Where we stand on B-decay Discrepancies
– Global Fits –

Diego Guadagnoli
CNRS, Annecy

Minimal TH considerations

(before any fit)

EFT considerations

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⇨ *well-suited to UV-complete models*

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How to resolve between the two scenarios?

⇨ *Accurate $B_s \to \mu\mu$ measurement*

- *present single-measurement error $\simeq$ 20 %*
- *exp combi may soon be able to confirm or exclude deviations of C_{10} of O(10%)*

More TH considerations

❸ *Pattern of Lepton Universality Violation in* $b \to s$

The observed new-physics hierarchy:

effects in ee $\ll$ *effects in* $\mu\mu$ $\ll$ *(allowed) effects in* $\tau\tau$

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Data now allow to disprove some, and to make more precise some other of these considerations

Weak-Effective-Theory

Global fits

1-Wilson-coeff. picture

[Aebischer *et al.*, 2019]

Coeff.	best fit	1σ	2σ	pull
$C_9^{bs\mu\mu}$	-0.97	$[-1.12, -0.81]$	$[-1.27, -0.65]$	5.9σ
$C_9^{\prime bs\mu\mu}$	$+0.14$	$[-0.03, +0.32]$	$[-0.20, +0.51]$	0.8σ
$C_{10}^{bs\mu\mu}$	$+0.75$	$[+0.62, +0.89]$	$[+0.48, +1.03]$	5.7σ
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$C_9^{bs\mu\mu} = C_{10}^{bs\mu\mu}$	$+0.20$	$[+0.06, +0.36]$	$[-0.09, +0.52]$	1.4σ
$C_9^{bs\mu\mu} = -C_{10}^{bs\mu\mu}$	-0.53	$[-0.61, -0.45]$	$[-0.69, -0.37]$	6.6σ

Similar fits (w/ non-identical conclusions) performed in:

[Algueró *et al.*, 1903.09578] [Ciuchini *et al.*, 1903.09632]

[Datta *et al.*, 1903.10086] [Kowalska *et al.*, 1903.10932]

[Arbey *et al.*, 1904.08399]

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- *Two scenarios stand out: C_9 alone or $C_9 = - C_{10}$ (μμ-channel only)*
- *$C_9 = - C_{10}$ now better than C_9 alone*
- *C_{10} alone also ok, but $B \to K^* \mu\mu$ unresolved*

C_9 vs. $C_9 = -C_{10}$

What makes $C_9 = -C_{10}$ more significant than C_9 alone?

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A concurrence of effects, mostly:

- $B_s \to \mu\mu$ *(new average)*
- $\Lambda_b \to \Lambda\, \mu\mu$: A_{FB} *and BR from LHCb*
- $\Delta F = 2$ *(mostly* ϵ_K *and* ΔM_s*)*

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How can ϵ_K (that doesn't depend on C_{10}) increase the C_{10} significance?

Role of correlated quantities

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Now consider the corresponding terms in the χ^2 *function*

(with $D_i \equiv O_i^{exp} - O_i^{th}$*)*

$$\chi^2 = \frac{D_1^2(C_{10})}{\sigma_1^2} + \frac{D_2^2}{\sigma_2^2} + \rho_{12}\frac{D_1(C_{10})D_2}{\sigma_1\sigma_2}$$

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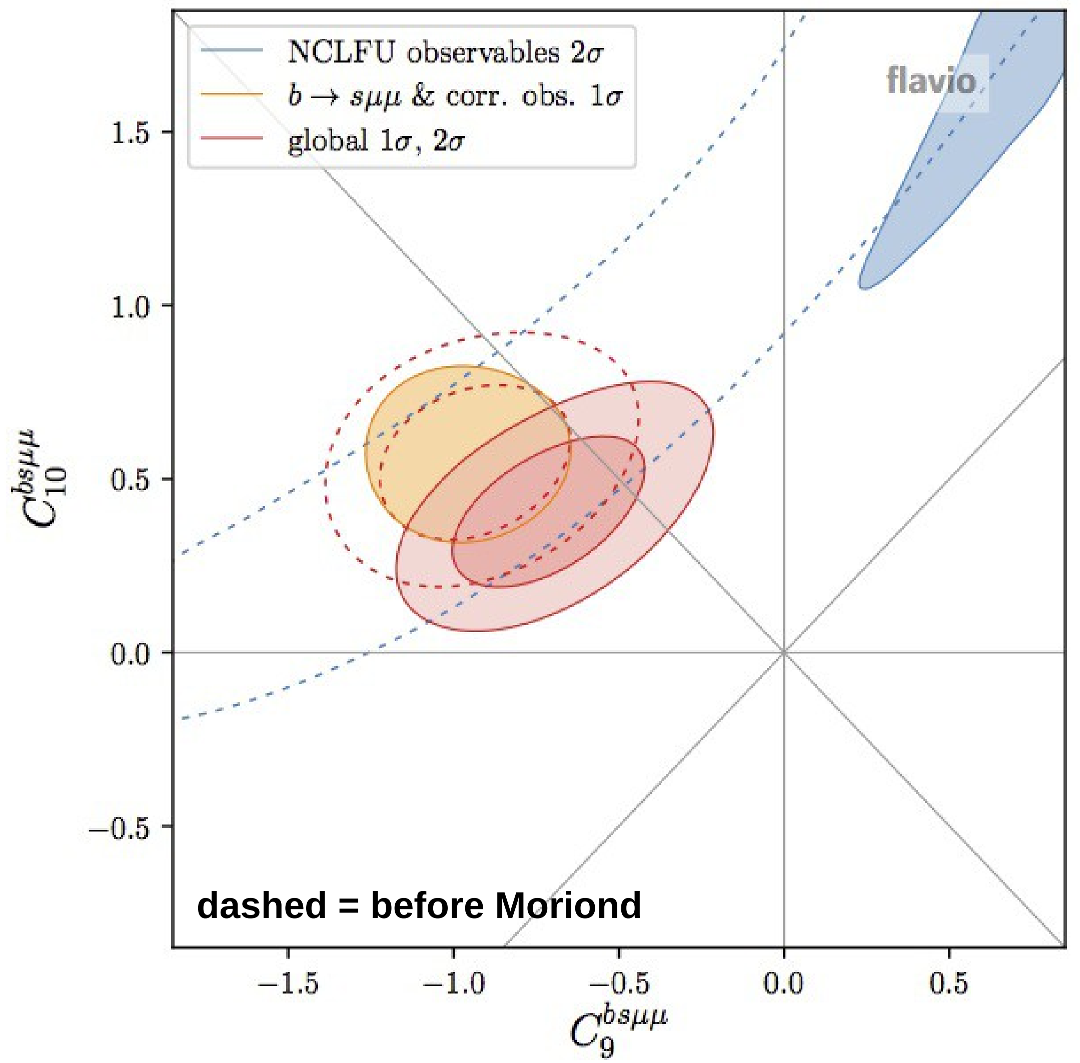
- *The 3*rd *term depends on* C_{10} *through* D_1
- *This term will influence the* C_{10} *value, depending on sign(*$D_2\ \rho_{12}$*)*

C_9 vs. $C_9 = - C_{10}$



Main point

- ***Before Moriond***

  $R_{K^{(*)}}$ & $b \to s\,\mu\mu$ in nearly perfect agreement

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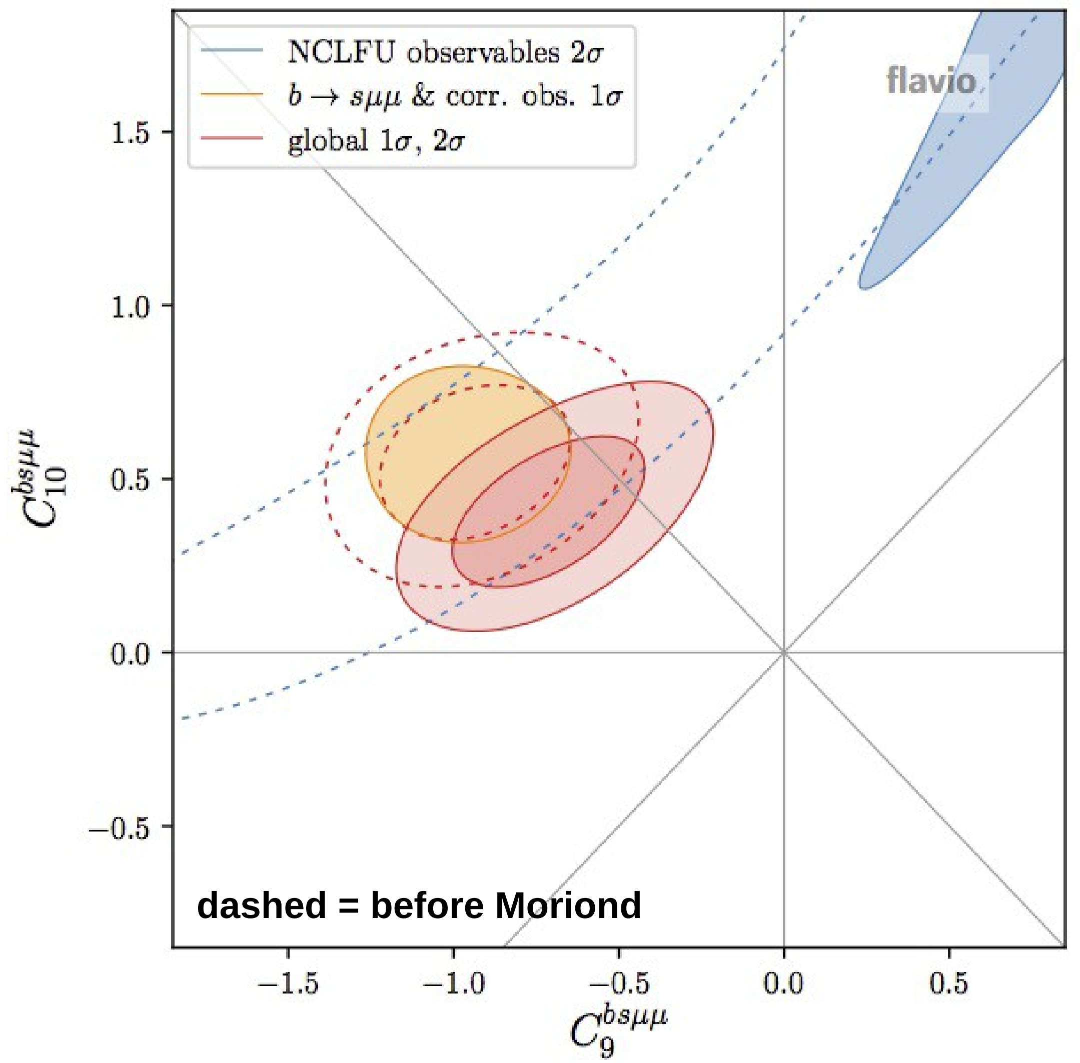

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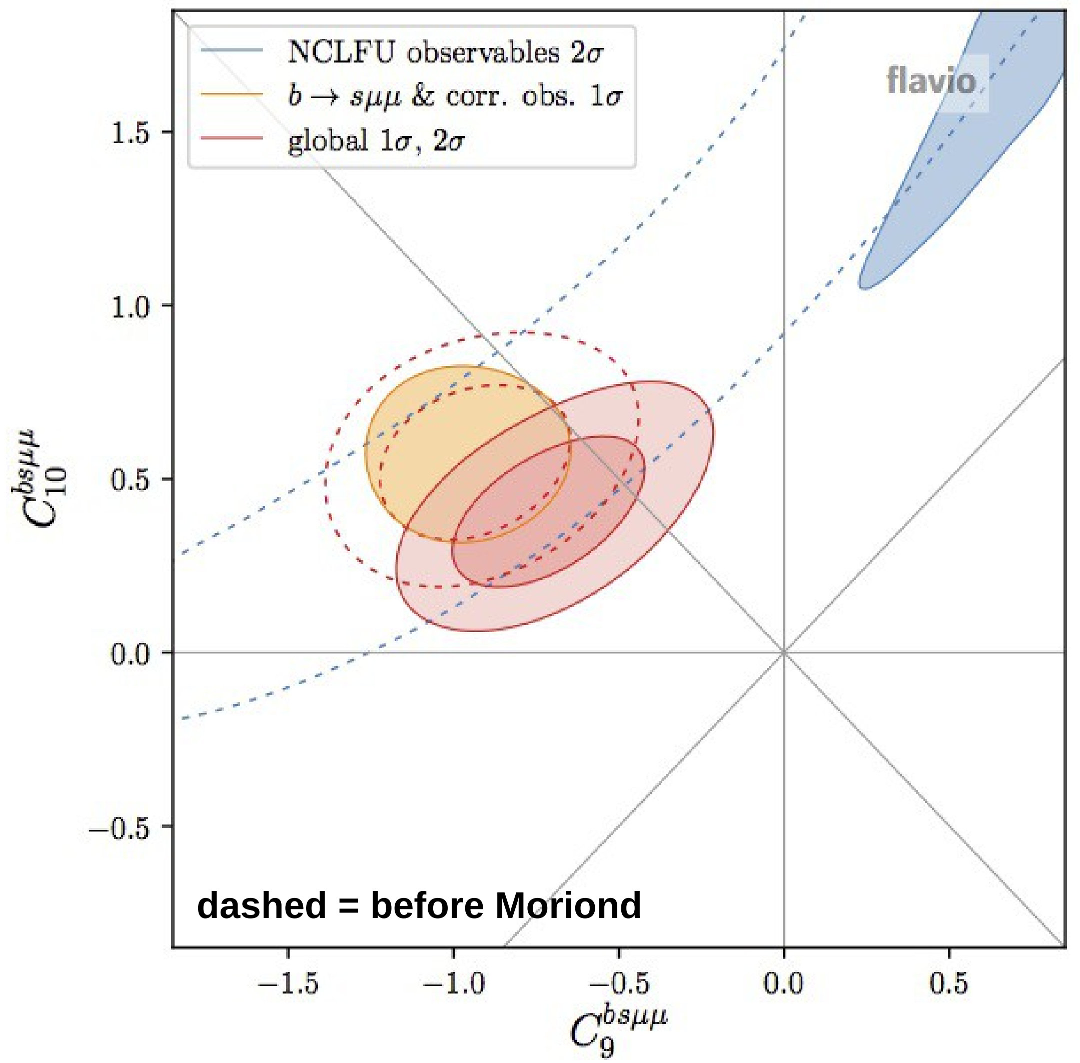

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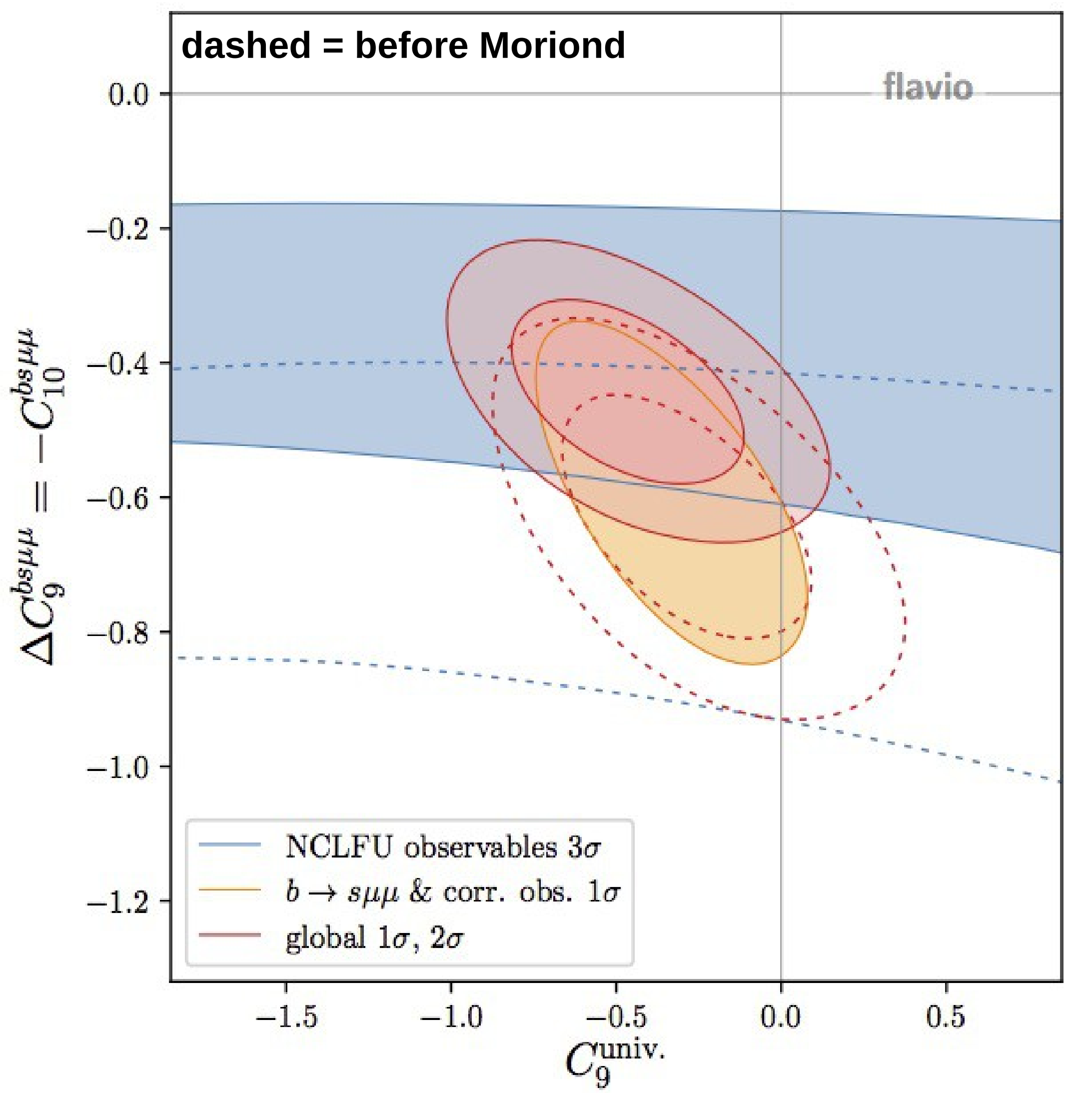
Note

a $C_9^{univ.}$ component would shift $b \to s\,\mu\mu$ data but not $R_{K^{(*)}}$

Univ. vs. non-univ. Wilson coeffs.



Notes

y-axis: μ-specific shift in $C_9 = - C_{10}$

x-axis: additional, lepton-univ. shift in C_9 only

After Moriond

Data tend to prefer $C_9^{univ.} \neq 0$

Both $C_9 = -C_{10}$ and $C_9^{univ.}$

well justified above the EW scale.

The SMEFT picture

SMEFT picture

Assume BSM d.o.f. to occur at a scale $\Lambda \gg M_{EW}$

⇨ *Dynamics below Λ described by ops.*

- *constructed with SM fields only*
- *and invariant under the full SM group*

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Then, two clear possibilities to generate the above pattern:

❶ *Contributions to muonic $C_9 = - C_{10}$ may come from SMEFT ops. directly matching onto $O_{9,10}$*

$$[O_{LQ}^{(1)}]_{2223} = \bar{L}_2 \gamma^\lambda L_2 \cdot \bar{Q}_2 \gamma_\lambda Q_3$$

$$[O_{LQ}^{(3)}]_{2223} = \bar{L}_2 \gamma^\lambda \sigma^a L_2 \cdot \bar{Q}_2 \gamma_\lambda \sigma^a Q_3$$

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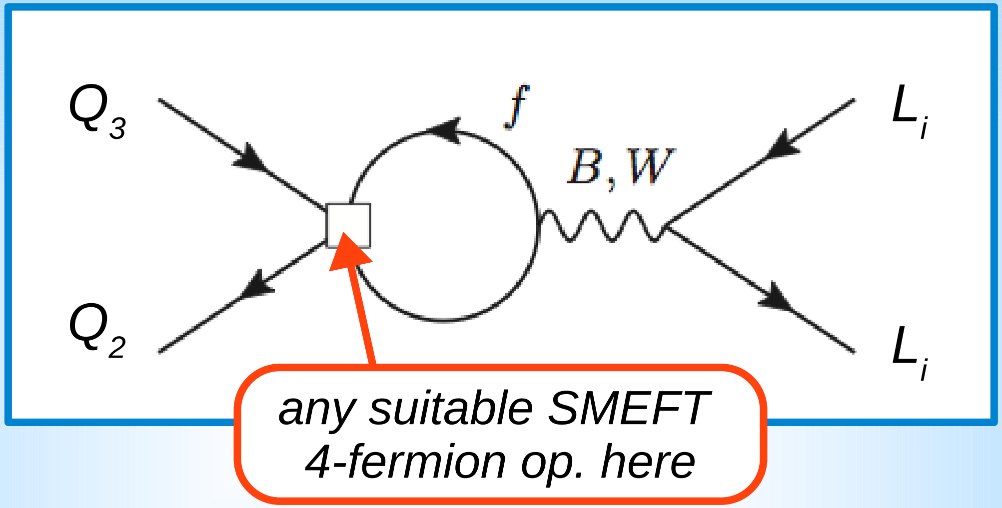
❷ *Contribs. to $C_9^{univ.}$ can come from RGE effects* [Bobeth-Haisch, *2011*]



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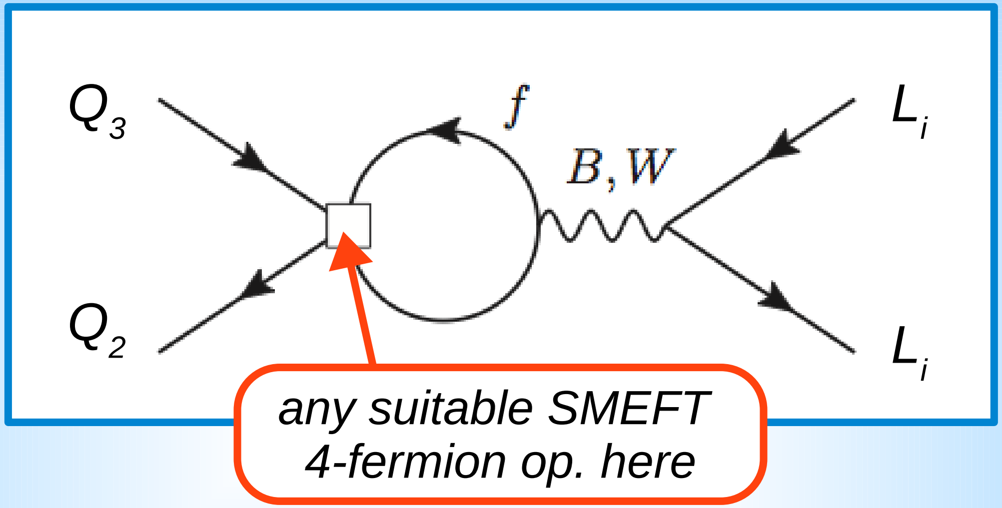

- *Case $f = \tau$ allows natural connection (right sign & size)*

  with $[O_{LQ}^{(1)}]_{3323}$ & $[O_{LQ}^{(3)}]_{3323}$ *responsible for* $b \to c\, \tau\nu$

[Crivellin, Greub, Müller, Saturnino, *2018*]

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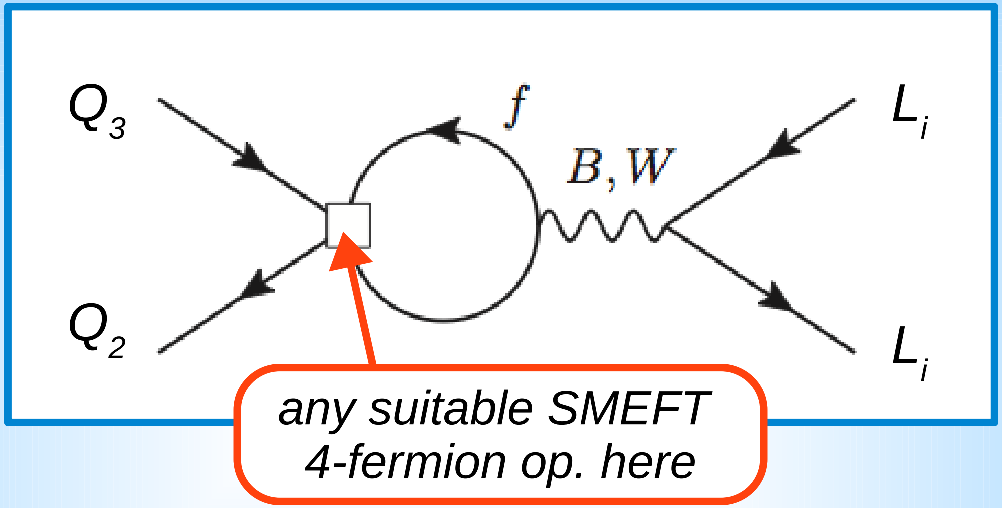

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  [Crivellin, Greub, Müller, Saturnino, *2018*]

- *Caveat: need* $[C^{(1)}_{LQ}]_{3323} \simeq [C^{(3)}_{LQ}]_{3323}$

  to avoid $B \to K(^*)\, \nu\nu$ *constraint* [Buras-Girrbach-Niehoff-Straub, 2014]

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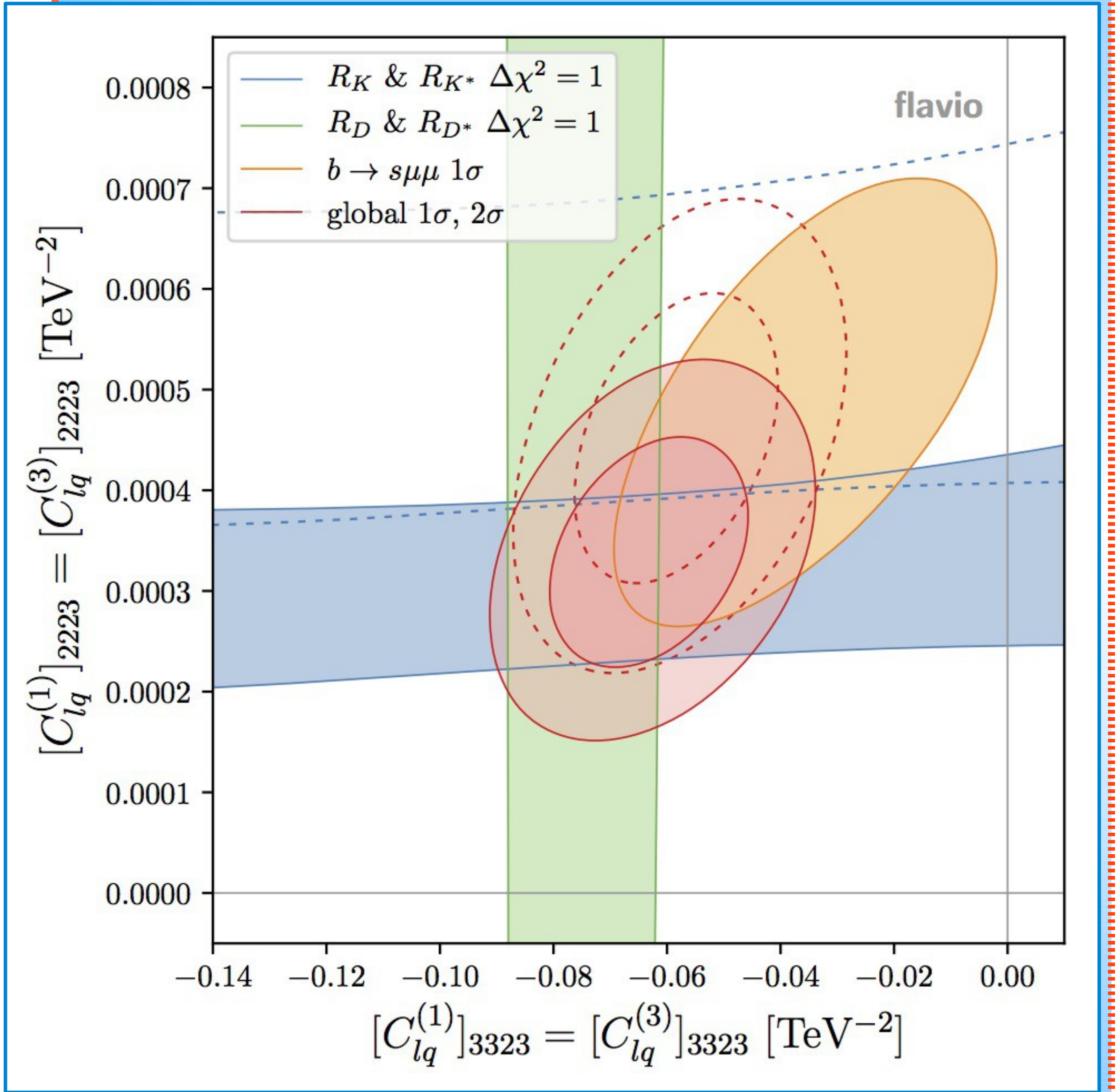

Before Moriond (dashed)

$R_{K^{(*)}}$ (blue) and $b \to s\,\mu\mu$ (orange) were in perfect agreement

in a region close to 0 in the x-axis

⇨ *$R_{D^{(*)}}$ not explained*

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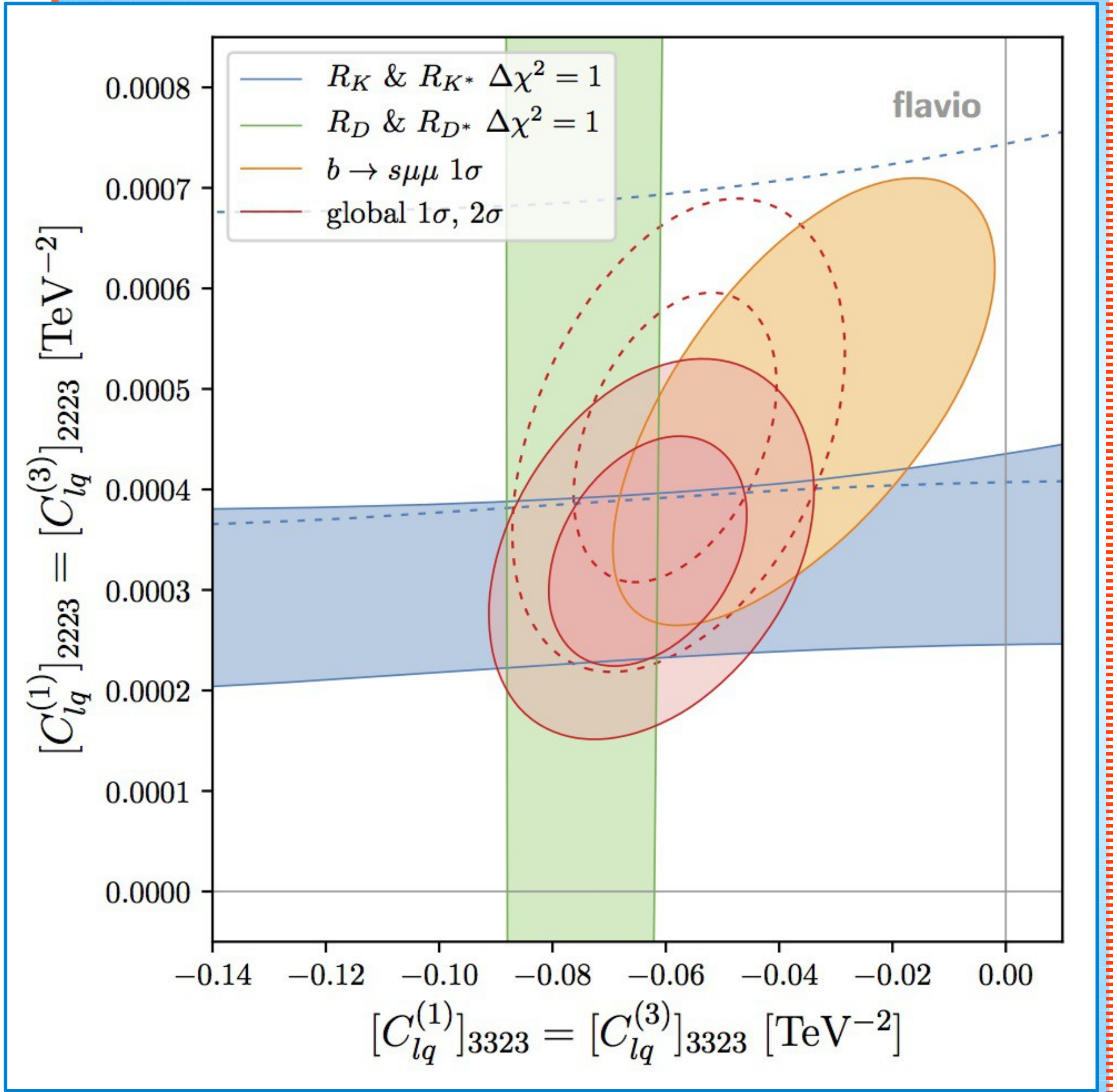

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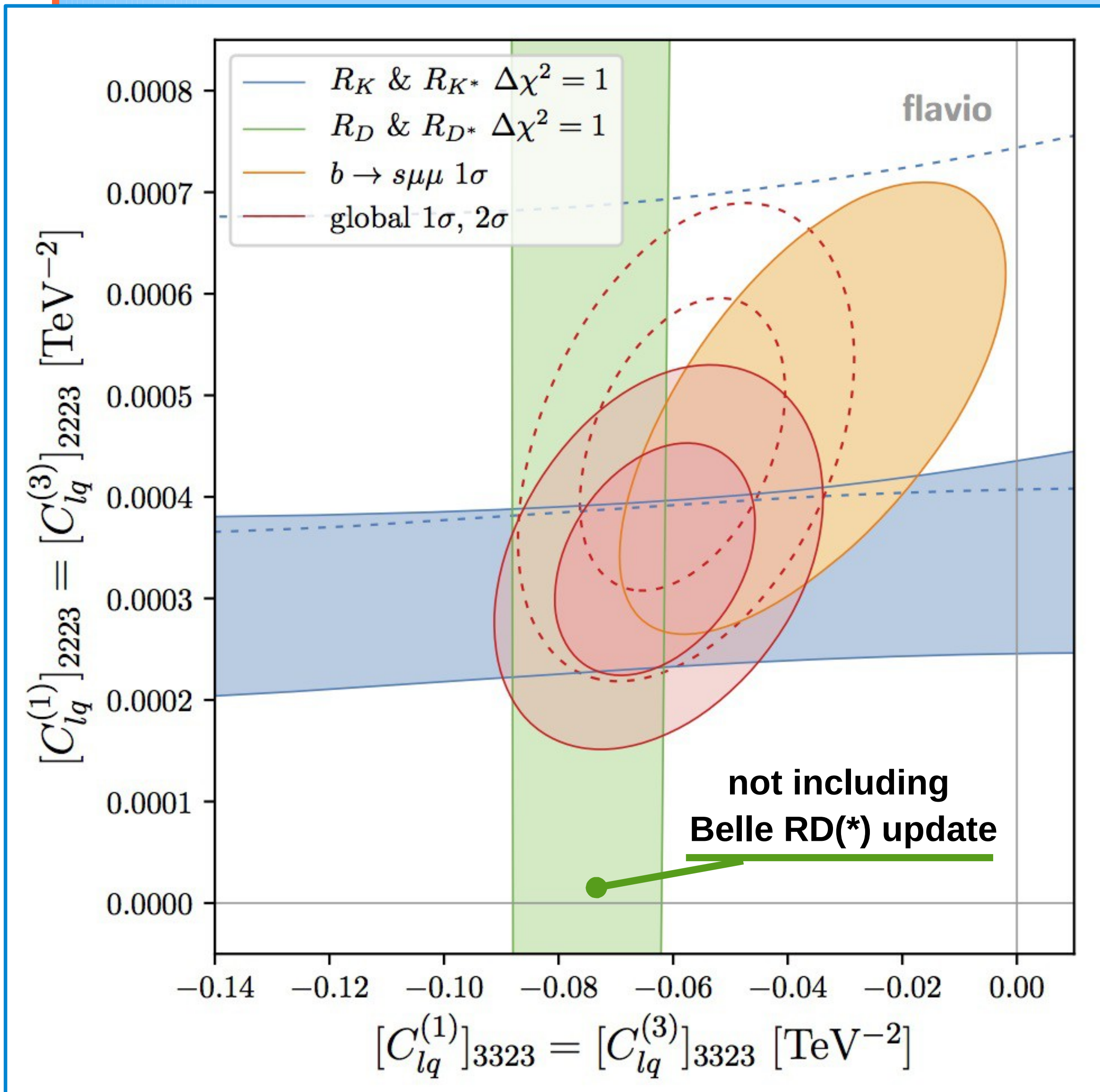

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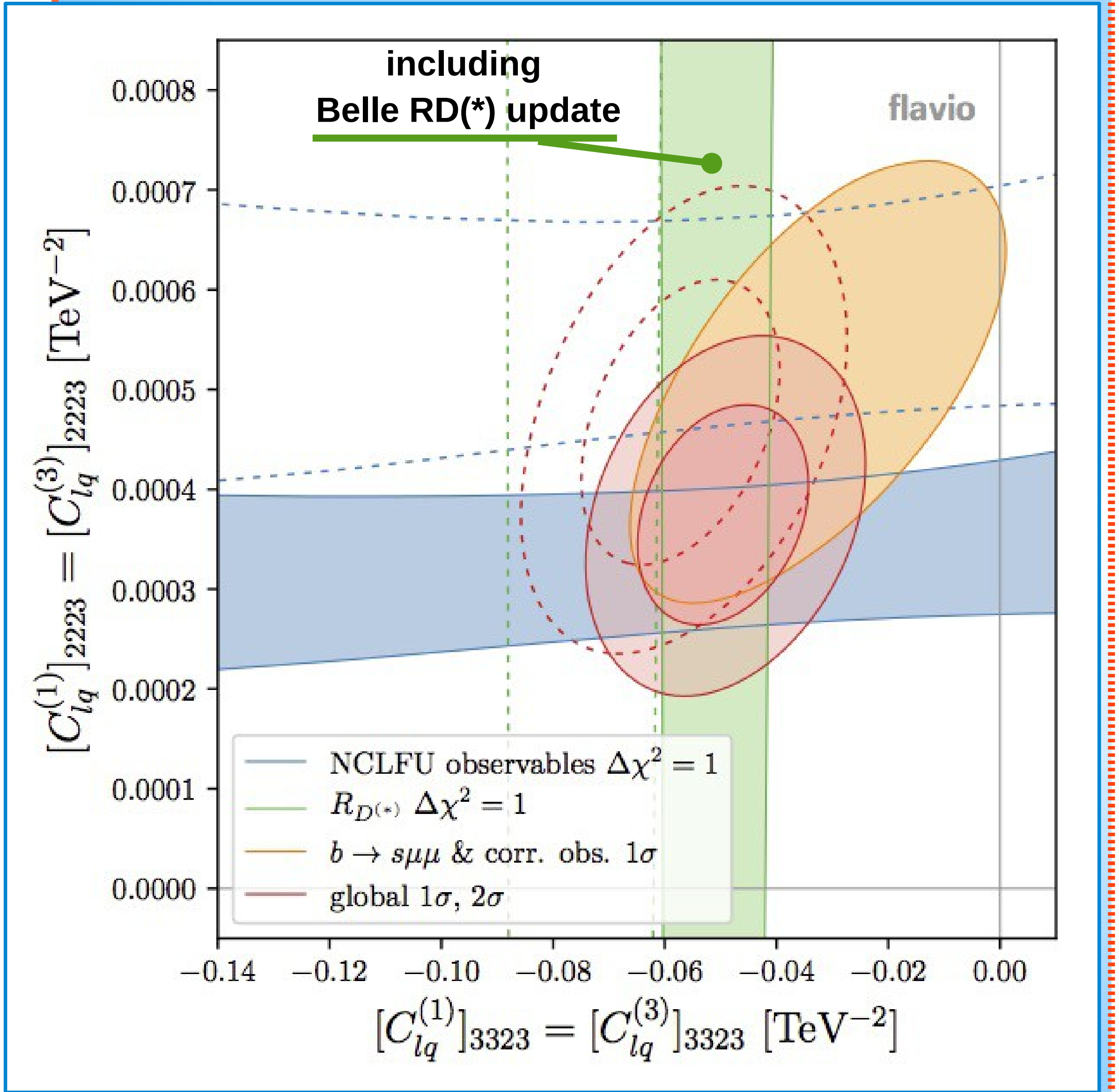

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Post-Moriond updates imply a nicely coherent TH picture, with

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- R_D & R_{D^*} > by O(10%) (not more) than SM
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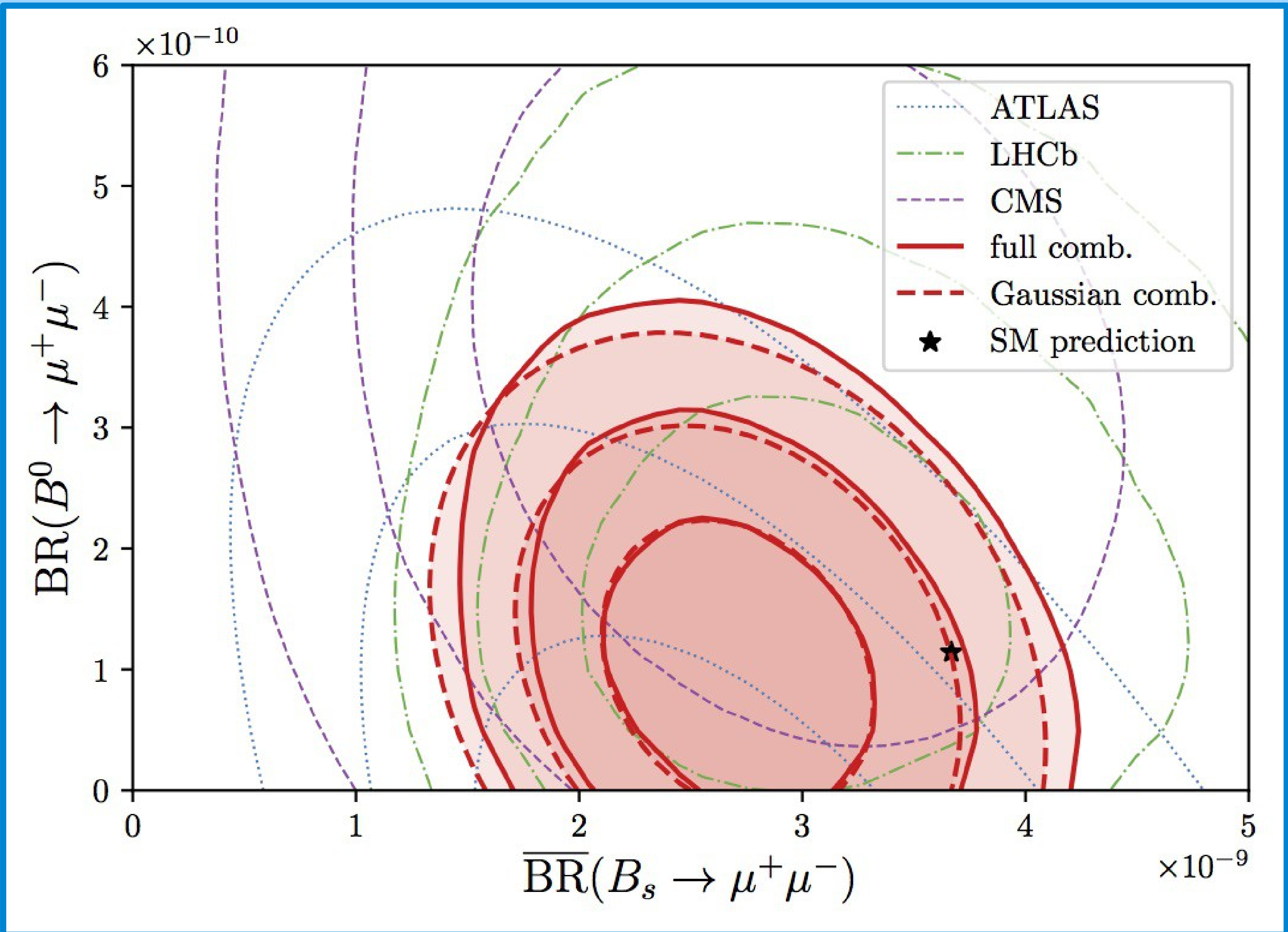
We'll know soon (?) whether this is all just a happy coincidence

$B_s \to$ μμ average

w/o CMS PAS BPH-16-004 (Aug. 2019 update) Credit: Peter Stangl



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with CMS PAS BPH-16-004 (Aug. 2019 update) Credit: Peter Stangl