Title: The Implications of like-sign dimuon anomaly

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Abstract: The D0 Collaboration recently reported a 3.2sigma deviation from the standard model prediction in the like-sign dimuon asymmetry. I will discuss the implications of this anomaly assuming that new physics contributes only to B_{d,s} mixing. The data allow universal new physics with similar contributions relative to the SM in the B_d and B_s systems, but favors a larger deviation in B_s than in B_d mixing. The general minimal flavor violation framework with flavor diagonal CP violating phases can account for the former and remarkably even for the latter case. This observation makes it simpler to speculate about which extensions with general flavor structure may also fit the data.

BEFORE WE BEGIN...

- let me remind you of two "flavor problems"

SM FLAVOR PUZZLE(S)

- quark flavor sector well measured
  - 10 parameters, exhibit a hierarchy (λ=0.22)

$$\begin{array}{lll} y_t \sim 1 & y_c \sim \lambda^3 & y_u \sim \lambda^7 \\ y_b \sim \lambda^2 & y_s \sim \lambda^5 & y_d \sim \lambda^6 \\ V_{us} \sim \lambda & V_{cb} \sim \lambda^2 & V_{ub} \sim \lambda^3 \end{array} \quad + \text{O(1) phase}$$

  - lepton sector less well measured, different hierarchies
- SM flavor puzzle: why this structure?
- the answer may well not be related to TeV scale

NP FLAVOR PUZZLE

- new physics expected at TeV
  - hierarchy problem
  - dark matter
- but generic flavor structure of TeV NP violates low energy flavor constraints
  $\Rightarrow$ NP flavor problem

THIS TALK

- will have nothing to say about SM flavor puzzle
- for NP flavor puzzle we will assume a particular solution
  - Minimal Flavor Violation
  - not important for the fit

ΔF=2 PROCESSES/NP PUZZLE

- NP contribs. to mixing (assuming (V-A)⊗(V-A) structure)

$$\mathcal{H}_{\rm eff} = \left(\frac{G_F^2 m_W^2}{8\pi^2}\left(V_{ti}^* V_{tj}\right)^2 C_0 + \frac{C_{\rm NP}}{\Lambda_{\rm NP}^2}\right)\left[\bar{d}_i \gamma_\mu (1-\gamma_5) d_j\right]^2$$

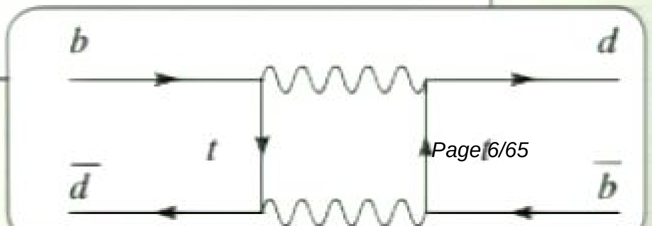
- measurms. exclude O(1) corrections

$$K-\bar{K}\text{ mix.: } \quad (\underbrace{V_{ts}^*}_{\sim\lambda^2}\underbrace{V_{td}}_{\sim\lambda^3})^2 \frac{1}{\Lambda_{\rm MFV}^2} > \frac{C_{\rm NP}}{\Lambda_{\rm NP}^2} \Rightarrow \Lambda_{\rm NP} \gtrsim 10^4 \text{ TeV}$$

$$B_d-\bar{B}_d\text{ mix.: } \quad (\underbrace{V_{tb}^*}_{\sim 1}\underbrace{V_{td}}_{\sim\lambda^3})^2 \frac{1}{\Lambda_{\rm MFV}^2} > \frac{C_{\rm NP}}{\Lambda_{\rm NP}^2} \Rightarrow \Lambda_{\rm NP} \gtrsim 5\cdot 10^2 \text{ TeV}$$

$$B_s-\bar{B}_s\text{ mix.: } \quad (\underbrace{V_{tb}^*}_{\sim 1}\underbrace{V_{ts}}_{\sim\lambda^2})^2 \frac{1}{\Lambda_{\rm MFV}^2} > \frac{C_{\rm NP}}{\Lambda_{\rm NP}^2} \Rightarrow \Lambda_{\rm NP} \sim 10^2 \text{ TeV}$$

$$\Lambda_{\rm MFV} = \sqrt{8}\pi / G_F m_W \sim 6 \text{ TeV}$$



MINIMAL FLAVOR VIOLATION

D'Ambrosio, Giudice, Isidori, Strumia, 2002
Buras et al, 2000; Chivukula, Georgi, 1987
Hall, Randall, 1990

- if NP at TeV it has a very nontrivial flavor structure
- can NP emulate the SM hierarchy?
- Minimal Flavor Violation hypothesis: flavor only broken by SM Yukawas
- a nonempty set: MSSM with gauge mediated SUSY breaking

MINIMAL FLAVOR VIOLATION

D'Ambrosio, Giudice, Isidori, Strumia, 2002

- use spurion analysis to construct NP opers./contribs.
- quark sector formally inv. under $U(3)_Q \otimes U(3)_u \otimes U(3)_d$, if the Yukawas promoted to spurions

$$Y'_{u,d} = V_Q Y_{u,d} V^\dagger_{u,d}$$

- constrains possible FV structures, e.g. (V-A)⊗(V-A)
  - allowed: $\bar{Q}(Y_u Y_u^\dagger)^n Q$
  - not allowed: $\bar{Q} Y_d^\dagger (Y_u Y_u^\dagger)^n Q$
- it gives SM like suppression of FCNC's since

$$(Y_u Y_u^\dagger)^n \sim (Y_u Y_u^\dagger) = V_{\rm CKM} {\rm diag}(0,0,1) V^\dagger_{\rm CKM}$$

- for (V-A) bilinear $\bar{b}_L s_L$ the suppression $\sim V_{tb} V^*_{ts}$

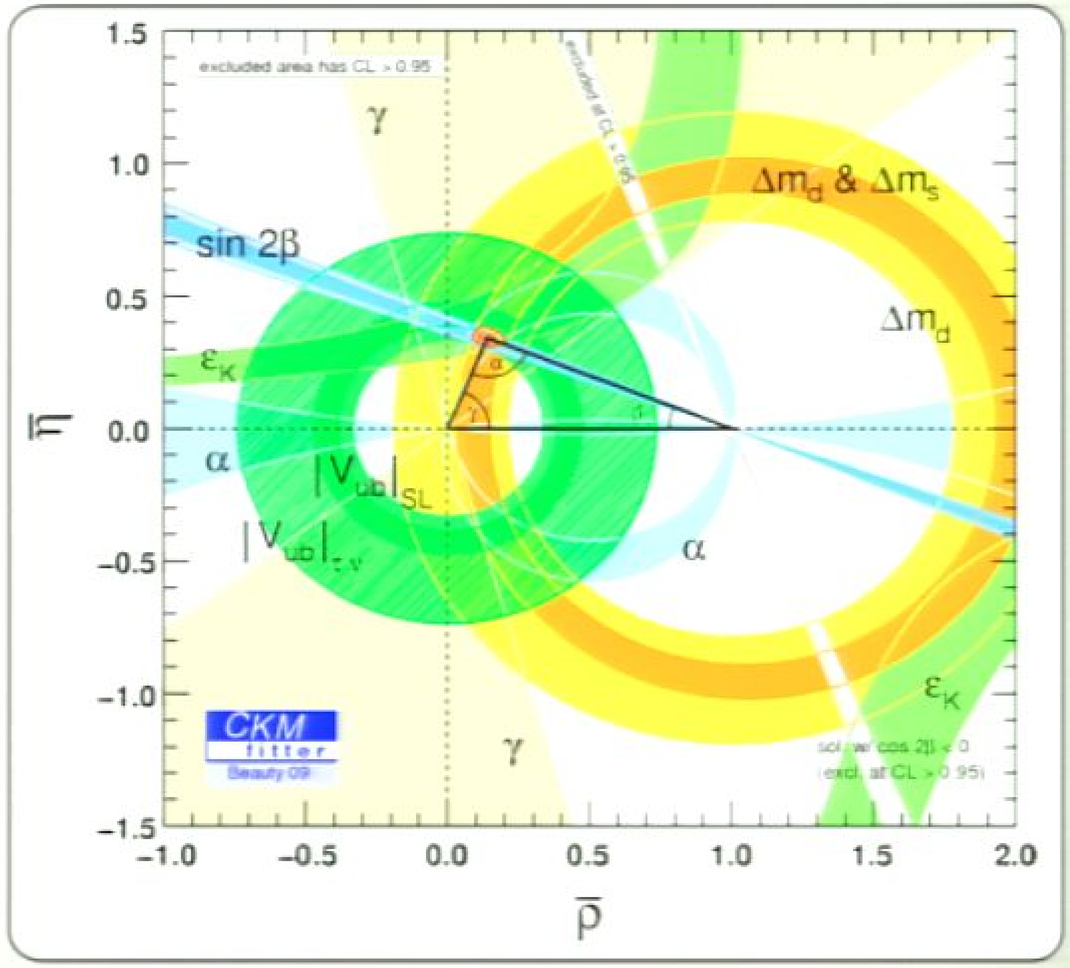
OUTLINE

- experimental situation
- model independent fit
- what it tells us about NP

EXPERIMENTAL SITUATION

PRESENT EXPERIMENTAL SITUATION

- SM CKM mechanism dominates
- global agreement between *B* and *K* systems
- but there are odd bits and pieces that are not in the fit



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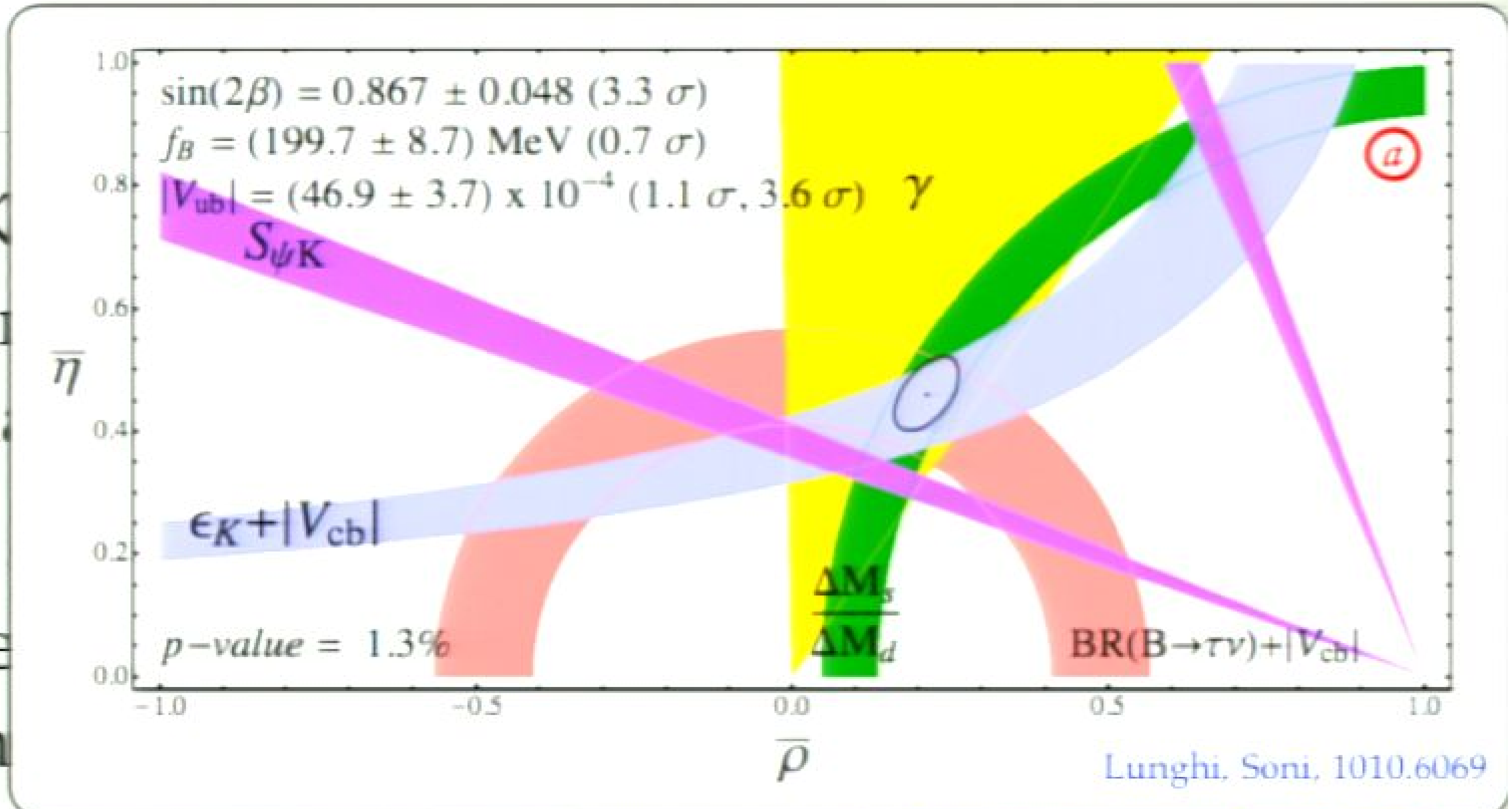

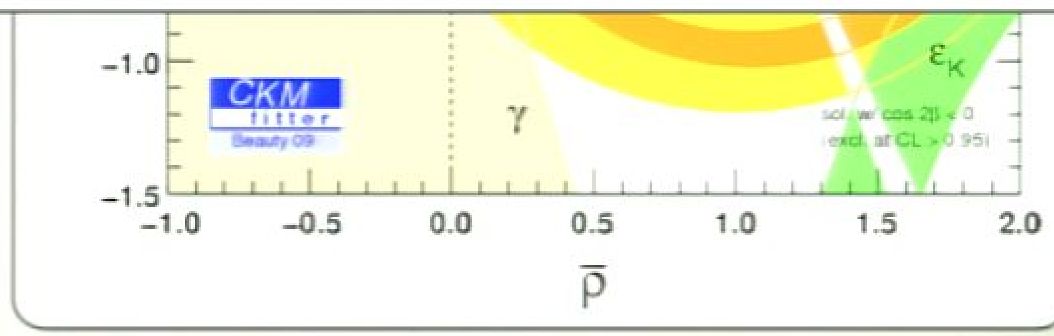

TENSIONS

- determination of V_{ub} from $B \to \tau\nu$ does not agree with global fit
- there may be tension with ε_K (depends on lattice B_K)

  Laiho et al., 0910.2928; Lunghi, Soni, 1010.6069
  Buras, Guadagnoli, 0805.3887; 0901.2056
  Charles et al., 1008.1593
- there is a 3.x sigma tension with SM in B_s mixing

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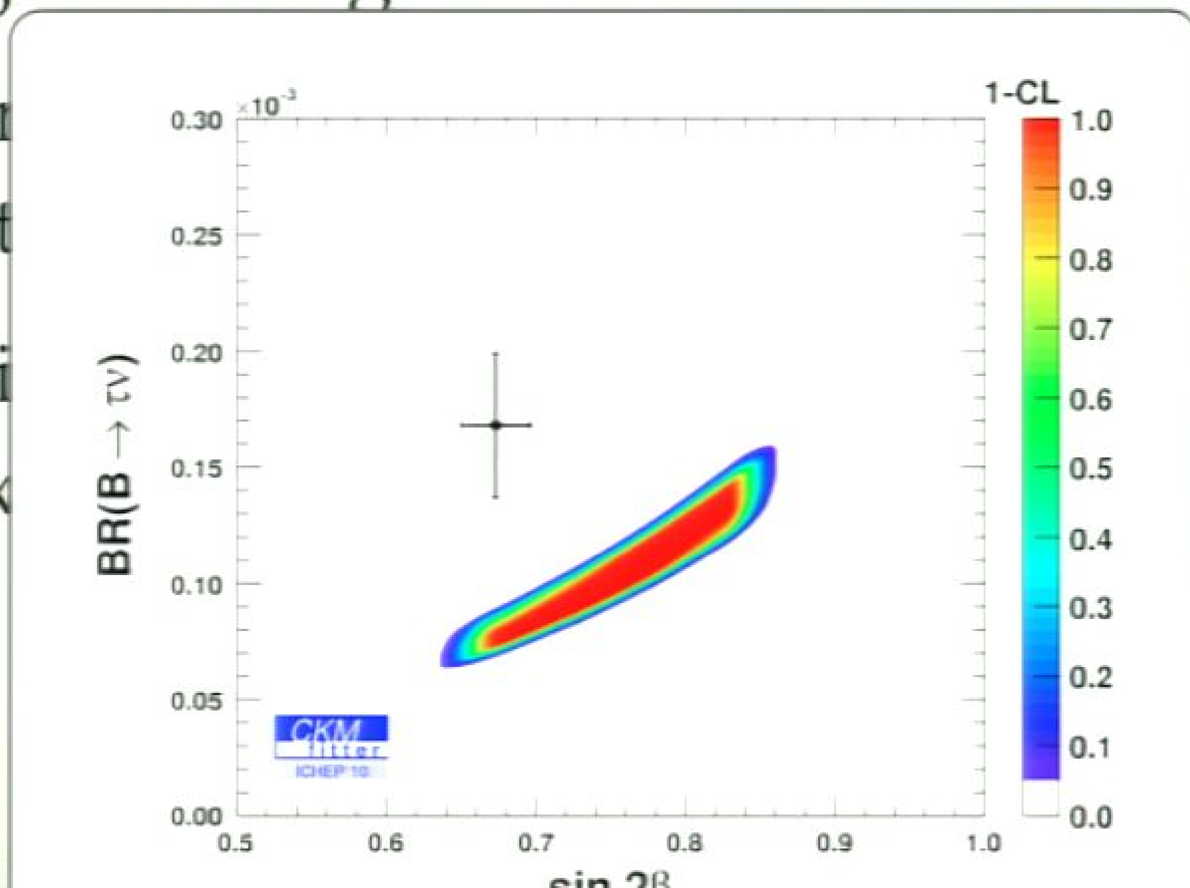

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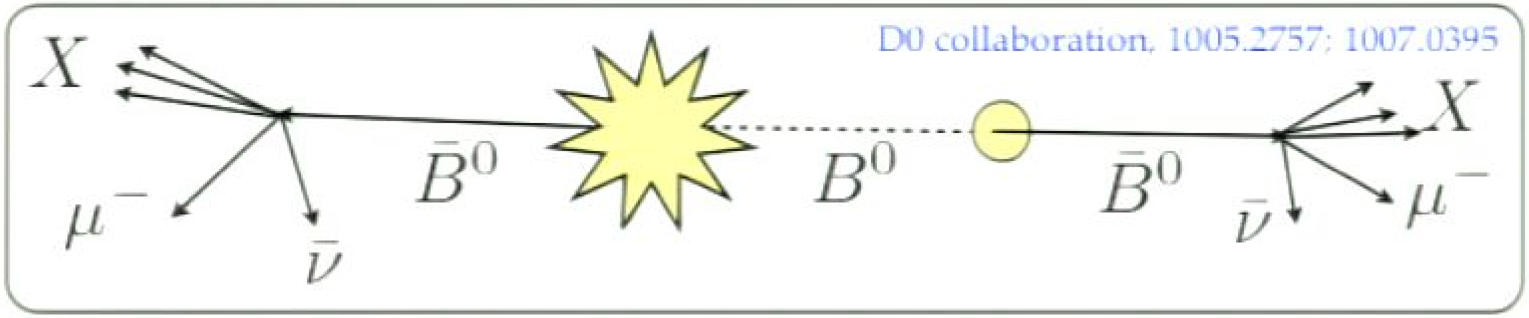
main topic of this talk

PHILOSOPHY

- focus on tensions that
  - require minimal theory input (i.e. no QCD info needed)
  - model independent interpretation
- like-sign dimuon anomaly at 3.2 sigma
- indication of NP phase in B_s mixing

DIMUON ANOMALY



- DØ measured $A_{SL}{}^b$ to be 3.2σ away from SM

$$A_{SL} = \frac{N(\mu^+\mu^+X) - N(\mu^-\mu^-X)}{N(\mu^+\mu^+X) + N(\mu^-\mu^-X)}$$

$$a^b_{SL} = -(9.57 \pm 2.51 \pm 1.46) \times 10^{-3} \quad \left(a^b_{SL}\right)^{\mathrm{SM}} = (-2.3^{+0.5}_{-0.6}) \times 10^{-4}$$

- note: exp. not known that it comes from B
- decay $\bar{B}^0 \to \mu^- \bar{\nu} X$ tags the flavor of B

COMPARISON

- at Tevatron both B_d and B_s produced

$$a^b_{SL} = (0.506 \pm 0.043)\, a^d_{SL} + (0.494 \pm 0.043)\, a^s_{SL}$$

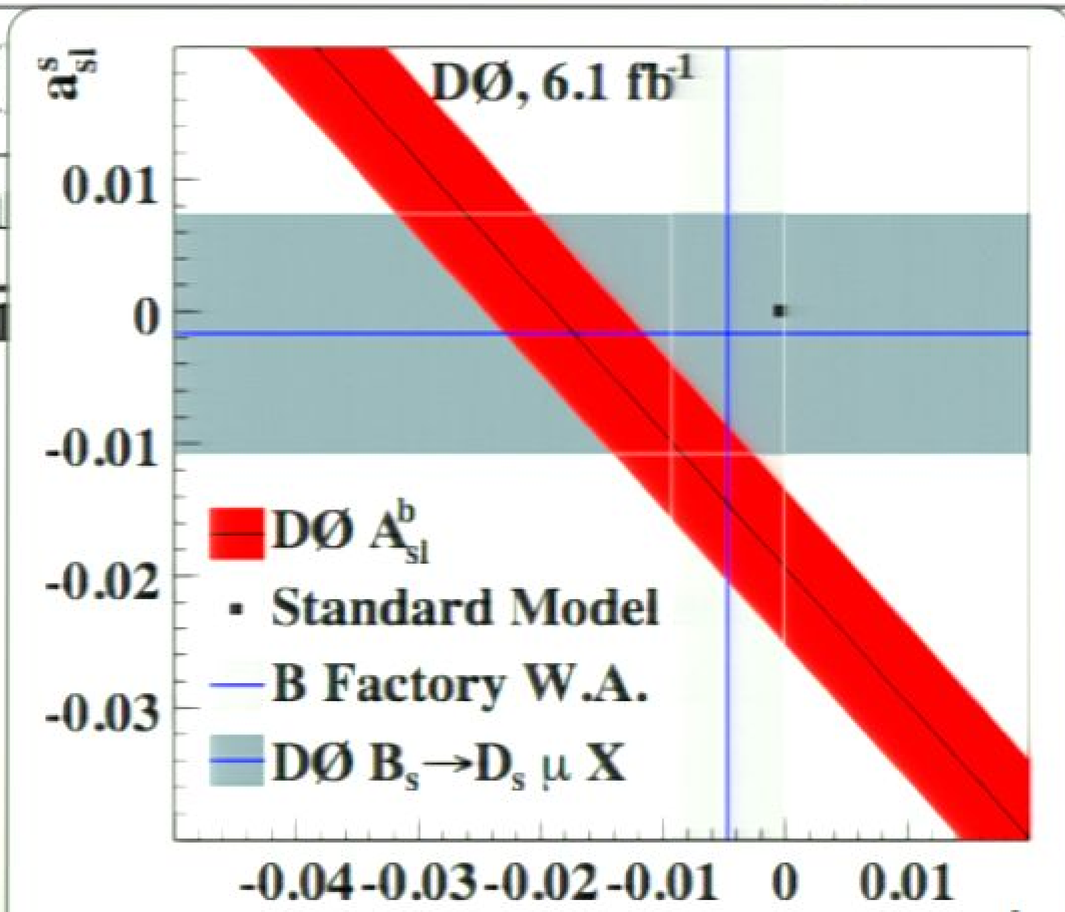
- the new measurement consistent with previous ones (but smaller errors)

COMPARISON

- at Tevatron both B_d and B_s produced

$$a^b_{SL} = (\quad\quad\quad\quad 43)\, a^s_{SL}$$

- the n … with previ …)



COMPARISON WITH $B_s \rightarrow J/\psi\phi$

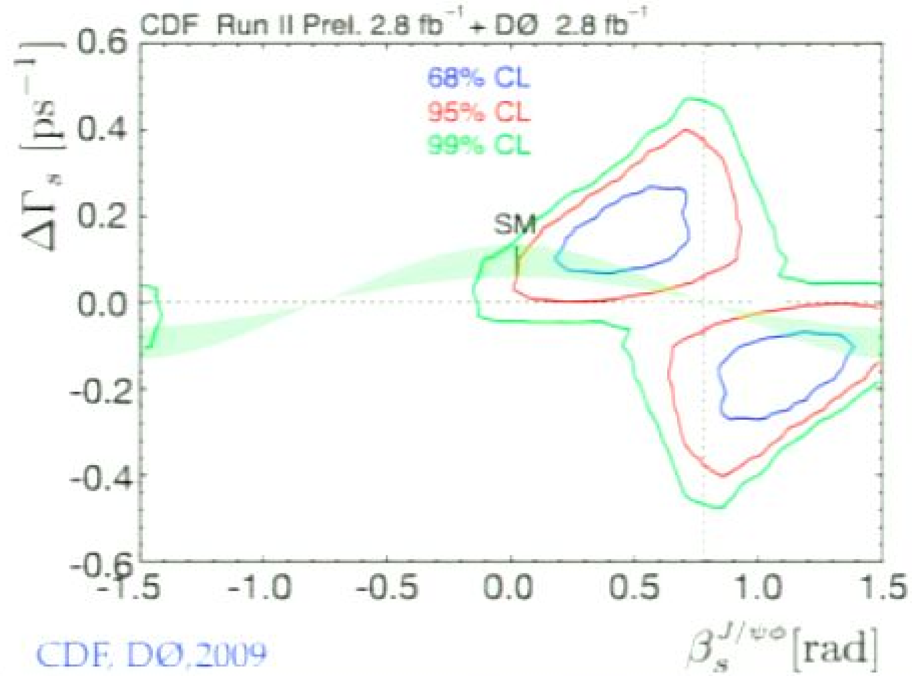
- time dependent measurement

$$B_s(t) \rightarrow J/\psi\phi$$

- can measure $\Delta\Gamma = \Gamma_L - \Gamma_H$ and β_s

$$\beta_s = -\arg(-M_{12}/\Gamma_{12})$$

- in SM $\beta_s = (1.04 \pm 0.05)^\circ$



CDF, DØ,2009

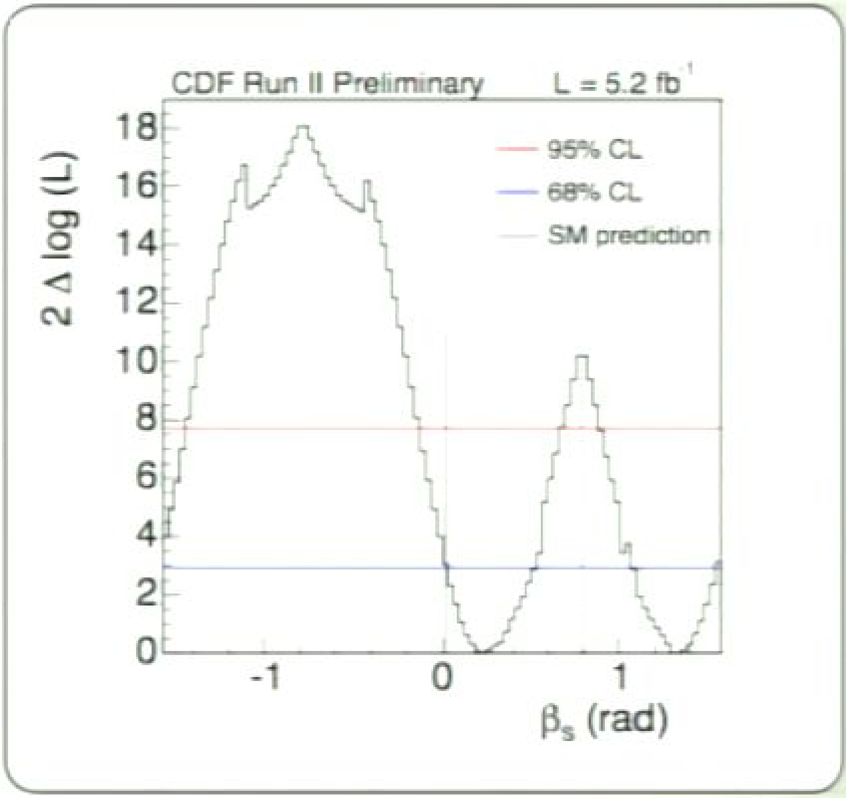
- pre FPCP 2010 combined CDF and DØ

2.12 σ away from SM

- no such combination available yet

COMPARISON WITH $B_S \rightarrow J/\psi\phi$

- use separately data from CDF (new) and DØ (old)
- from CDF we use 1D likelihood
  - no 2D LL available
- data presented at FPCP 2010 (May 2010)

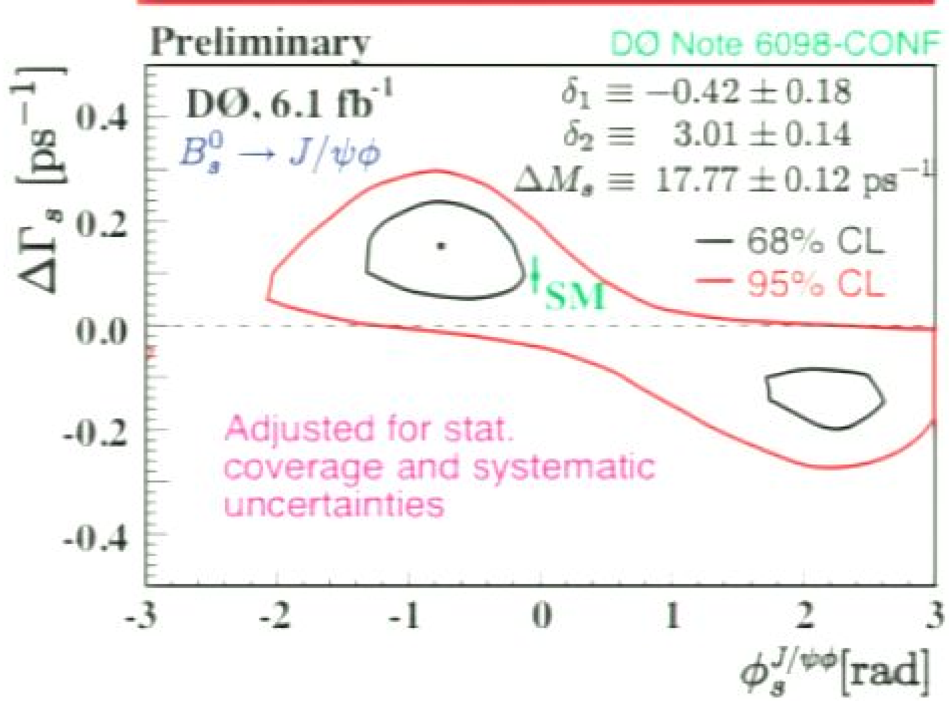


- moved closer to SM (now 0.8σ away)
- consistent with all other measurements

COMPARISON WITH $B_s \to J/\psi\phi$

- from DØ use old 2D LL
- new data uses constr. on strong phases from $B_d \to J/\psi\phi$
- old data no such constr. (same as CDF)
- new and old DØ data well consistent
  - previously (2008) $\phi_s = -0.57^{+0.24+0.07}_{-0.30-0.02}$

$$\phi_s^{J/\psi\phi} = -0.76^{+0.38}_{-0.36} \pm 0.02$$



- no large effect expected from this approximation

NEW PHYSICS?

- What does all this mean?
  - new physics?
  - just statistical fluctuation(s)?
- Will explore the possibility of NP
  - assume that dominant effect due to NP in the mixing
  - in the decay amplitudes has to compete with tree level

GENERAL ANALYSIS

GENERAL PARAMETRIZATION

- NP only in mixing

$$M_{12}^{d,s} - \frac{i}{2}\Gamma_{12}^{d,s} = \langle B_{d,s}^0 | H^{\text{eff}} | \bar{B}_{d,s}^0 \rangle$$

- B_d and B_s systems described by 4 real parameters

$$M_{12}^{d,s} = \left(M_{12}^{d,s}\right)^{\text{SM}} \left(1 + h_{d,s}\, e^{2i\sigma_{d,s}}\right)$$

- the observables are then

$$\begin{aligned}
\Delta m_q &= \Delta m_q^{\text{SM}} \left|1 + h_q e^{2i\sigma_q}\right| , \\
\Delta\Gamma_s &= \Delta\Gamma_s^{\text{SM}} \cos\left[\arg\left(1 + h_s e^{2i\sigma_s}\right)\right] . \\
A_{\text{SL}}^q &= \text{Im}\left\{\Gamma_{12}^q / \left[M_{12}^{q,\text{SM}}\left(1 + h_q e^{2i\sigma_q}\right)\right]\right\} , \\
S_{\psi K} &= \sin\left[2\beta + \arg\left(1 + h_d e^{2i\sigma_d}\right)\right] , \\
S_{\psi\phi} &= \sin\left[2\beta_s - \arg\left(1 + h_s e^{2i\sigma_s}\right)\right]
\end{aligned}$$

THE FIT

Ligeti, Perez, Papucci, JZ, (1006.0432)

- the fit done using `CKMFitter` package
- correlation between B_s and B_d systems is through $A_{SL}{}^{b}$
- $\Delta\Gamma_s$ floated in the fit ($|\Gamma_{12}|$ in range 0-0.25 ps^{-1})
  - cf. SM pred. $|\Gamma_{12}|=0.048\pm0.011\ ps^{-1}$ Nierste, CKM2010
  - uses OPE, eng. release only $m_b-2m_c \sim 2$GeV
  - data prefers $\Delta\Gamma_s$ ~2.5 bigger than the prediction

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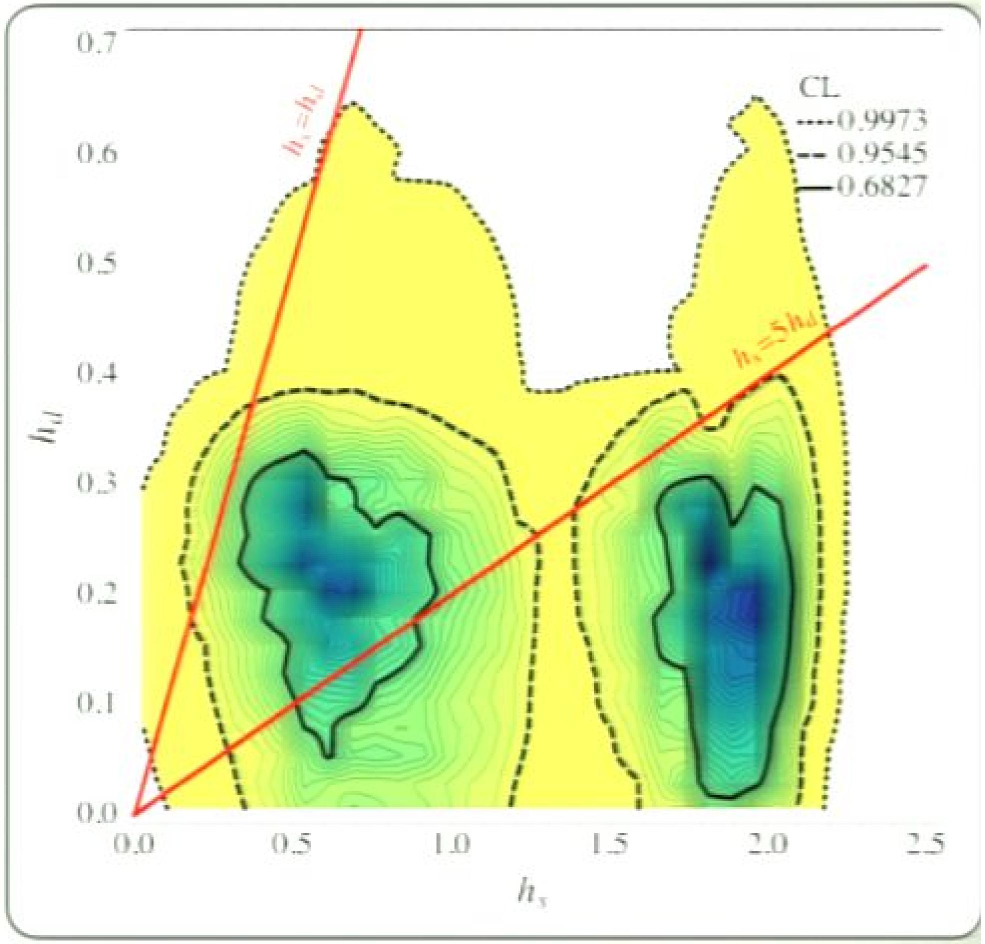
RESULTS OF THE FIT

- no NP hypothesis $h_d = h_s = 0$ is disfavored at 3.3 σ level
- two best fit regions for $h_s \sim 0.5$ and $h_s \sim 1.8$ have large phases
- in h_s-σ_s the no NP point $h_s = 0$ disf. at 2.6σ
- in h_d-σ_d the no NP point $h_d = 0$ allowed below 2σ



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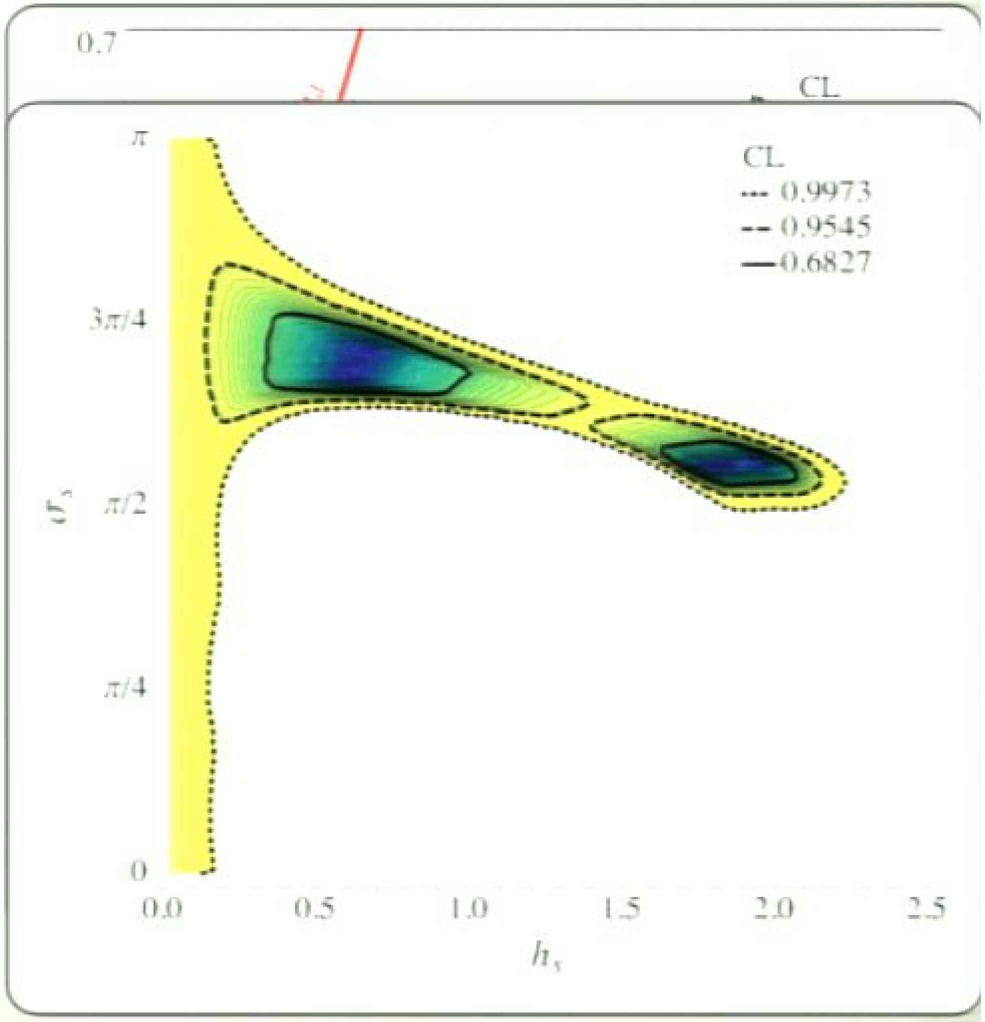

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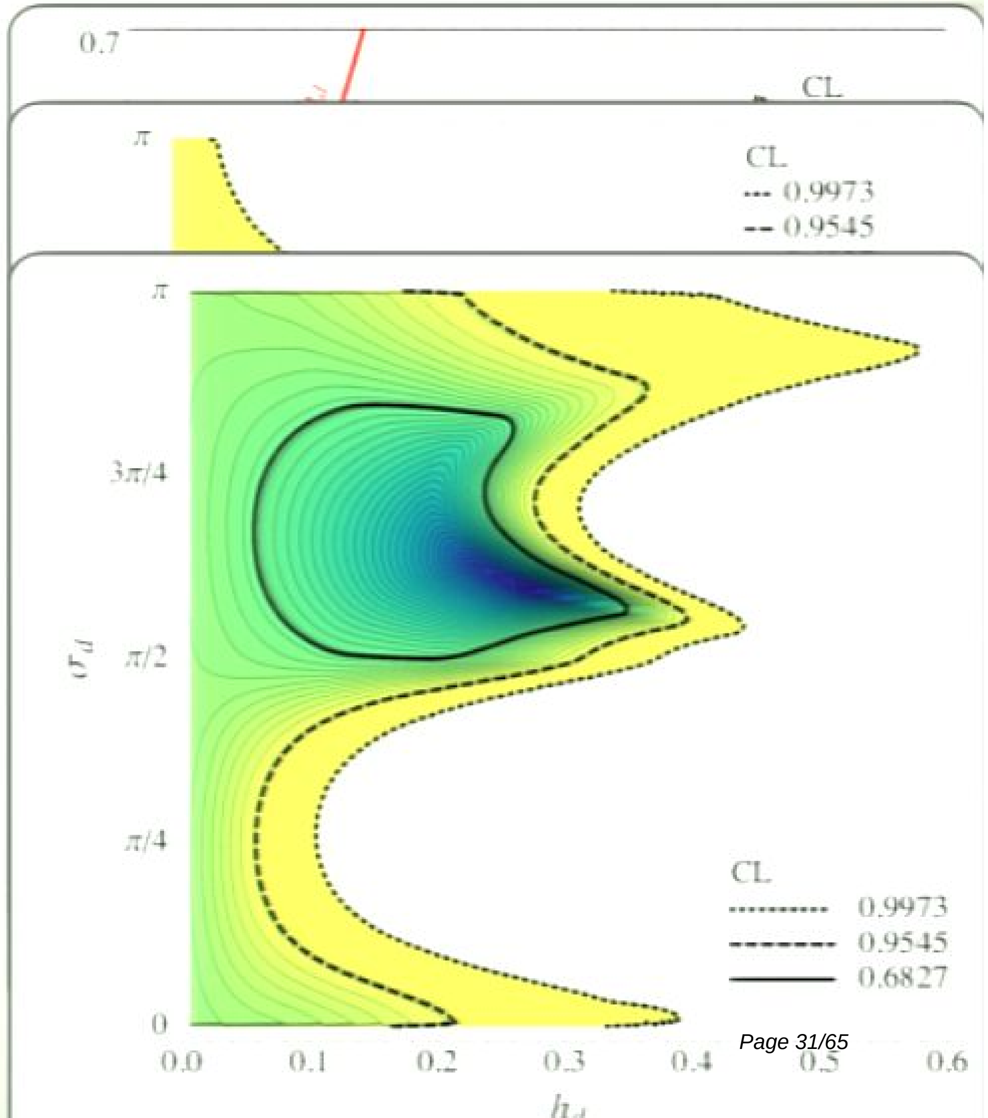
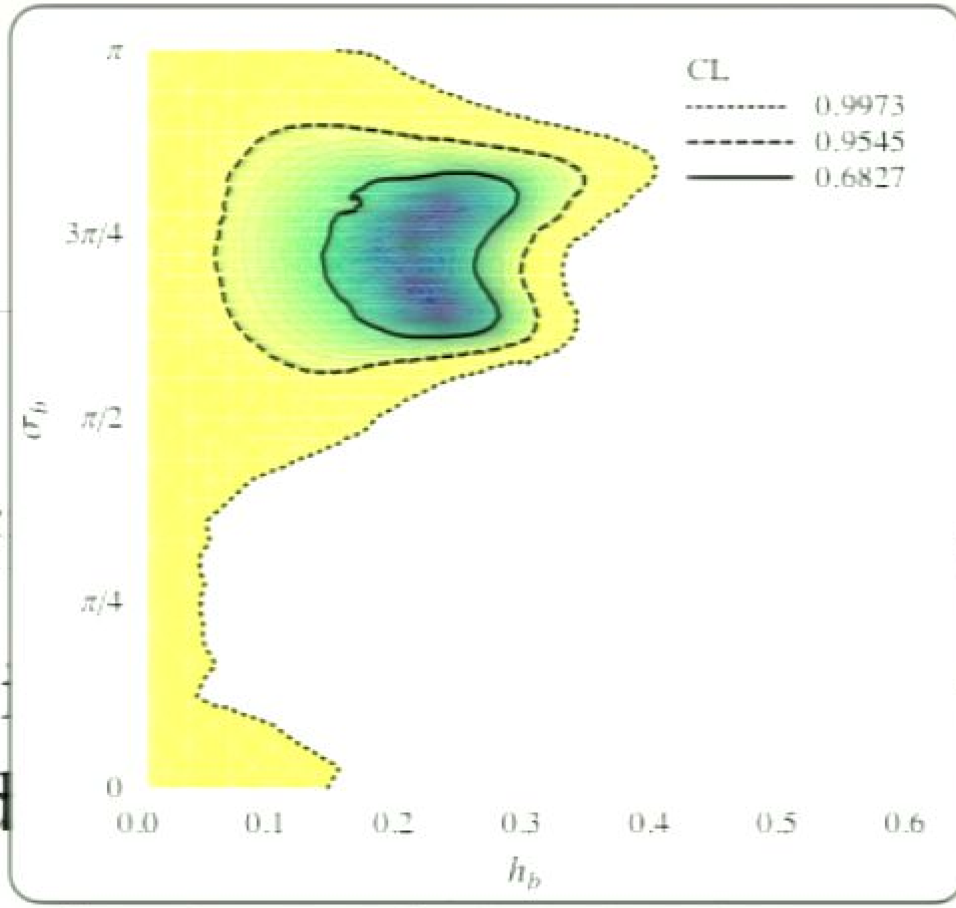


PATTERNS

- most of the favored param. space has $h_s > h_d$
- $h_s >> h_d$ is preferred, but $h_s \sim h_d$ is still allowed
- redoing the fit with $h_s = h_d \equiv h_b$ and $\sigma_s = \sigma_d \equiv \sigma_b$ worsens the fit
  - allowed region is $h_b \sim 0.25$, $\sigma_b \sim 120^o$



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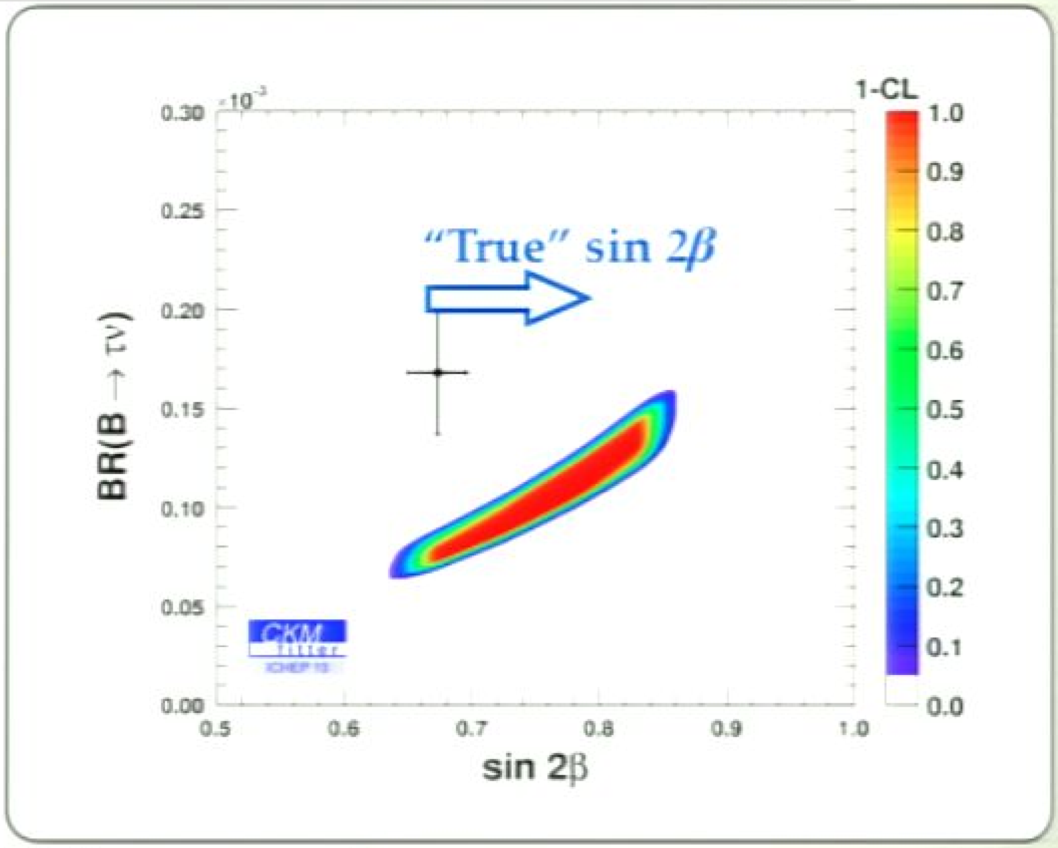
COMMENT ON $B \to \tau\nu$

- CKMfitter also perf. the fit Charles et al., 1008.1593
- included $B \to \tau\nu$
  - if no NP in decay: goes in the right direction



- tension with SM at 3.7sigma when combined everything

SUMMARY SO FAR

- present data support the hypothesis of new CP violation contributions
  - and that it mainly contributes to $\Delta F=2$ mixing amplitude
- the SM extensions with $SU(2)_q$ "universality" are not preferred

MINIMAL FLAVOR VIOLATION & GENERAL MFV

DIFFERENT MFV'S

- MFV: expansion in Y_u, Y_d
- sometime additional assumptions are made
  - CP only violated by Yukawas
  - only SM 4-quark operators
- we will not make such assumptions
- for simplicity work in large $\tan\beta$ limit

A QUESTION

- Y_u, Y_d have O(1) eigenvalues $y_{t,b}$:
  why are we able to expand $\bar{Q} f(\epsilon_u Y_u, \epsilon_d Y_d) Q$?
  - if $\varepsilon_{u,d} << 1$: series truncates after first few terms ⇒
    Linear MFV ⇒ expansion in $Y_{u,d}$
  - if $\varepsilon_{u,d} = O(1)$: higher terms important ⇒
    Nonlinear MFV ⇒ need to reorganize expansion
- can we distinguish LMFV vs. NLMFV?
  - interesting since $\varepsilon_{u,d} \propto \log(\mu_W / \Lambda_F)$ ⇒ could give a handle on physics at higher scales (with caveats)

Kagan, Perez, Volansky, JZ, 2009

GENERAL MFV

- formalism inspired by nonlinear sigma model
- G^{SM} broken by $y_{t,b}$ to H^{SM}=U(2)$_Q$⊗U(2)$_u$⊗U(2)$_d$⊗U(1)$_3$, we mod out broken symm. generators of G^{SM}/H^{SM}

$$Y_{u,d} = e^{i\hat{\rho}_Q} e^{\pm i\hat{\chi}/2} \tilde{Y}_{u,d} e^{-i\hat{\rho}_{u,d}}, \qquad \tilde{Y}_{u,d} = \begin{pmatrix} \phi_{u,d} & 0 \\ 0 & y_{t,b} \end{pmatrix}$$

- ρ_i spurion "Goldstone bosons", can be set to zero
- χ the misalignement spurion, in down quark basis

$$\hat{\chi} = \begin{pmatrix} 0 & \chi \\ \chi^\dagger & 0 \end{pmatrix}, \quad \chi^\dagger \to i(V_{td}, V_{ts}), \quad \phi_u \to V_{\rm CKM}^{(2)\dagger} \,{\rm diag}(\frac{m_u}{m_t}, \frac{m_c}{m_t})$$

- the bilinears are invariant under H^{SM}

$$\chi' = U_Q^{2\times2}\chi, \qquad \phi'_{u,d} = U_Q^{2\times2}\phi_{u,d}U_{u,d}^{2\times2\dagger}$$

COMPARING WITH THE USUAL MFV NOTATION

- MFV LL example ($\Delta^k_{ij} = y_k^2 V^*_{ki} V_{kj}$ with i≠j)

$$\bar{Q}\left[a_1 Y_u Y_u^\dagger + a_2 (Y_u Y_u^\dagger)^2\right] Q + \left[b_2\,(\bar{Q} Y_u Y_u^\dagger Y_d Y_d^\dagger) Q + h.c.\right] + \cdots =$$
$$\bar{d}^i_L\left[(a_1 + a_2 y_t^2)\Delta^t_{ij} + a_1 \Delta^c_{ij}\right] d^j_L + \left[b_2 y_b^2\, \bar{d}^i_L \Delta^t_{ib} b_L + h.c.\right]$$

  - LMFV: $a_1 >> a_2, b_2$, NLMFV: $a_1 \sim a_2 \sim b_2$
  - $a_{1,2}$ are real, b_2 can be complex
- in GMFV notation

$$(c_b \overline{d_L^{(2)}} \chi b_L + h.c) + c_t \overline{d_L^{(2)}} \chi \chi^\dagger d_L^{(2)} + c_c \overline{d_L^{(2)}} \phi_u \phi_u^\dagger d_L^{(2)}$$

- LO: $c_b \simeq (a_1 y_t^2 + a_2 y_t^4 + b_2 y_b^2),\ c_t \simeq a_1 y_t^2 + a_2 y_t^4,\ c_c \simeq a_1$

WHY THIS USEFUL?

- is this useful?
  - if one is interested in higher order terms in $\phi_{u,d}, \chi$ expansion
  - to make general statements

CP VIOLATION

- using GMFV formalism we can prove the following:

  assuming MFV, there can be significant new CPV effects only if there are new flavor diagonal CP sources

CP VIOLATION

- using GMFV formalism we can prove the following:

assuming MFV, there can be significant new CPV effects only if there are new flavor diagonal CP sources

- proof: the leading CKM generated flavor-diag. phase $\chi^\dagger[\phi_u^\dagger\phi_u, \phi_d^\dagger\phi_d]\chi$ is very small

$$[\phi_u^\dagger\phi_u, \phi_d^\dagger\phi_d] \sim (m_s/m_b)^2(m_c/m_t)^2 \sin\theta_C \sim 10^{-9}$$

CONTRIBUTIONS TO B MIXING

Kagan, Perez, Volansky, JZ, 0903.1794 see also G. Colangelo, E. Nikolidakis and C. Smith, 0807.0801

- 2 classes of non-hermitian $\Delta B = 2$ effective operators
  - class-1 (no $d_R^{(2)}$): $(\overline{d_L^{(2)}} \chi b_{L,R})^2, \ldots$
  - class-2 (with $d_R^{(2)}$): $(\overline{d_R^{(2)}} \phi_d^\dagger \chi b_L)(\overline{d_L^{(2)}} \chi b_R), \ldots$
- class-2 contribs. only to $B_s - \bar{B}_s$ mixing (up to m_d / m_s)
- $SU(3)_F$ breaking in $B_{d,s}$–$B_{d,s}$ bag parameters small $\Rightarrow$ same NP phase shift in $B_d - \bar{B}_d$ and $B_s - \bar{B}_s$
- class-1 contribs. dominate if Λ comparable for all ops.
- sizable CPV in B_s system requires class-2 contribs.
- barring cancelations NP CPV in $B_s - \bar{B}_s$ mix. > NP CPV in $B_d - \bar{B}_d$ mixing

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  same NP phase shift in $B_d - \bar{B}_d$ and $B_s - \bar{B}_s$
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Observed pattern

sizable CPV in B_s system requires class-2 contribs.

barring cancelations

NP CPV in $B_s - \bar{B}_s$ mix. > NP CPV in $B_d - \bar{B}_d$ mixing

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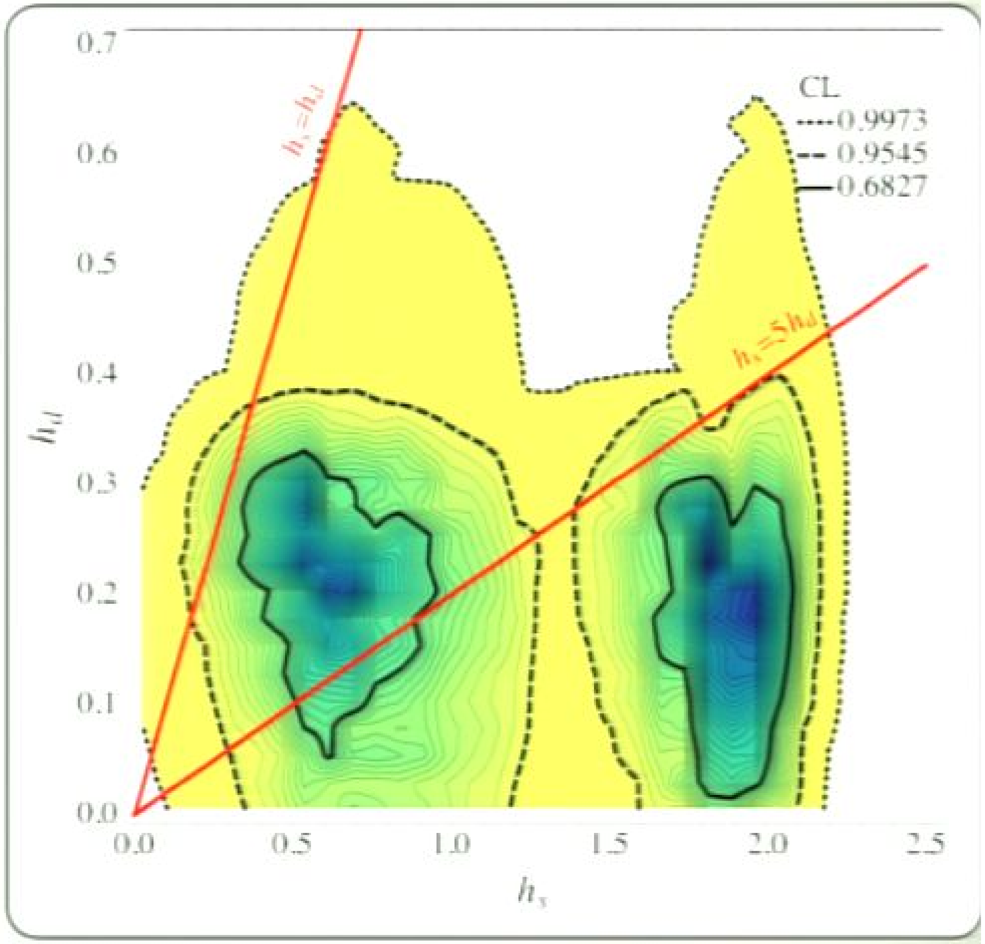
PATTERNS

- most of the favored param. space has $h_s > h_d$
- $h_s >> h_d$ is preferred, but $h_s \sim h_d$ is still allowed
- redoing the fit with $h_s = h_d \equiv h_b$ and $\sigma_s = \sigma_d \equiv \sigma_b$ worsens the fit
  - allowed region is $h_b \sim 0.25$, $\sigma_b \sim 120^o$

Ligeti, Perez, Papucci, JZ, (1006.0432)

RESULTS OF THE FIT

- no NP hypothesis $h_d = h_s = 0$ is disfavored at 3.3 σ level
- two best fit regions for $h_s \sim 0.5$ and $h_s \sim 1.8$ have large phases
- in h_s-σ_s the no NP point $h_s = 0$ disf. at 2.6σ
- in h_d-σ_d the no NP point $h_d = 0$ allowed below 2σ



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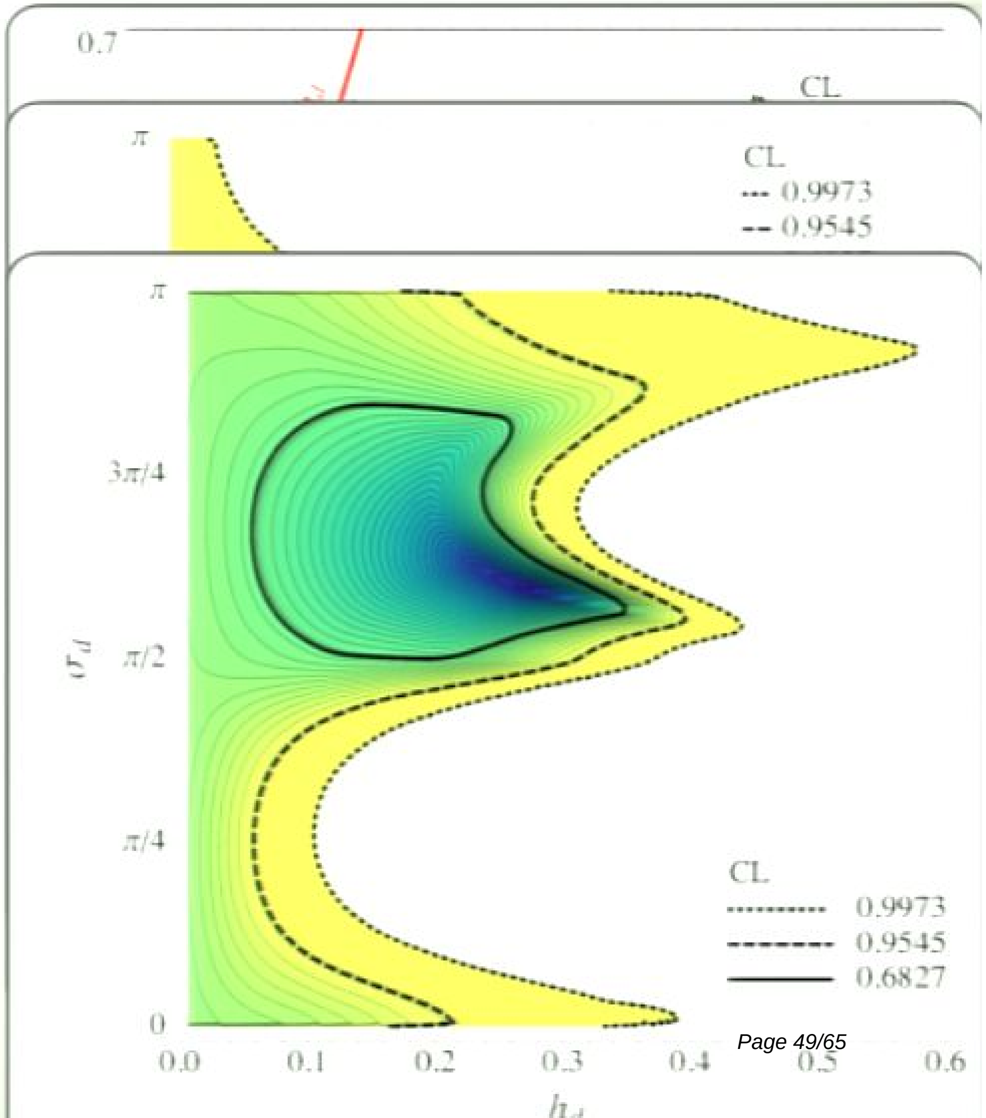

SUMMARY SO FAR

- present data support the hypothesis of new CP violation contributions
  - and that it mainly contributes to $\Delta F=2$ mixing amplitude
- the SM extensions with $SU(2)_q$ "universality" are not preferred

DIFFERENT MFV's

- MFV: expansion in Y_u, Y_d
- sometime additional assumptions are made
  - CP only violated by Yukawas
  - only SM 4-quark operators
- we will not make such assumptions
- for simplicity work in large tanβ limit

A QUESTION

- Y_u, Y_d have O(1) eigenvalues $y_{t,b}$:
  why are we able to expand $\bar{Q} f(\epsilon_u Y_u, \epsilon_d Y_d) Q$?
  - if $\varepsilon_{u,d} << 1$: series truncates after first few terms ⇒ Linear MFV ⇒ expansion in $Y_{u,d}$
  - if $\varepsilon_{u,d} = O(1)$: higher terms important ⇒ Nonlinear MFV ⇒ need to reorganize expansion
- can we distinguish LMFV vs. NLMFV?
  - interesting since $\varepsilon_{u,d} \propto \log(\mu_W/\Lambda_F)$ ⇒ could give a handle on physics at higher scales (with caveats)

WHY THIS USEFUL?

- is this useful?
  - if one is interested in higher order terms in $\phi_{u,d},\chi$ expansion
  - to make general statements

CONTRIBUTIONS TO B MIXING

Kagan, Perez, Volansky, JZ, 0903.1794

see also G. Colangelo, E. Nikolidakis and C. Smith, 0807.0801

- 2 classes of non-hermitian $\Delta B = 2$ effective operators
  - class-1 (no $d_R^{(2)}$): $(\overline{d_L^{(2)}} \chi b_{L,R})^2, \ldots$
  - class-2 (with $d_R^{(2)}$): $(\overline{d_R^{(2)}} \phi_d^\dagger \chi b_L)(\overline{d_L^{(2)}} \chi b_R), \ldots$
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EDM CONSTRAINTS

- to explain nonzero B_s mixing phase CP violation beyond CKM is needed
- Q: does one avoid bounds on flavor diagonal phases from EDM's?
  - at the level of operators OK
    - CP violating class-II operators that contrib. to B_s vanish in $V_{CKM} \to 1$ Batell, Pospelov, 1006.2127
  - but concrete models can contrib. to other oprs.
    - can be a problem in models

EXAMPLE 1: 2HDM+MFV

Buras, Carlucci, Gori, Isidori, 1005.5310
Buras, Isidori, Paradisi, 1007.5291

- 2HDM+MFV
- FCNCs from neutral higgs exchanges
  - "Yukawa phases" in *f*-*f*-*H* coupl.: $(\bar{d}_L Z^d Y_d d_R)H$

$$Z^d_{ij} = \bar{a}\delta_{ij} + \left[a_0 V^\dagger \lambda_u^2 V + a_1 V^\dagger \lambda_u^2 V \Delta + a_2 \Delta V^\dagger \lambda_u^2 V\right]_{ij}$$

    - gives type I (LR)(LR) and type II (RL)(LR) ops.
  - CP odd-CP even higgs mixing
    - needed for type I operators
- gives EDMs close to exp. bounds (or slightly above)

EXAMPLE 2:

Paradisi, Straub, 0906.4551

MSSM WITH MFV AND CPV

- MSSM+MFV, but not assumed CP cons.
- EDM's constrain phases

$M_i\mu$, $A_I\mu$ and $A_I^* M_i$

$$|\sin\phi_\mu| \lesssim 10^{-3}\left(\frac{m_{\rm SUSY}}{300\ {\rm GeV}}\right)^2\left(\frac{10}{t_\beta}\right),$$

$$|\sin\phi_A| \lesssim 10^{-2}\left(\frac{m_{\rm SUSY}}{300\ {\rm GeV}}\right)^2,$$

- ad hoc fix: if flavor blind phases arg(A_U)=arg(A_D)=0

$$\mathrm{Im}\,A_b \gg \mathrm{Im}\,A_{s,d}$$
$$\mathrm{Im}\,A_\tau \gg \mathrm{Im}\,A_{\mu,e}$$

$$\mathrm{Im}\,A_t \gg \mathrm{Im}\,A_{c,u}$$

- then EDM's constraints are obeyed

$$\mathbf{m}_D^2 = m_D^2\Big[\mathbf{1} + \mathbf{Y}_d\Big(r_3 + r_4\mathbf{Y}_u^\dagger\mathbf{Y}_u + r_5\mathbf{Y}_d^\dagger\mathbf{Y}_d + (c_2\mathbf{Y}_d^\dagger\mathbf{Y}_d\mathbf{Y}_u^\dagger\mathbf{Y}_u + \mathrm{h.c.})\Big)\mathbf{Y}_d^\dagger\Big],$$

$$\mathbf{A}^U = A_U\mathbf{Y}_u\Big(\mathbf{1} + c_3\mathbf{Y}_d^\dagger\mathbf{Y}_d + c_4\mathbf{Y}_u^\dagger\mathbf{Y}_u + c_5\mathbf{Y}_d^\dagger\mathbf{Y}_d\mathbf{Y}_u^\dagger\mathbf{Y}_u + c_6\mathbf{Y}_u^\dagger\mathbf{Y}_u\mathbf{Y}_d^\dagger\mathbf{Y}_d\Big),$$

$$\mathbf{A}^D = A_D\mathbf{Y}_d\Big(\mathbf{1} + c_7\mathbf{Y}_u^\dagger\mathbf{Y}_u + c_8\mathbf{Y}_d^\dagger\mathbf{Y}_d + c_9\mathbf{Y}_d^\dagger\mathbf{Y}_d\mathbf{Y}_u^\dagger\mathbf{Y}_u + c_{10}\mathbf{Y}_u^\dagger\mathbf{Y}_u\mathbf{Y}_d^\dagger\mathbf{Y}_d\Big),$$

MANY MODELS ON THE MARKET...

- explanations proposed so far
  - 2HDM + MFV — Buras, Carlucci, Gori, Isidori, 1005.5310
  - uplifted MSSM (EDM's assumed ok) — Dobrescu, Fox, Martin, 1005.4238
  - split 3^{rd}-(1^{st}/2^{nd}) MSSM — Endo, Shirai, Yanagida, 1009.3366
  - scalar octet exchanges — Wise, Trott, 1009.2813
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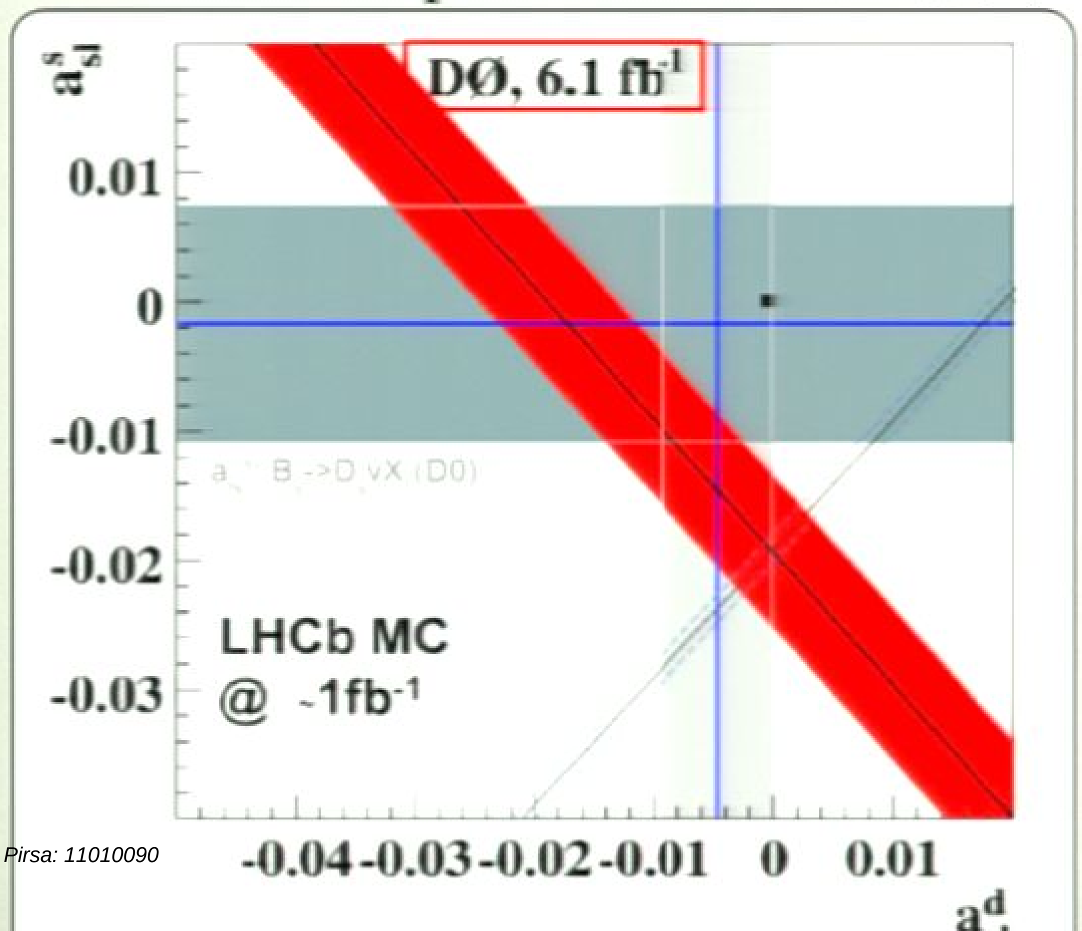
- LHCb will measure $a_{sl}^s - a_{sl}^d$
- also phase from $B_s \rightarrow J/\psi \phi$



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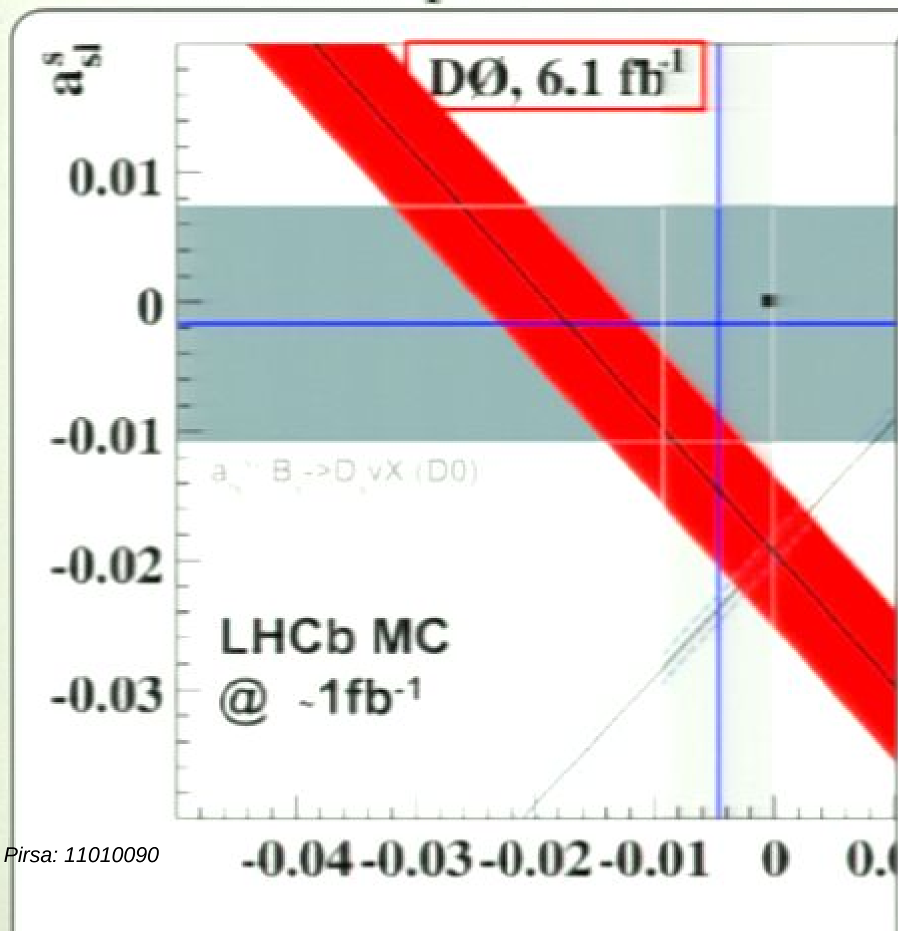

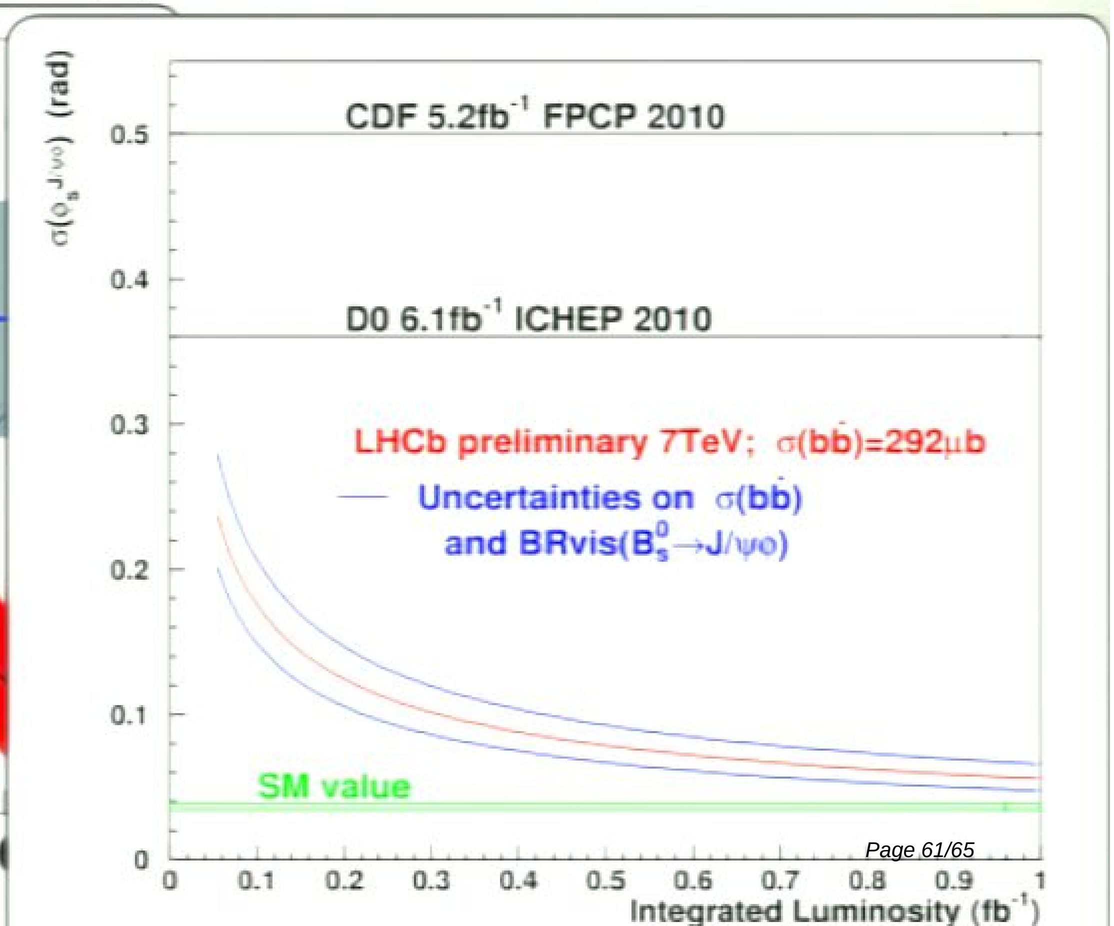

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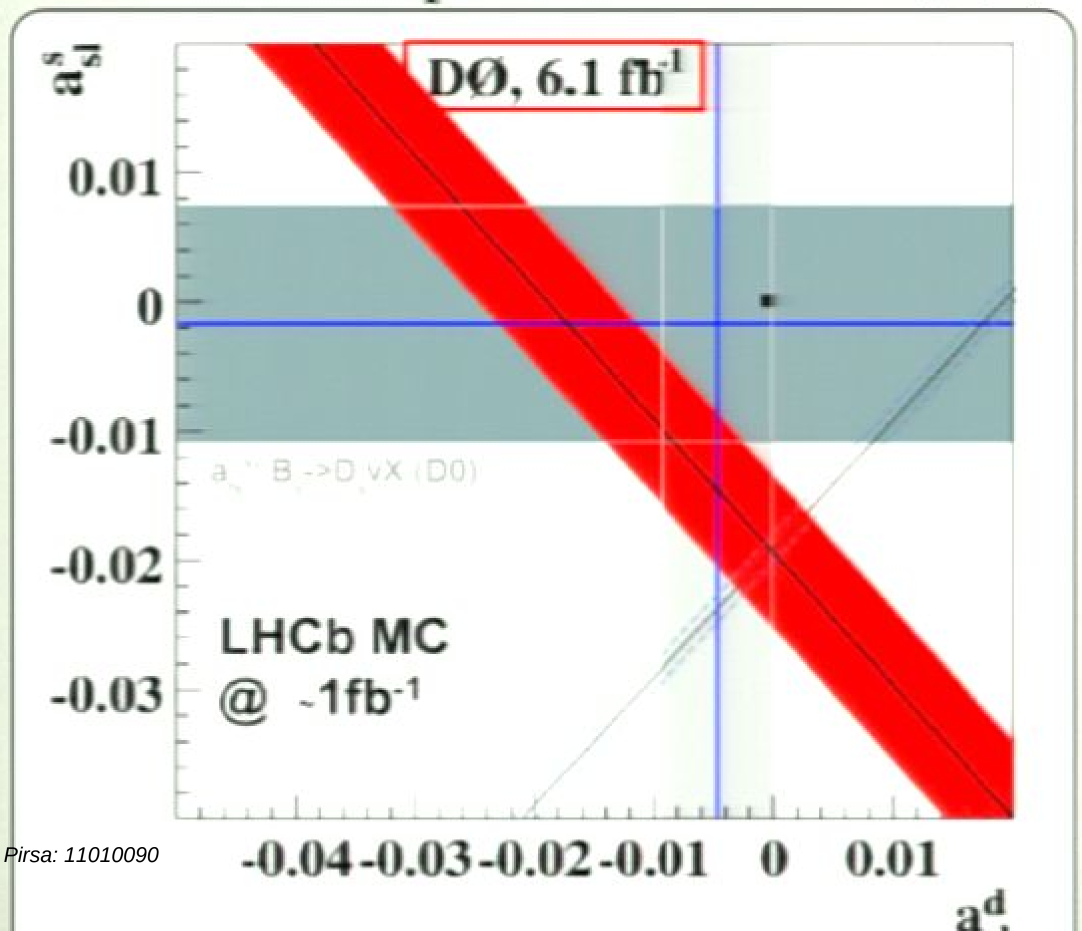

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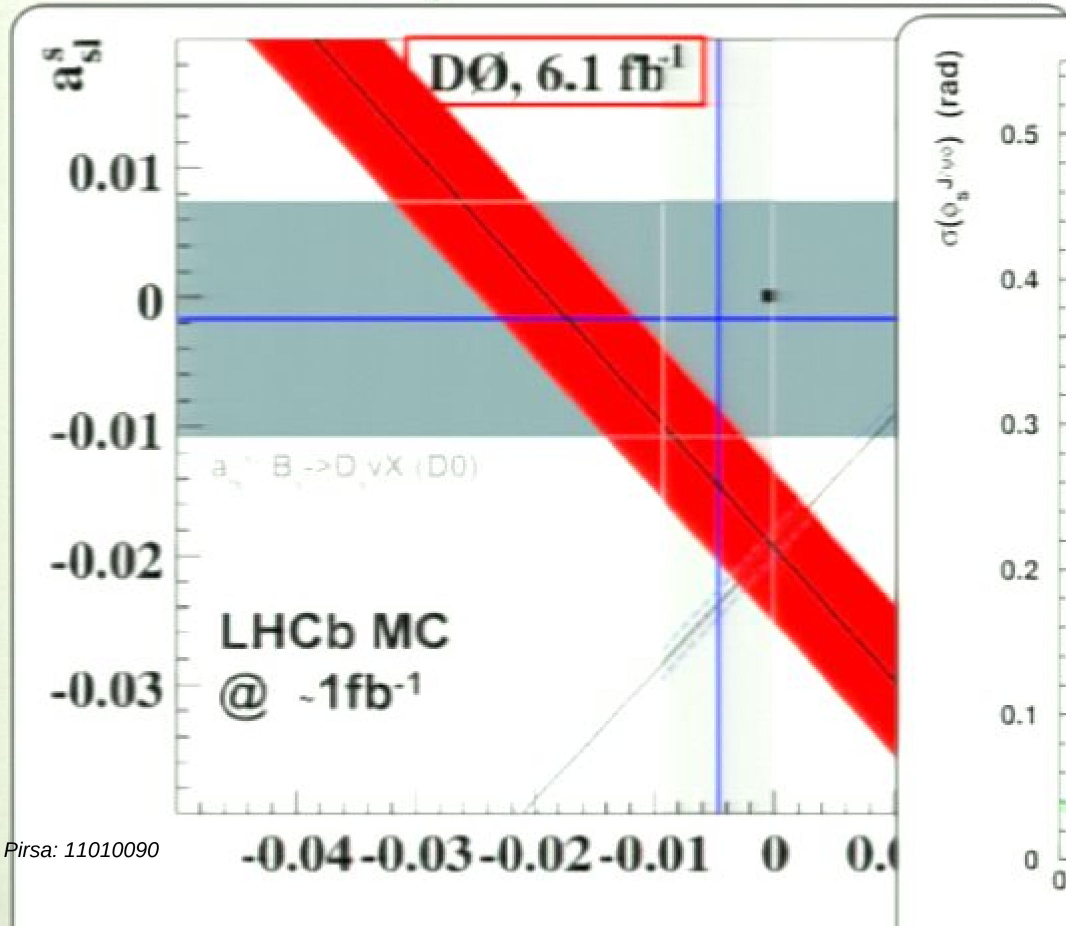

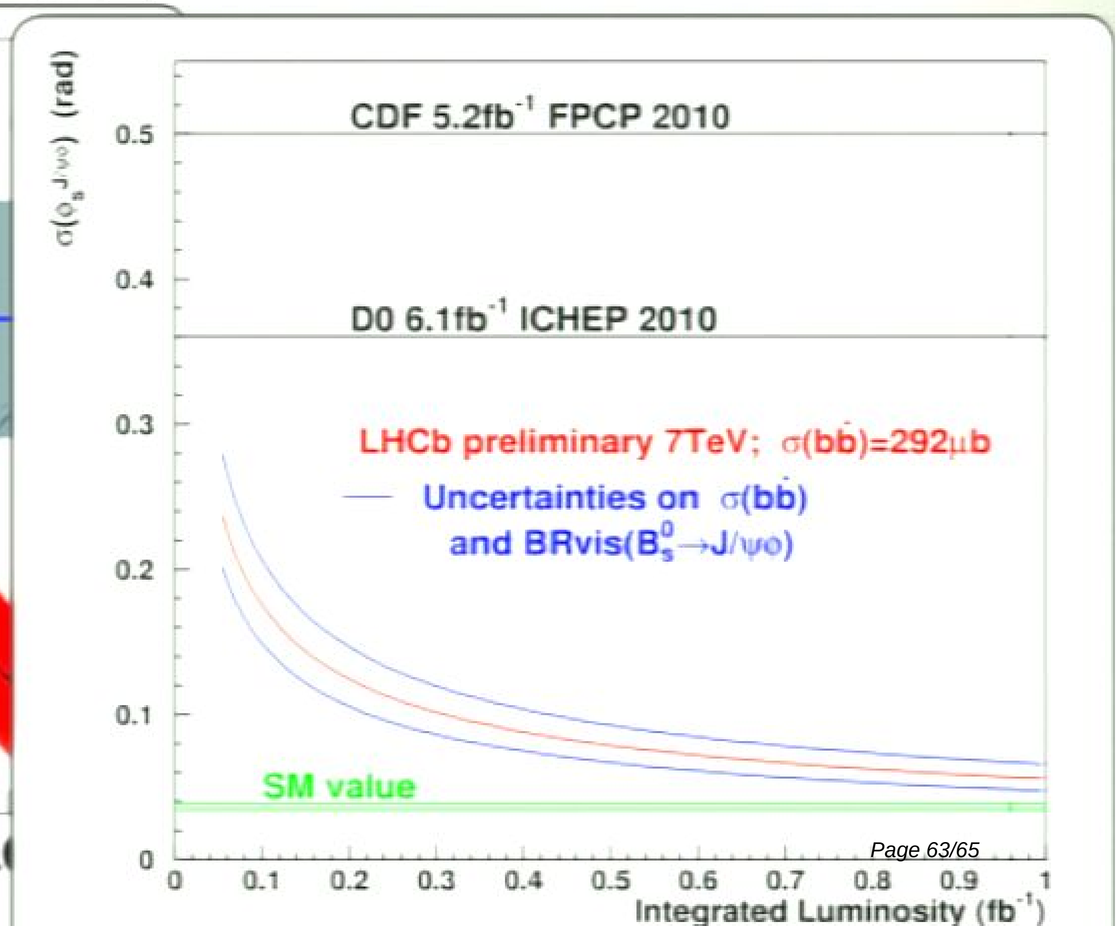

CONCLUSIONS

- observed like-sign dimuon asymmetry is well described by NP contributions to B_s mixing
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