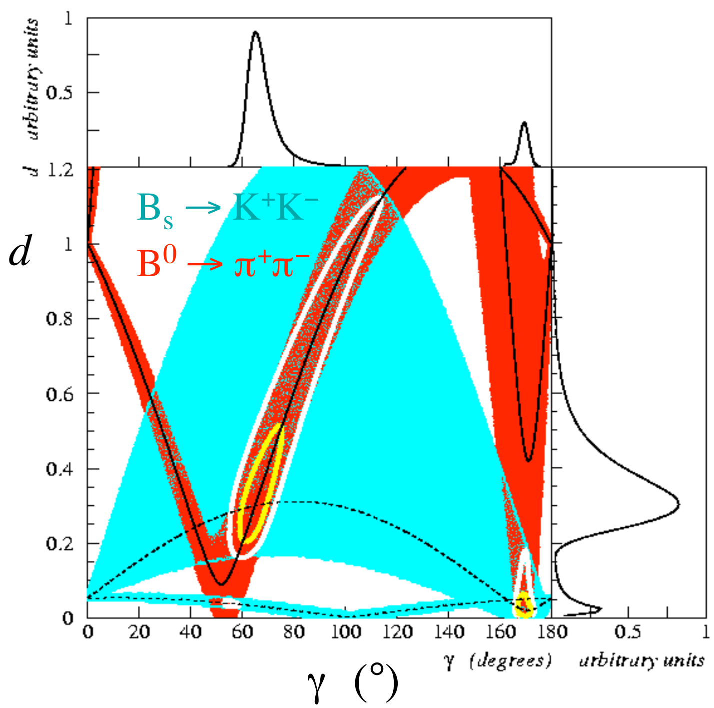
- The decays $B_d \to \pi^+\pi^-$ and $B_s \to K^+K^-$ are related to each other through the interchange of all down and strange quarks:

$$\boxed{U\text{-spin symmetry}} \quad \Rightarrow \quad d' = d,\ \theta' = \theta$$

  - Determination of γ and hadronic parameters $d(= d')$, θ and θ'.
  - Internal consistency check of the U-spin symmetry: $\theta \stackrel{?}{=} \theta'$.

[R.F., Phys. Lett. **B459** (1999) 306 [hep-ph/9903456]]

- Detailed studies show that this strategy is very promising for LHCb:



$\rightarrow$ experimental accuracy for γ of a few degrees!

[LHCb Collaboration (B. Adeva *et al.*) LHCb-PUB-2009-029, arXiv:0912.4179v2]

Let's have a fresh look:

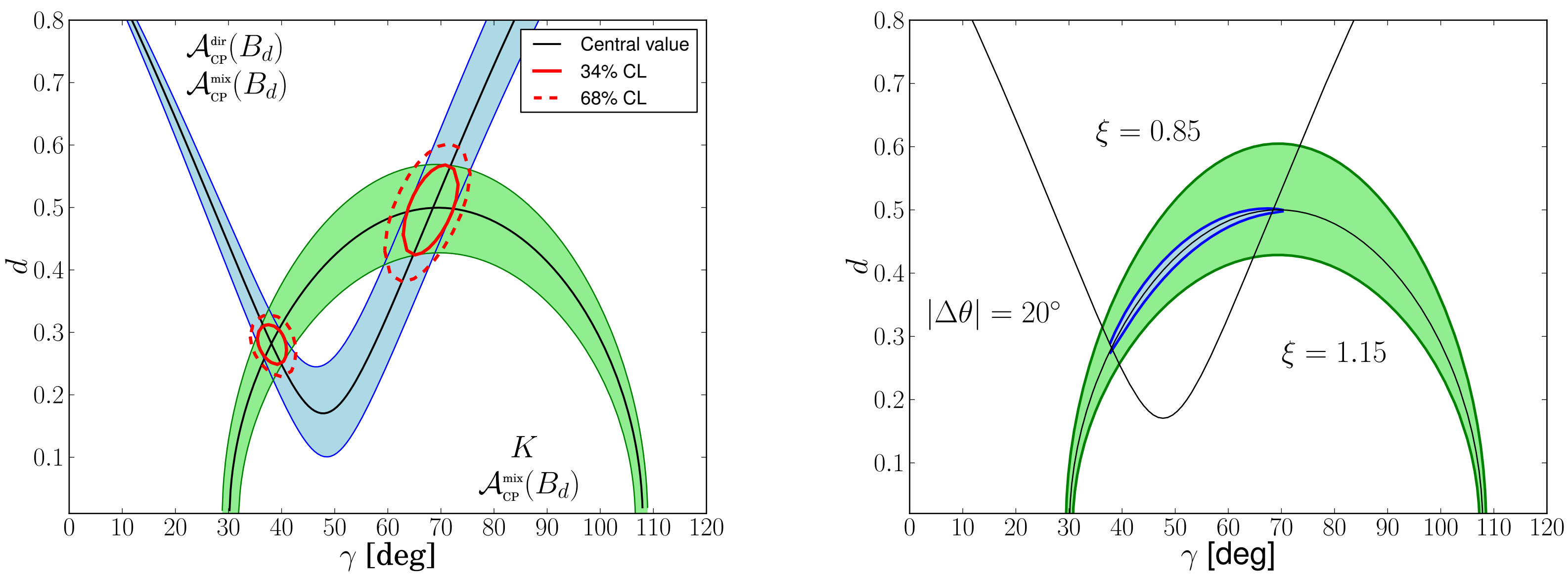
$\rightarrow$ **get ready for LHCb data...**

- Use B-factory data as input, as well as ...
- BR$(B_s \to K^+K^-)$ measurements by CDF and Belle @ $\Upsilon(5S)$,
- updated information of U-spin-breaking form-factor ratios.

[with Robert Knegjens, Eur. Phys. J. **C71** (2011) 1532 [arXiv:1011.1096 [hep-ph]]]

Current Picture for γ

- Input data:
  - Information on $K \propto \mathrm{BR}(B_s \to K^+K^-)/\mathrm{BR}(B_d \to \pi^+\pi^-)$;
  - CP violation in $B_d^0 \to \pi^+\pi^-$ and $B_d^0 \to \pi^\mp K^\pm$;
  - U-spin-breaking corrections: $\xi \equiv d'/d = 1{\pm}0.15$, $\Delta\theta \equiv \theta' {-} \theta = \pm 20^\circ$:



$$\Rightarrow \boxed{\gamma = \left(68.3^{+4.9}_{-5.7}\Big|_{\rm input}{}^{+5.0}_{-3.7}\Big|_{\xi}{}^{+0.1}_{-0.2}\Big|_{\Delta\theta}\right)^\circ}$$

(2-fold ambiguity can be resolved [R.F. ('07)])

- Fits of the UT: $\gamma = (67.2^{+3.9}_{-3.9})^\circ$ (CKMfitter), $(69.6 \pm 3.1)^\circ$ (UTfit).

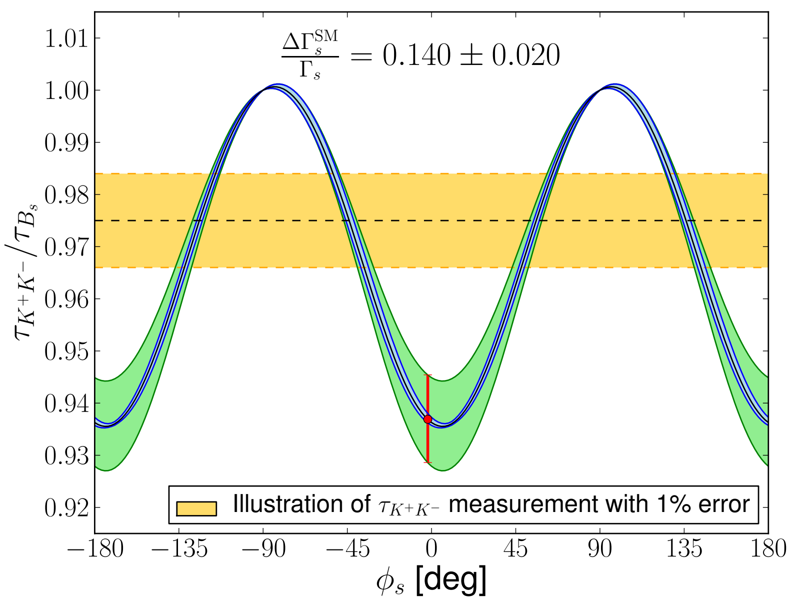
$\Rightarrow$ *disfavours large CP-violating NP contributions to decay amplitudes.*

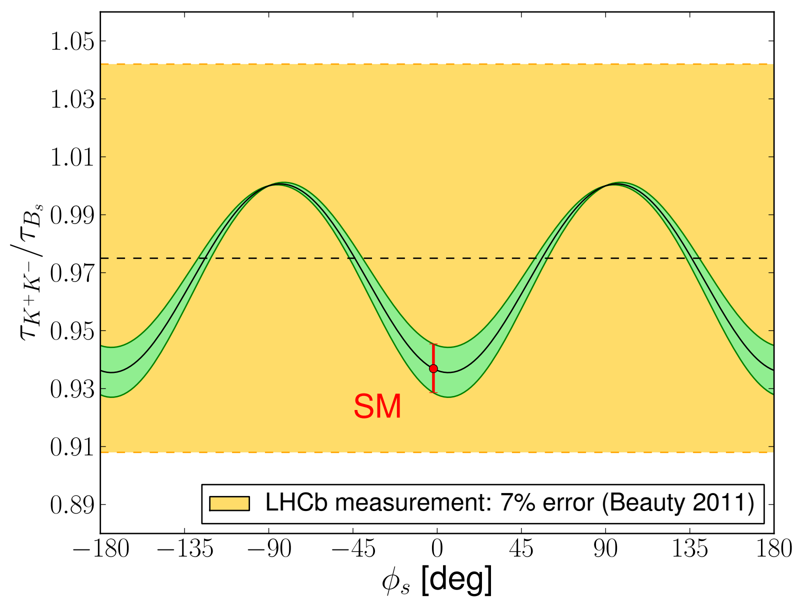
The Effective $B_s^0 \to K^+K^-$ Lifetime

- Particularly nice and simple observable: $[\langle\Gamma(B_s(t) \to f)\rangle \to$ "untagged" rate$]$

$$\tau_{K^+K^-} \equiv \frac{\int_0^\infty t\ \langle\Gamma(B_s(t) \to K^+K^-)\rangle\ dt}{\int_0^\infty \langle\Gamma(B_s(t) \to K^+K^-)\rangle\ dt}$$

- Using K, $\mathcal{A}_{\rm CP}^{\rm dir}(B_d \to \pi^\mp K^\pm)$ and $\gamma = (68 \pm 7)^\circ$ [$\oplus$ U-spin-breaking]: $\Rightarrow$





$\Rightarrow$ **probe for NP in B_s^0–$\bar{B}_s^0$ mixing**

- *First* LHCb result: [$\to$ talk by Vincenzo Vagnoni @ Beauty 2011]

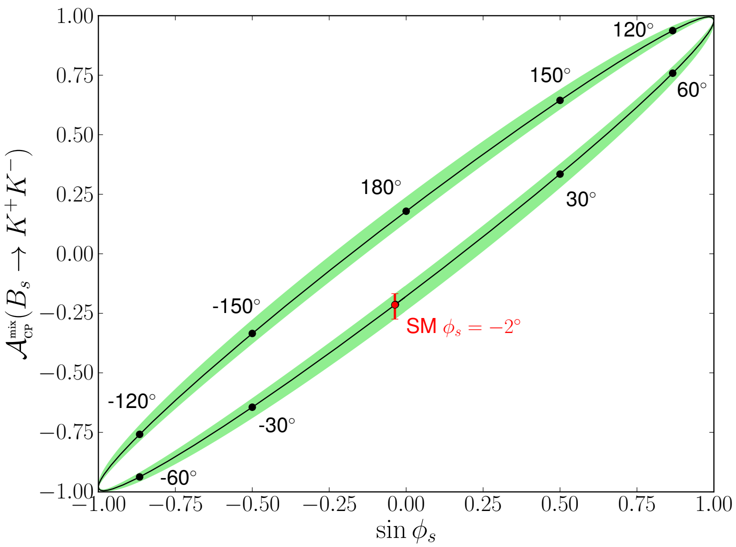
$$\tau_{K^+K^-} = (1.440 \pm 0.096 \pm 0.010)\ \text{ps}$$

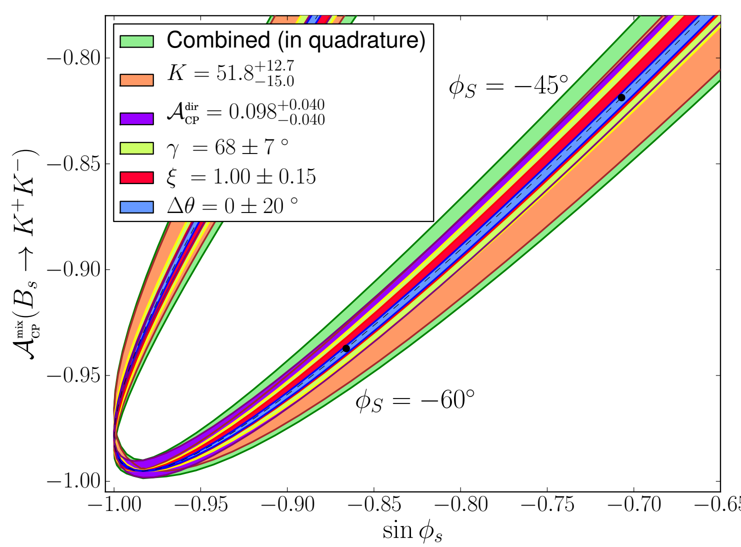
Mixing-Induced $B_s^0 \to K^+K^-$ CP Asymmetry

- The next observable to enter the stage: $\mathcal{A}_{\rm CP}^{\rm mix}(B_s \to K^+K^-)$

$$a_{\rm CP}(t) = \frac{\mathcal{A}_{\rm CP}^{\rm dir}\cos(\Delta M_s t) + \mathcal{A}_{\rm CP}^{\rm mix}\sin(\Delta M_s t)}{\cosh(\Delta\Gamma_s t/2) + \mathcal{A}_{\Delta\Gamma}\sinh(\Delta\Gamma_s t/2)}$$

- Using K, $\mathcal{A}_{\rm CP}^{\rm dir}(B_d \to \pi^\mp K^\pm)$, $\gamma \oplus U$-spin-breaking effects: $\Rightarrow$





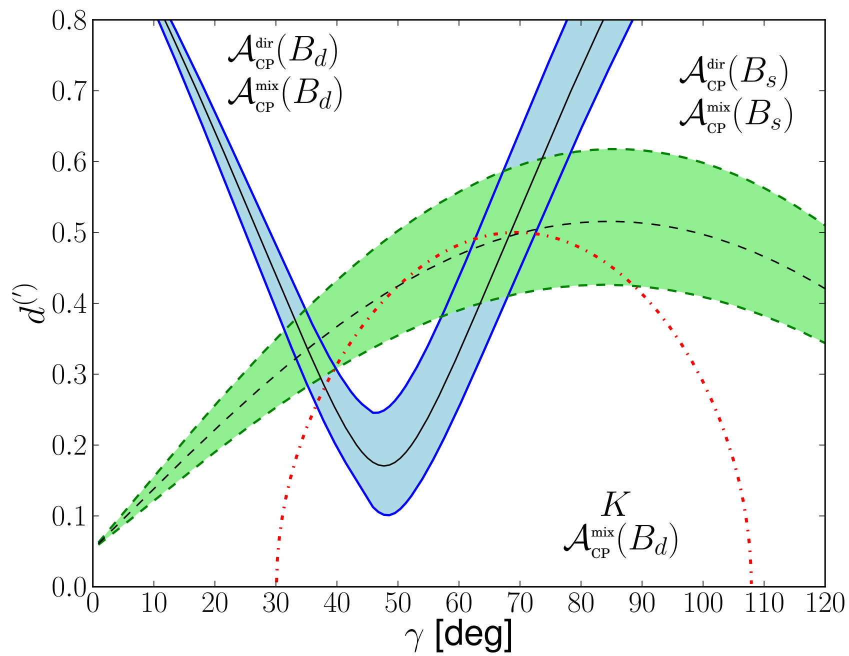
– Correlation is very robust with respect to uncertainties.
– Allows also an unambiguous determination of ϕ_s with $\sin\phi_s$.

$\Rightarrow$ Another interesting probe for NP in B_s^0–$\bar{B}_s^0$ mixing

Optimal Determination of γ

- <u>Measurement of the CP asymmetries of $B_s^0 \to K^+K^-$:</u>

$\Rightarrow$ theoretically clean contour in the γ–d' plane:



[Green band represents the 1σ errors of the current SM projection.]

- Intersection with the γ–d contour fixed through the CP asymmetries of $B_s^0 \to \pi^+\pi^-$ allows us to determine γ, $d = d'$ and θ, θ' [$\to$ U-spin test].

- Expect a stable situation with respect to U-spin-breaking corrections.

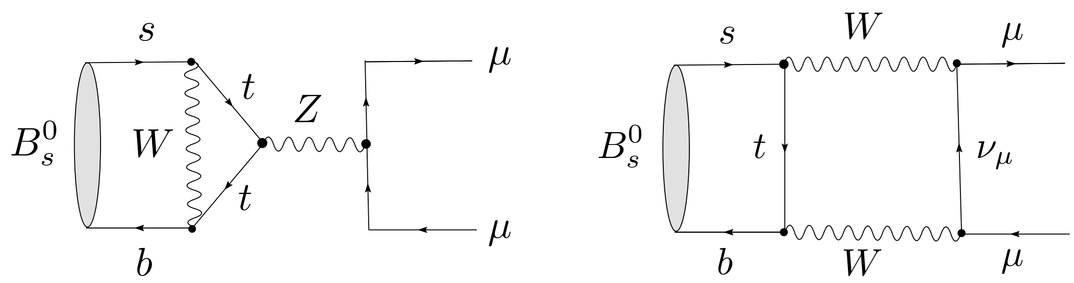
Search for New Physics

in

$B_s \to \mu^+ \mu^-$

Search for New Physics in $B_s^0 \to \mu^+\mu^-$

- Only loop contributions in the SM ("penguins' & "box" diagrams):



$\Rightarrow$ strongly suppressed & sensitive to NP

- Hadronic sector: $\to$ simple situation (only B decay constant f_{B_s} enters):

$\Rightarrow$ $B_s^0 \to \mu^+\mu^-$ is one of the cleanest rare B decays

- SM prediction: BR$(B_s \to \mu^+\mu^-) = (3.6 \pm 0.4) \times 10^{-9}$ [A.J. Buras ('09)]

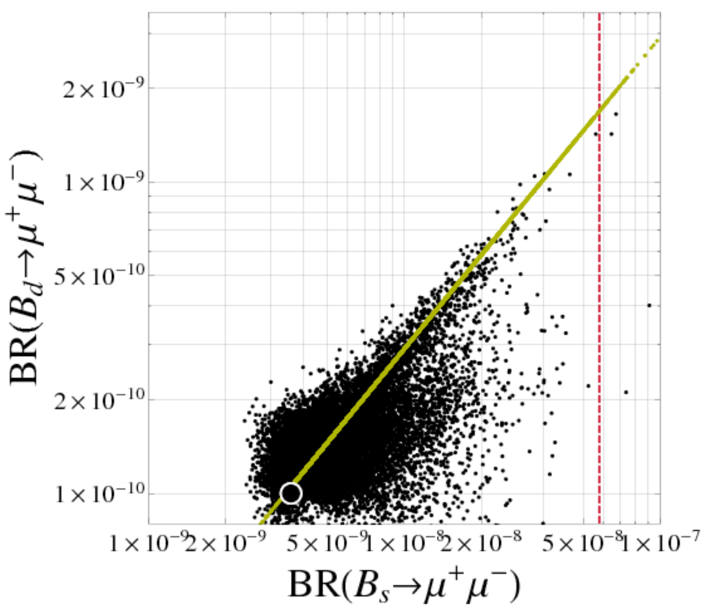
- Most recent experimental upper bounds (95% C.L.):

BR$(B_s \to \mu^+\mu^-) < 4.3\times10^{-8}$ (CDF), 5.1×10^{-8} (DØ), 5.6×10^{-8} (LHCb)
new [Moriond '11]

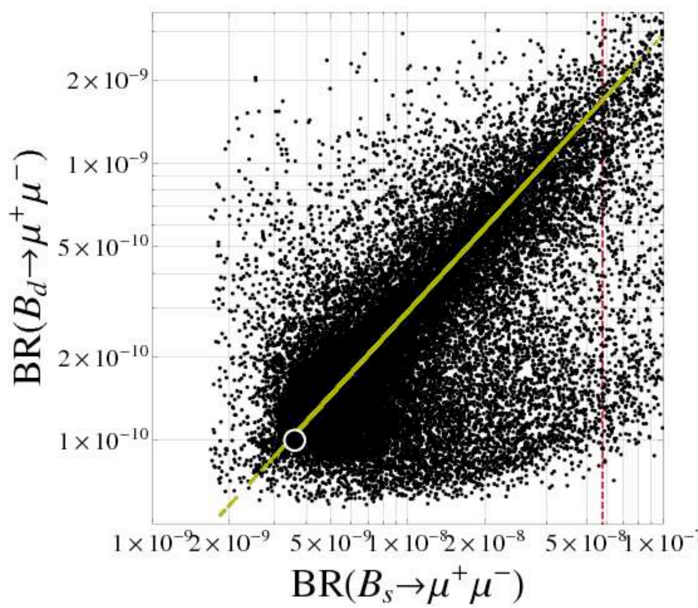
$\Rightarrow$ still a long way (?)

NP may enhance BRs significantly...

- Example of a recent analysis: $\rightarrow$ *supersymmetric flavour models:*



(RVV2 model)



(δLL model)

[Altmannshofer, Buras, Gori, Paradisi & Straub (2009);
see also review by A. Buras, arXiv:1012.1447 [hep-ph]]

Prospects for $B_s \to \mu^+\mu^-$ @ LHCb

- At LHCb, the extraction of BR$(B_s^0 \to \mu^+\mu^-)$ will rely on normalization channels ($B_u^+ \to J/\psi K^+$, $B_d^0 \to K^+\pi^-$ and/or $B_d^0 \to J/\psi K^{*0}$):

$$\text{BR}(B_s^0 \to \mu^+\mu^-) = \text{BR}(B_q \to X)\frac{\epsilon_X}{\epsilon_{\mu\mu}}\frac{N_{\mu\mu}}{N_X}\frac{f_q}{f_s}$$

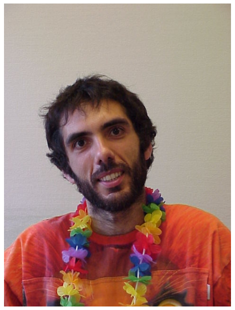
  - ϵ factors are total detector efficiencies.
  - N factors denote the observed numbers of events.
  - f_q are fragmentation functions, which describe the probability that a b quark will fragment in a B_q meson ($q \in \{u, d, s\}$).

- A closer look shows: f_q/f_s is the major source of uncertainty

  - Limits the ability to detect a 5σ deviation from the SM at LHCb to BR$(B_s^0 \to \mu^+\mu^-) > 11 \times 10^{-9}$ (assuming $\Delta f_d/f_s = 13\%$).
  - How can we meet the high precision at LHCb?

[LHCb Collaboration, B. Adeva *et al.*, LHCb-PUB-2009-029, arXiv:0912.4179v2]

$\rightarrow$ New Strategy: f_d/f_s @ LHCb



[R.F., N. Serra & N. Tuning, Phys. Rev. **D82** (2010) 034038 [arXiv:1004.3982 [hep-ph]]]

$\star$ *First LHCb analysis* $\rightarrow$ Niels Tuning @ Beauty 2011

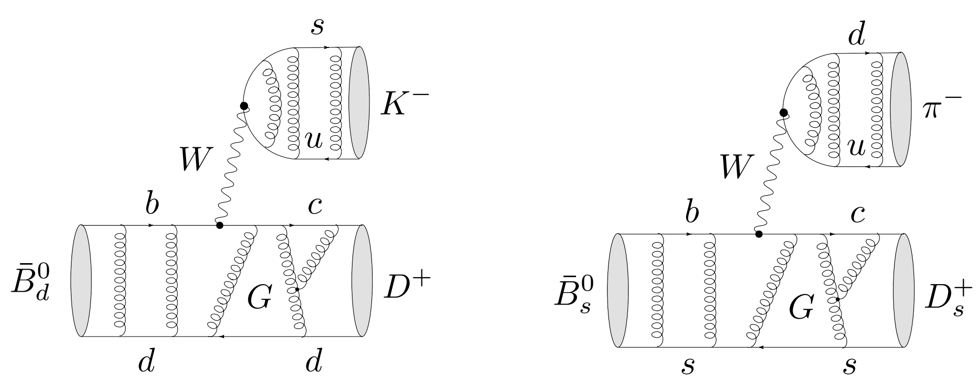
In a nutshell...

- Starting point: $$\frac{N_s}{N_d} = \frac{f_s}{f_d} \times \frac{\epsilon(B_s \to X_1)}{\epsilon(B_d \to X_2)} \times \frac{\text{BR}(B_s \to X_1)}{\text{BR}(B_d \to X_2)}$$

- Knowing the ratio of the branching ratios, we could extract f_d/f_s.

- In order to implement this feature in practice, the $B_s \to X_1$ and $B_d \to X_2$ decays have to satisfy the following requirements:
  - the ratio of their branching ratios must be "easy" to measure at LHCb;
  - the decays must be robust with respect to the impact of NP;
  - the ratio of their BRs must be theoretically well understood:

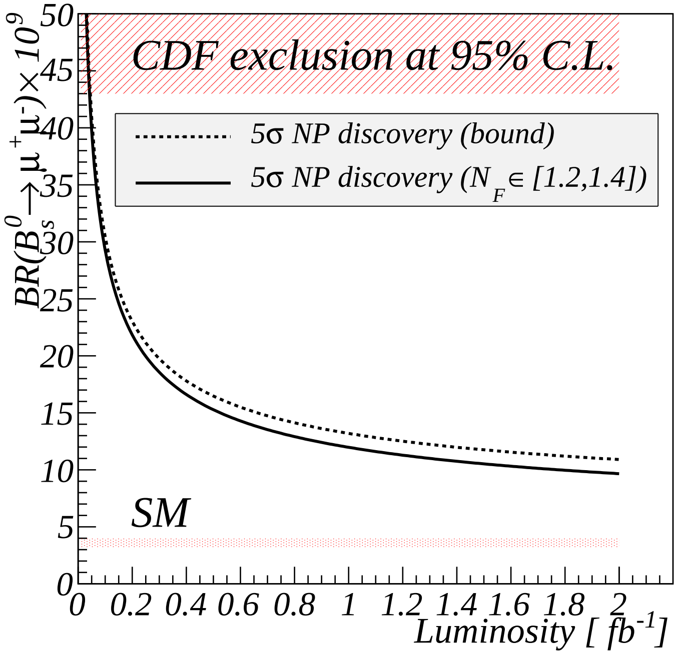
$\Rightarrow$ **U-spin-related $\bar{B}_s^0 \to D_s^+\pi^-$, $\bar{B}_d^0 \to D^+K^-$ system:**

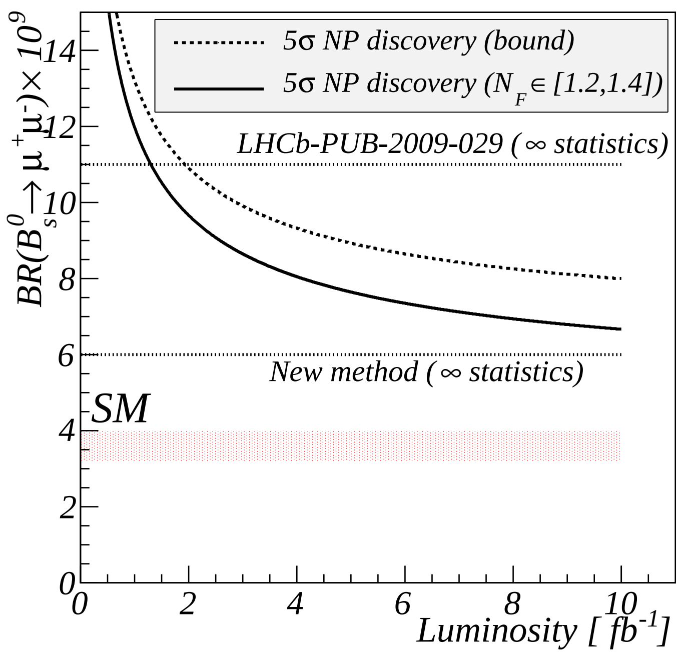


* Factorization is expected to work very well in these decays;
* Theoretical precision limited by non-fact., U-spin-breaking effects.

Resulting NP Reach for $B_s \to \mu^+\mu^-$ at LHCb

- Contours corresponding to the detection of a 5σ NP signal:



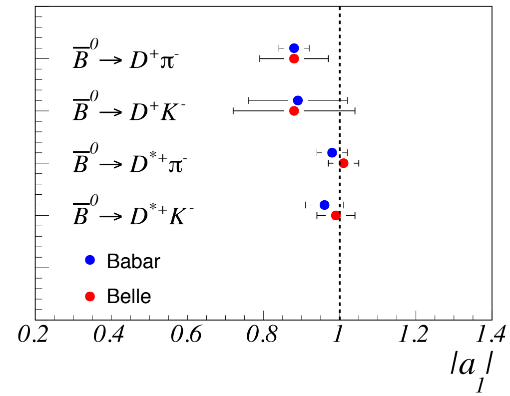


$\Rightarrow$ $B_s \to \mu^+\mu^-$ NP reach at LHCb is increased by ~ 2

- Non-fact. U-spin-breaking effects: $\Rightarrow$ few percent uncertainty [$\to$ data].
- Factorizable U-spin-breaking effects: $\Rightarrow$ $F_0^{(s)}(m_\pi^2)/F_0^{(d)}(m_K^2)$, required with $\sim 20\%$ precision to match LHCb [$\to$ lattice QCD: in progress ...].
- Lower bound on BR$(B_s \to \mu^+\mu^-)$: independent of the form-factor ratio.

Tests & Variant: $B \to D_s^{(*)} P$ $(P \in \{\pi, K\})$

- Tests of factorization and $SU(3)$ relations:



  – *Cannot resolve non-factorizable effects* within the experimental resolution:

    $\Rightarrow$ as small as 5% (most fortunate cases).

  – *No indication for non-factorizable $SU(3)$-breaking corrections*, with an experimental resolution as small as $\sim 5\%$, even for decays with large colour-suppressed tree contributions ($\to$ non-factorizable).

  – Moreover: *exchange topologies are as small as naively expected* $\Rightarrow$

- Replace $\bar{B}^0_d \to D^+K^-$ (Cabibbo-suppressed) by the $\bar{B}^0_d \to D^+\pi^-$ channel:

  – (2006) CDF data for the $\bar{B}^0_s \to D_s^+\pi^-$, $\bar{B}^0_d \to D^+\pi^-$ system:[3]

$$\Rightarrow (f_s/f_d)_{\rm NL} = 0.285 \pm 0.036 \quad [\text{vs. } (f_s/f_d)_{\rm SL} = 0.284 \pm 0.038]$$

[R.F., N. Serra & N. Tuning, Phys. Rev. **D83** (2011) 014017 arXiv:1012.2784 [hep-ph]]

[3] Assumes that the corresponding $SU(3)$-breaking form-factor ratio equals 1 $\to$ lattice QCD (see above).

First (Preliminary) LHCb Results on f_s/f_d

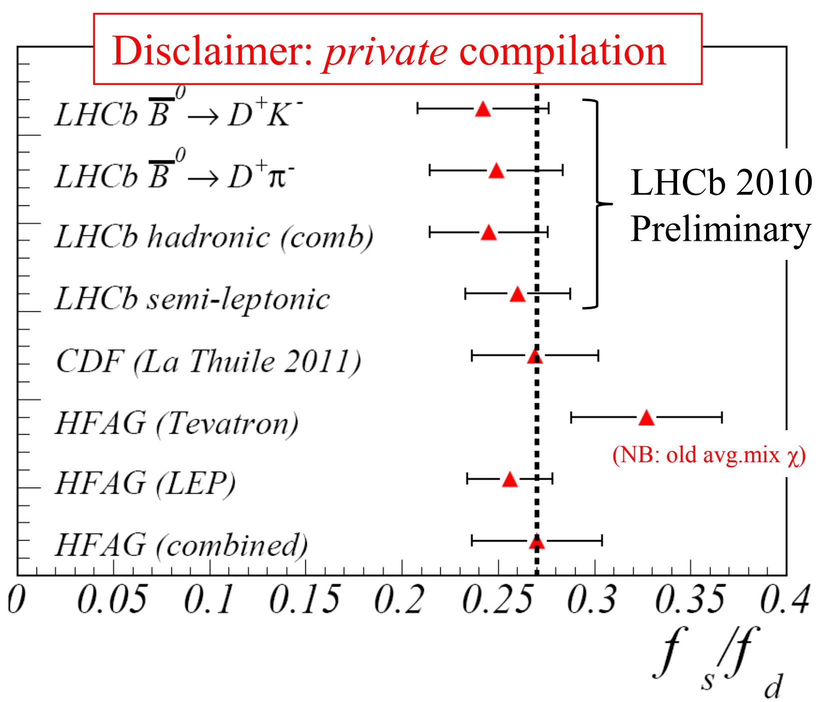
- Analysis of non-leptonic decays: $\bar{B}^0_s \to D^+_s \pi^- \oplus$

$$\bar{B}^0_d \to D^+ K^- : \quad f_s/f_d = 0.242 \pm 0.024|_{\rm stat} \pm 0.018|_{\rm sys} \pm 0.016|_{\rm theo}$$
$$\bar{B}^0_d \to D^+ \pi^- : \quad f_s/f_d = 0.249 \pm 0.013|_{\rm stat} \pm 0.020|_{\rm sys} \pm 0.025|_{\rm theo}$$
$$\text{Average}: \quad f_s/f_d = 0.245 \pm 0.017|_{\rm stat} \pm 0.018|_{\rm sys} \pm 0.018|_{\rm theo}$$

- In excellent agreement with a semileptonic $B_{(s)}$ decay analysis:

$$\bar{B}^0_{(s)} \to D X \mu^- \bar{\nu} : \quad f_s/f_d = 0.260 \pm 0.008|_{\rm stat} \pm 0.026|_{\rm sys}$$

- Compilation of results:



[Niels Tuning @ Beauty 2011]

Concluding Remarks

Moving towards New Frontiers ...

- Exciting times for B physics in Spring 2011:
  - Lots of activity at the Tevatron $\oplus$ *first physics results from LHCb.*
- B (flavour) physics takes part in the big adventure of this decade: LHC
  - Specific NP scenarios still leave room for sizeable effects.
  - Promising channels to find *first* NP signals @ LHCb [and the LHC(?)]:
    - $B_s^0 \to J/\psi\phi$, nicely complemented by $B_s^0 \to K^+K^-$;
    - $B_s^0 \to \mu^+\mu^-$ [$\oplus$ $B_d^0 \to K^{*0}\mu^+\mu^-$, $B_s^0 \to \phi\mu^+\mu^-$].
- Theoretical topics: [$\leftrightarrow$ strong interaction with the LHCb community]
  - Further critically review SM phenomena, develop strategies to control hadronic uncertainties (preferably through guidance by data).
  - Further progress with lattice QCD/non-pert. methods is very desirable.
  - Explore the patterns in specific NP scenarios:

    $\Rightarrow$ *correlations* $\Rightarrow$ *what kind of NP?*
  - Exploit/look for synergies with the high-Q^2 physics @ ATLAS & CMS.