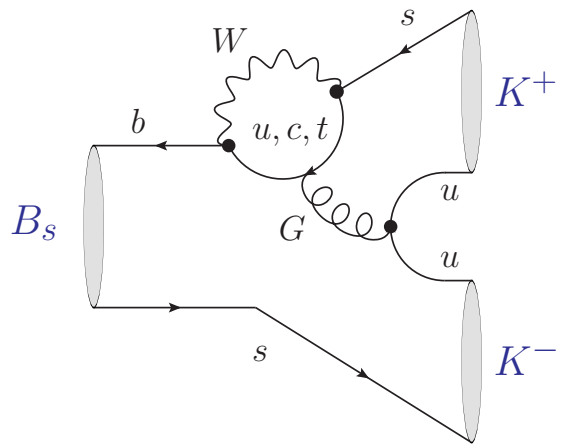
In Pursuit of New Physics with B_s Mesons

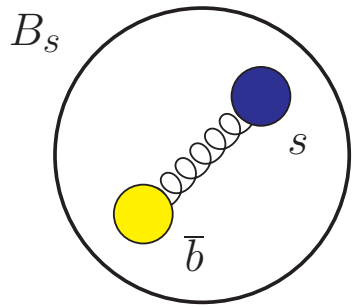
Rob Knegjens (Nikhef)



R. Fleischer and R. K, Eur. Phys. J. C 71, 1532 (2011)

Introducing B Meson Physics

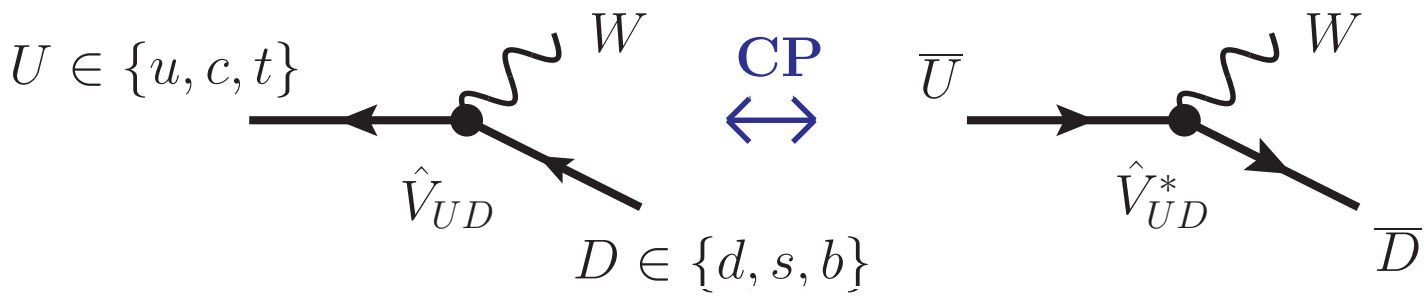
- Mesons are quark-anti-quark bound states



- B variety contain the heavy b quark
  $\Longrightarrow$ decays in many different ways
- Precision measurements probe **quark mixing**
  $\rightarrow$ indirect signals of **New Physics**?
- $B_d^0 \rightarrow$ already studied at B-factories
- Heavier B_s^0 will be studied (after Tevatron) by LHCb

Quark Mixing

- In the Standard Model (SM) quark mixing described by the Cabibbo-Kobayashi-Maskawa matrix $\hat{V}$



- Charge-Parity (CP) symmetry is violated in nature if $\hat{V}$ is complex

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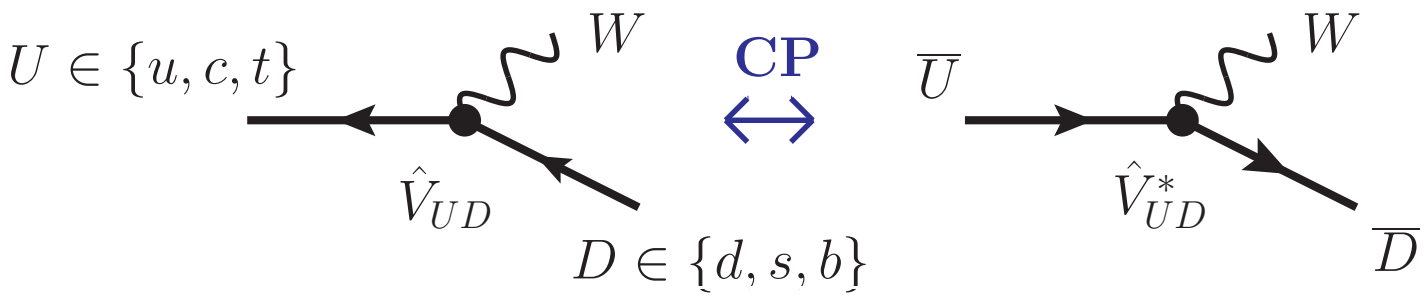
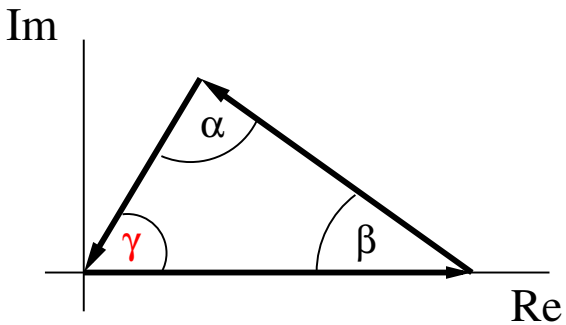
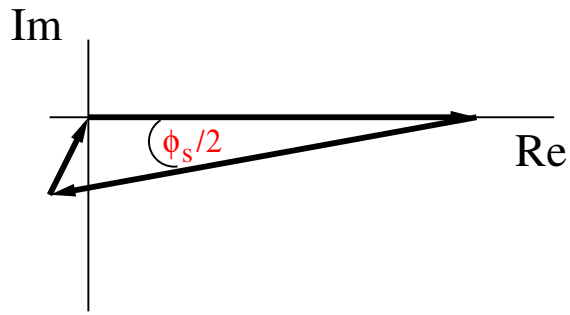


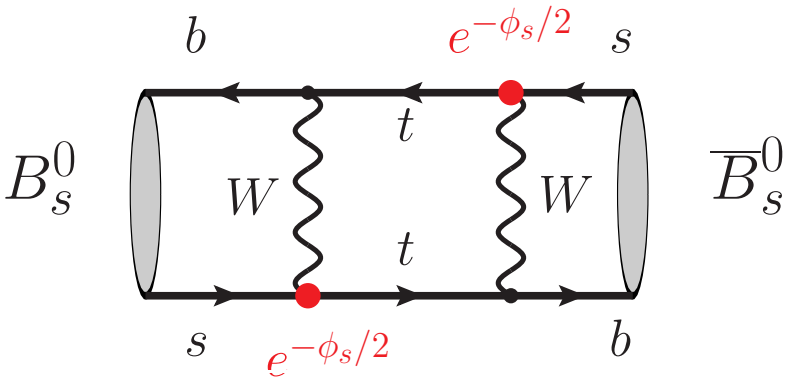
- Charge-Parity (CP) symmetry is violated in nature if $\hat{V}$ is complex
- This CP violation can be depicted by unitarity conditions on the complex plane





New Physics in B_s^0 mixing

- Quark mixing in turn means that B_s mesons mix



- In Standard Model amplitude is supressed and the CP violating phase is tiny $\phi_s = -2^\circ$

New Physics in B_s^0 mixing

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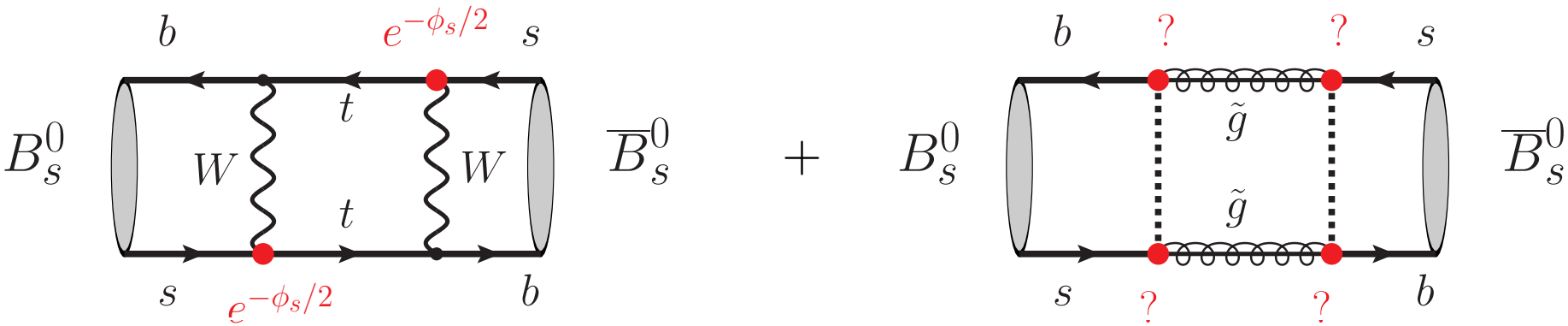
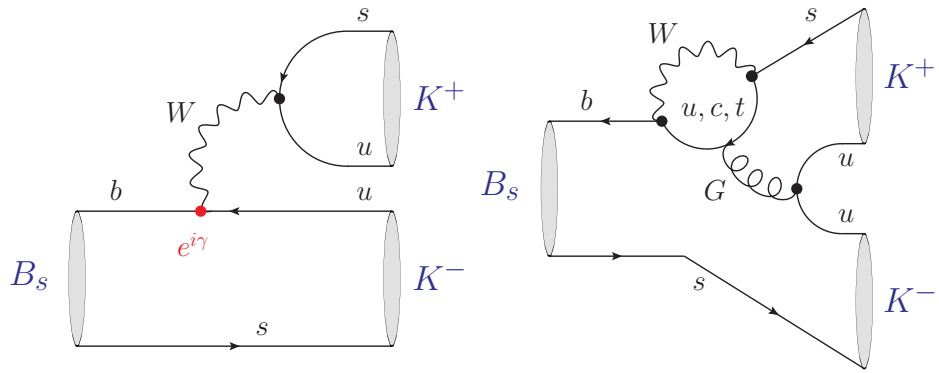


- In Standard Model amplitude is supressed and the CP violating phase is tiny $\phi_s = -2°$
- This makes it **very sensitive** to New Physics appearing in the loop
  - 4th generation fermions
  - Z' bosons
  - Sparticles

The $B_s \to K^+K^-$ decay

- Both tree and penguin contributions:



$$\mathrm{Ampl}(B_s \to K^+K^-) \propto \epsilon\, \mathcal{A}_1 e^{i\gamma} + \mathcal{A}_2\, 1$$

- Including B_s mixing, the CP violating observable:

$$\mathcal{O}_{\mathrm{CP}} \equiv \frac{\Gamma(B_s(t) \to K^+K^-) - \Gamma(\overline{B_s}(t) \to K^+K^-)}{\Gamma(B_s(t) \to K^+K^-) + \Gamma(\overline{B_s}(t) \to K^+K^-)}$$

$$\text{depends on:} \quad \gamma, \quad \phi_s, \quad \mathcal{H} \equiv \frac{\mathcal{A}_2}{\mathcal{A}_1} \in \mathbb{C}$$

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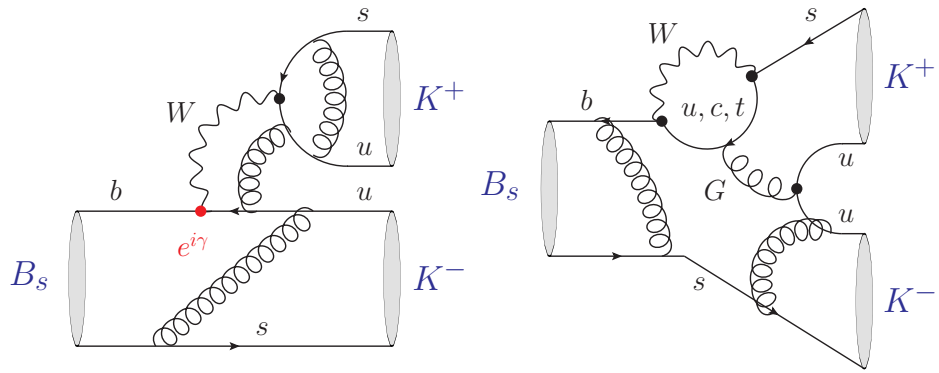

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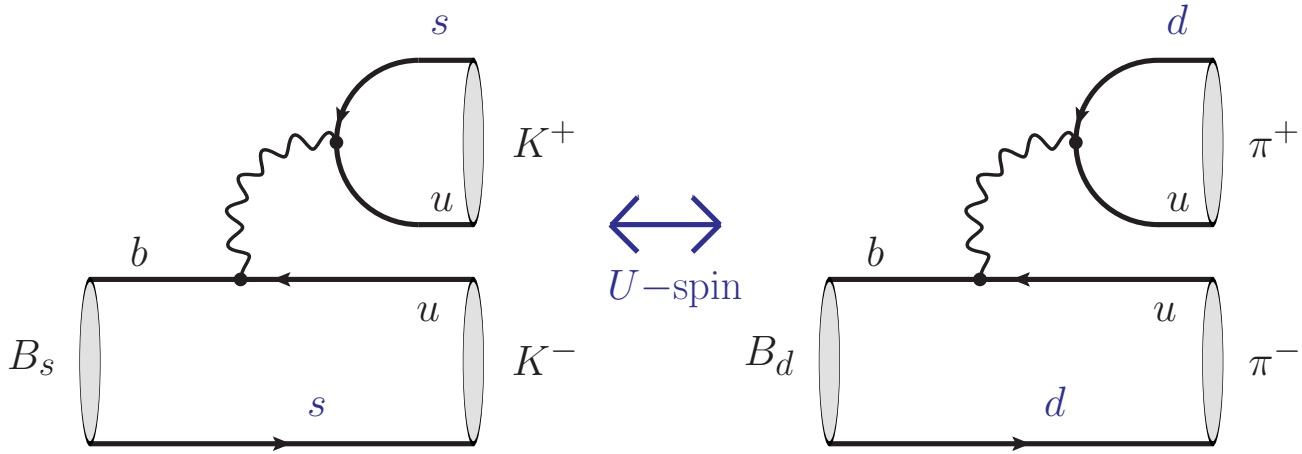
- But $\mathcal{H}$ has non-pertubative QCD corrections...

Solution: U-spin flavour symmetry

- U-**spin**: $SU(2)$ subgroup of $SU(3)$ strong flavour symmetry that relates d and s quarks
- Analagous to iso-spin relation between u and d quarks



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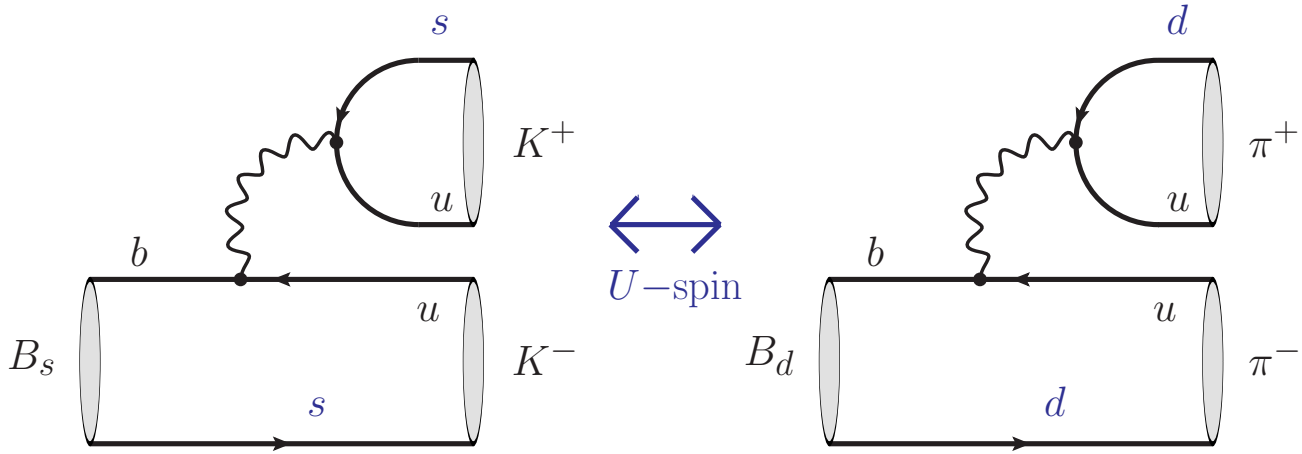

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- Exact U-spin symmetry $\Longrightarrow \mathcal{H} = \mathcal{H}'$

Determining γ with U-spin symmetry

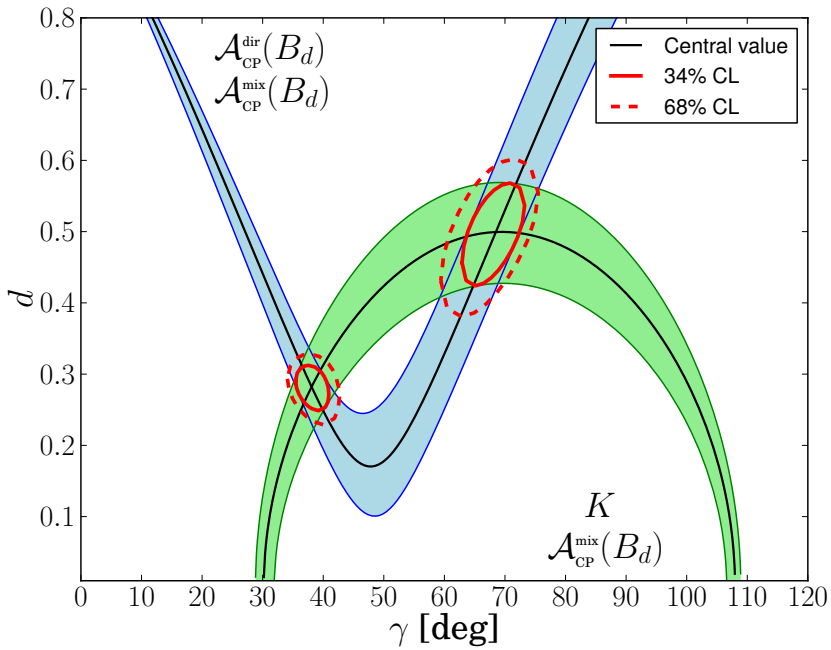
- Let $\mathcal{H} = de^{i\theta}$ and $\mathcal{H}' = d'e^{i\theta'}$

Already measured	To be measured by LHCb
$B_d \to \pi^+\pi^-$ mixing ind. CPV $\to \gamma, d', \theta'$	$B_s \to K^+K^-$ mixing ind. CPV $\to \gamma, \phi_s, d, \theta$
$B_d \to \pi^+\pi^-$ direct CPV $\to \gamma, d', \theta'$	$B_s \to K^+K^-$ direct CPV $\to \gamma, d, \theta$
$K \propto \frac{\mathrm{Br}(B_s \to K^+K^-)}{\mathrm{Br}(B_d \to \pi^+\pi^-)} \to \gamma, d', \theta', d, \theta$	

- Assuming U-spin symmetry $\Longrightarrow$ 3 unknowns, 3 constraints!

Determining γ with U-spin symmetry

- Combining $\gamma - d$ contours gives an intersection:



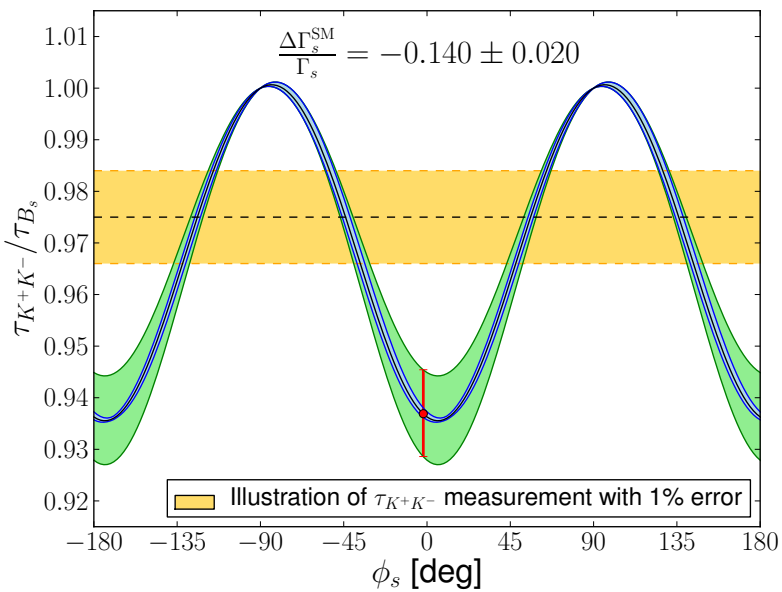
- Find good agreement with fits of CKM matrix (CKMfitter, UTfit):

$$\gamma = (68.3^{+4.9}_{-5.7}|_{\text{input}}{}^{+5.0}_{-3.7}|_{U-\text{spin}})^\circ,$$

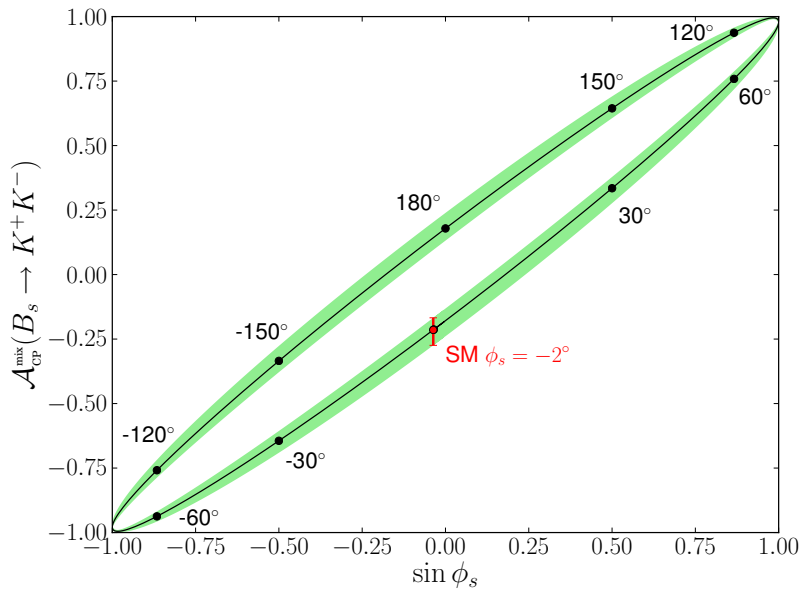
In Pursuit of New Physics

- Current data with U-spin symmetry gives the following predictions for $B_s \to K^+K^-$:

Effective lifetime

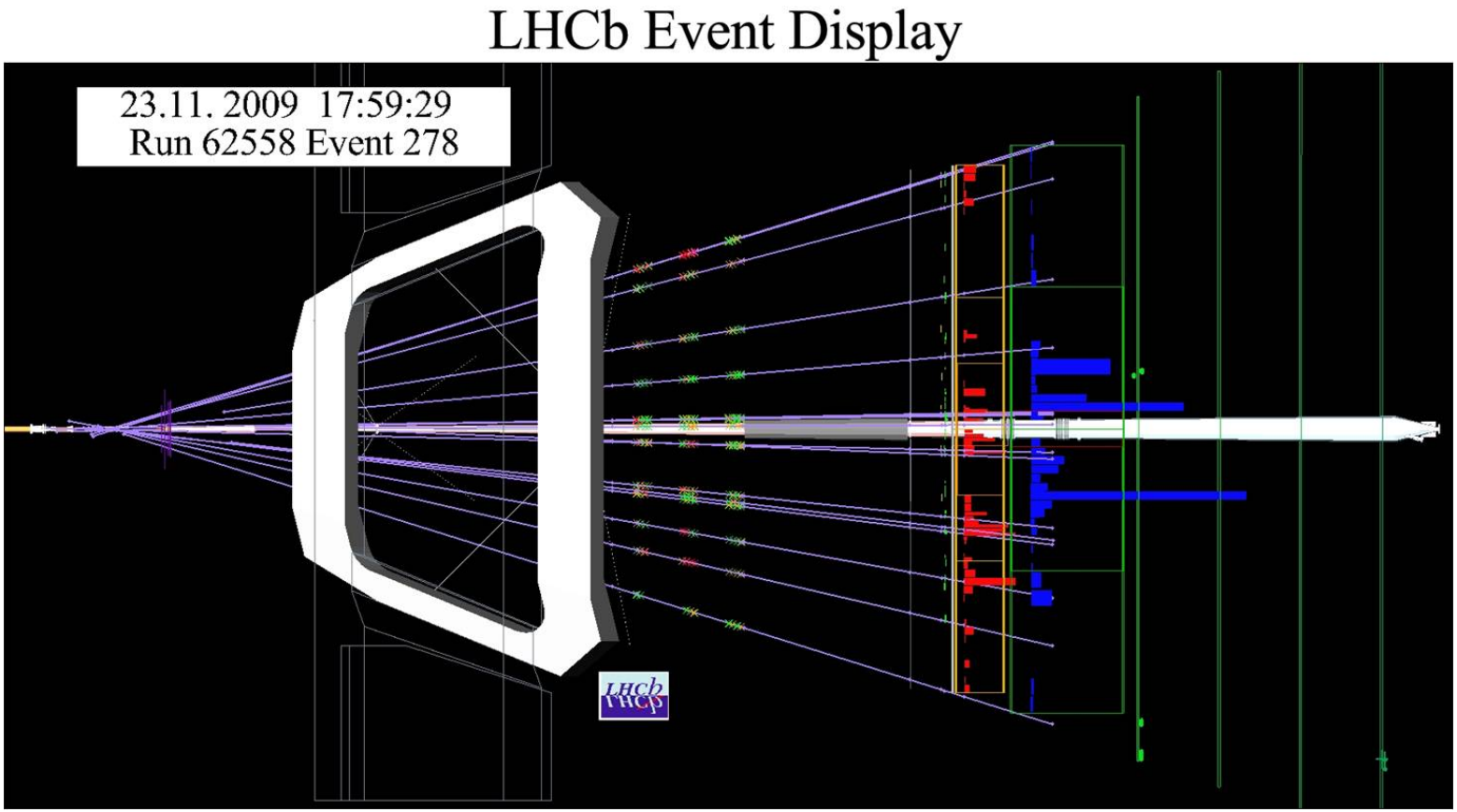


Mixing induced CP asymmetry



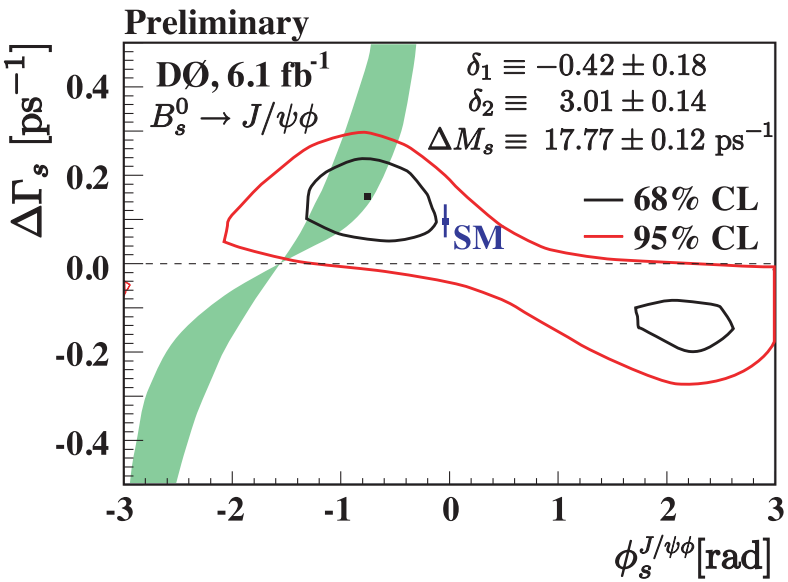
Conclusion

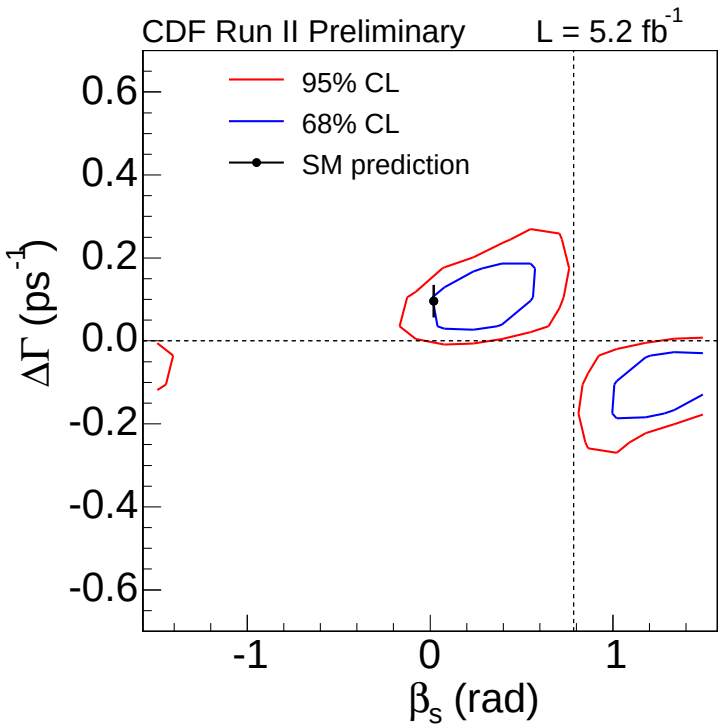
- We eagerly await LHCb data



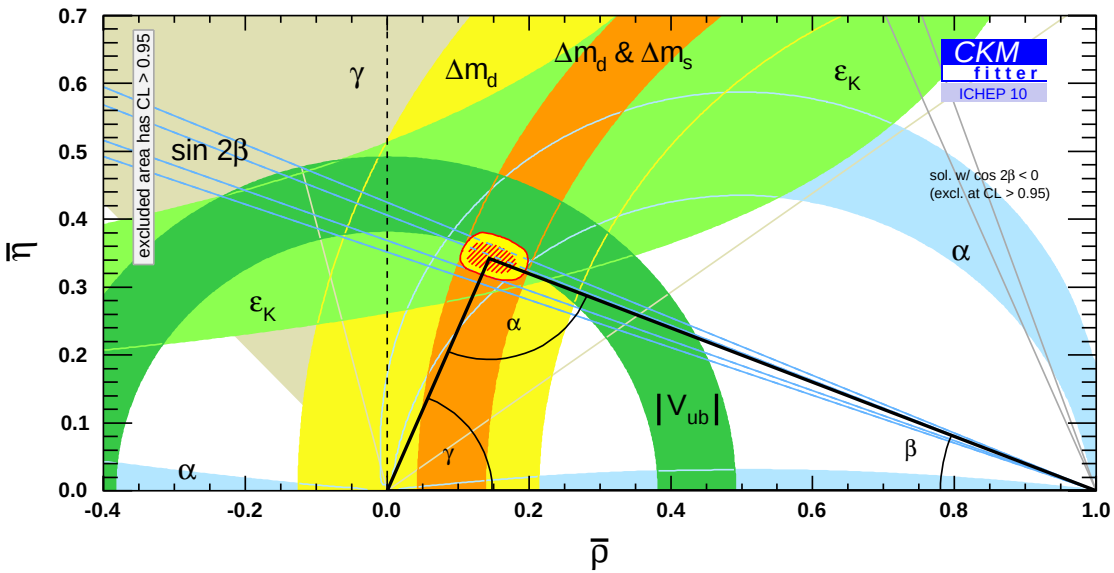
Backup: Measurements of ϕ_s

- CDF/D0 at the Tevatron have already measured a deviation of $\sin\phi_s$ from the SM through the $B_s \to J/\psi\phi$ channel

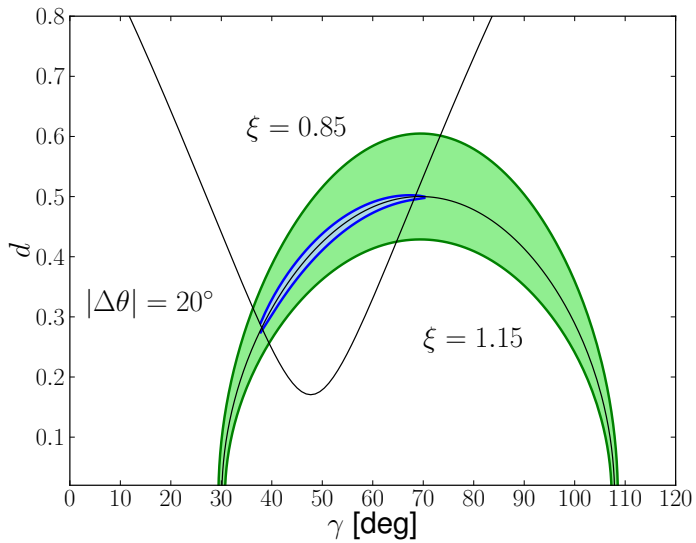




Backup: The Unitarity Triangle



Backup: U-spin error



Backup: Clean γ Extraction

- The last observable to be measured will be the direct CP asymmetry.
- It will allow a theoretically clean extraction of γ and a U-spin consistency check: