2007.10338

Exp/SM

$\bar{B}_s \to D_s^+ \pi^-$ } $b \to c\bar{u}d$ $3.00(23)/4.42(21) \simeq 0.68$

$\bar{B}_s \to D_s^{*+} \pi^-$ $2.0\ (5)/\ 4.3\ (9) \simeq 0.47$

$\bar{B}_d \to D^+ K^-$ } $b \to c\bar{u}s$ $0.186(20)/0.326(15) \simeq 0.57$

$\bar{B}_d \to D^{*+} K^-$ $0.212(15)/0.327(^{22}_{34}) \simeq 0.65$

$$\mathcal{H}_{\rm eff}^{SM} = \frac{G_F}{\sqrt{2}} V_{cb} V_{ud}^* \left(C_1 Q_1 + C_2 Q_2 \right)$$

$$Q_2 = \bar{c}^{\alpha} \gamma^{\mu} (1-\gamma_5) b^{\alpha} \cdot \bar{d}^{\beta} \gamma_{\mu} (1-\gamma_5) u^{\beta}$$

$$Q_1 = \bar{c}^{\alpha} \gamma^{\mu} (1-\gamma_5) b^{\beta} \cdot \bar{d}^{\beta} \gamma_{\mu} (1-\gamma_5) u^{\alpha}$$

$$C_2 \simeq +1.010 \qquad C_1 = -0.291$$

Amplitudes proportional to a_1

In my notation

$$a_1^{SM} = \underbrace{C_2^{SM}}_{\text{colour singlet}} + \underbrace{\frac{C_1^{SM}}{3}}_{\text{colour rearranged}} \simeq 0.913$$

For a rough estimate

$$\frac{Br^{Exp}}{Br^{SM}} = \frac{|a_1^{BSM}|^2}{|a_1^{SM}|^2} \simeq 0.6$$

$$\Rightarrow \frac{a_1^{BSM}}{a_1^{SM}} \simeq 0.77 = 1 - 0.23$$

$$= \frac{a_1^{SM} + \delta a_1^{BSM}}{a_1^{SM}} = 1 + \frac{\delta a_1^{BSM}}{a_1^{SM}} \Rightarrow \delta a_1^{BSM} \simeq 0.2$$

2007.10328 quote $\Delta a_1 = -0.18 \pm 0.03$

Is this possible and consistent with other experimental bounds?

1) BSM effects only in Q_1, Q_2 ……▸ Gilberto

$$\boxed{\begin{array}{ll} C_1 = C_1^{SM} + \Delta C_1 & \\ C_2 = C_2^{SM} + \Delta C_2 & \Delta C_i \in \mathbb{C} \end{array}}$$

2008.01086

PHYSICAL REVIEW D **102,** 071701(R) (2020)

Rapid Communications

Implications for new physics from a novel puzzle in $\bar{B}^0_{(s)} \to D^{(*)+}_{(s)}\{\pi^-, K^-\}$ decays

Syuhei Iguro[1,*] and Teppei Kitahara[2,3,†]

[1]Department of Physics, Nagoya University, Nagoya 464-8602, Japan
[2]Institute for Advanced Research, Nagoya University, Nagoya 464-8601, Japan
[3]Kobayashi-Maskawa Institute for the Origin of Particles and the Universe, Nagoya University, Nagoya 464-8602, Japan

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Recently, the standard model predictions for the B-meson hadronic decays, $\bar{B}^0 \to D^{(*)+}K^-$ and $\bar{B}^0_s \to D^{(*)+}_s \pi^-$, have been updated based on the QCD factorization approach. This improvement sheds light on a novel puzzle in the B-meson hadronic decays: there are mild but universal tensions between data and the predicted branching ratios. Assuming the higher-order QCD corrections are not huge enough to solve the tension, we examine several new physics interpretations of this puzzle. We find that the tension can be partially explained by a left-handed W' model, which can be compatible with other flavor observables and collider bounds.

* MFV – excluded by dijet

B-decays Dijet

$\Lambda < 0.49\,\text{TeV}$ ↯ $\Lambda < 3.7\,\text{TeV}$

* left-handed W'

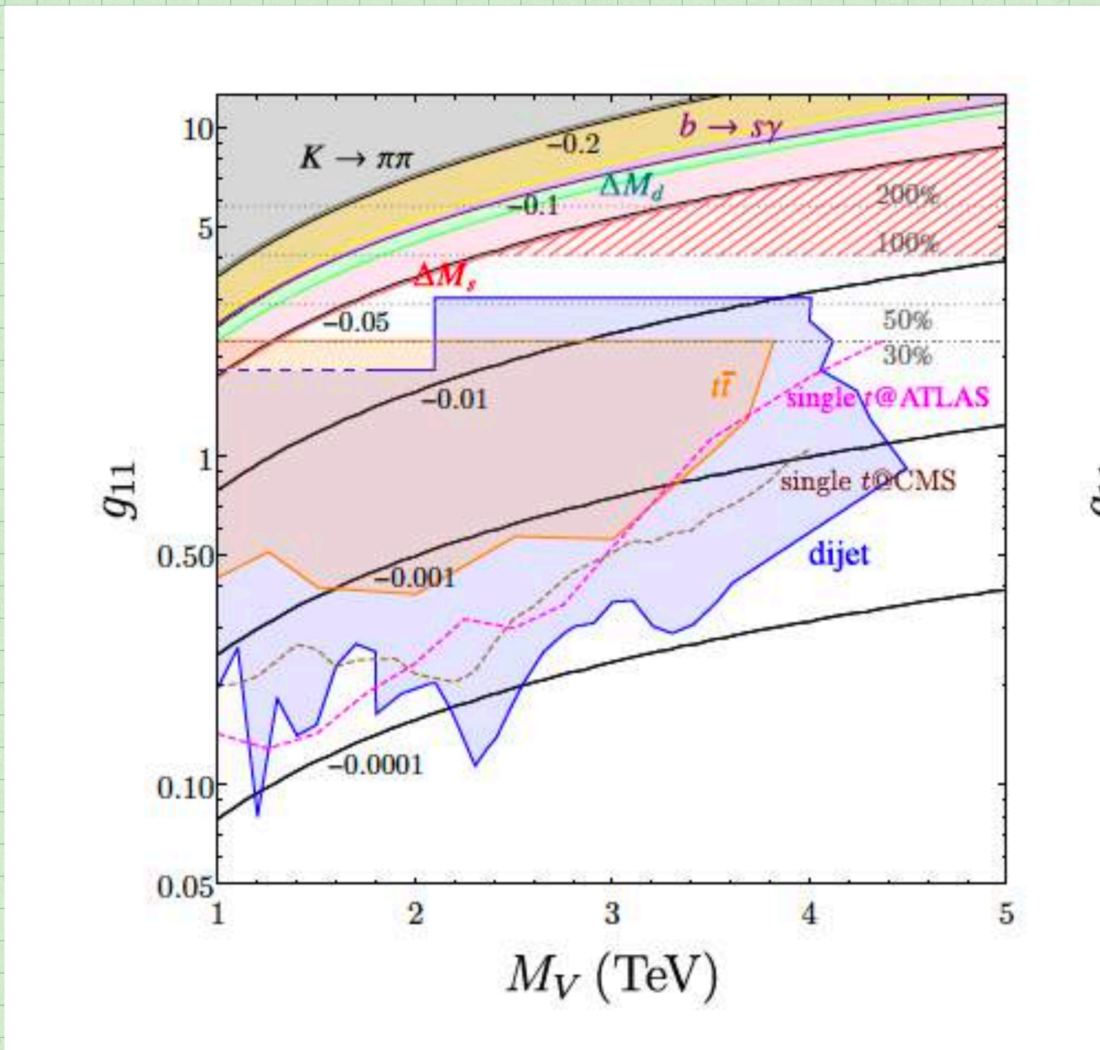
$SU(2) \times SU(2) \times U(1)_Y$

D-mixing

$$\begin{pmatrix} g_{11} & 0 & 0 \\ 0 & \underset{=g_{11}}{g_{22}} & g_{23} \\ 0 & g_{23} & g_{33} \end{pmatrix}$$

Scenario 1 : $g_{23} = 0$
— " — 2 : $g_{33} = 0$
— " — 3 : all $\neq 0$

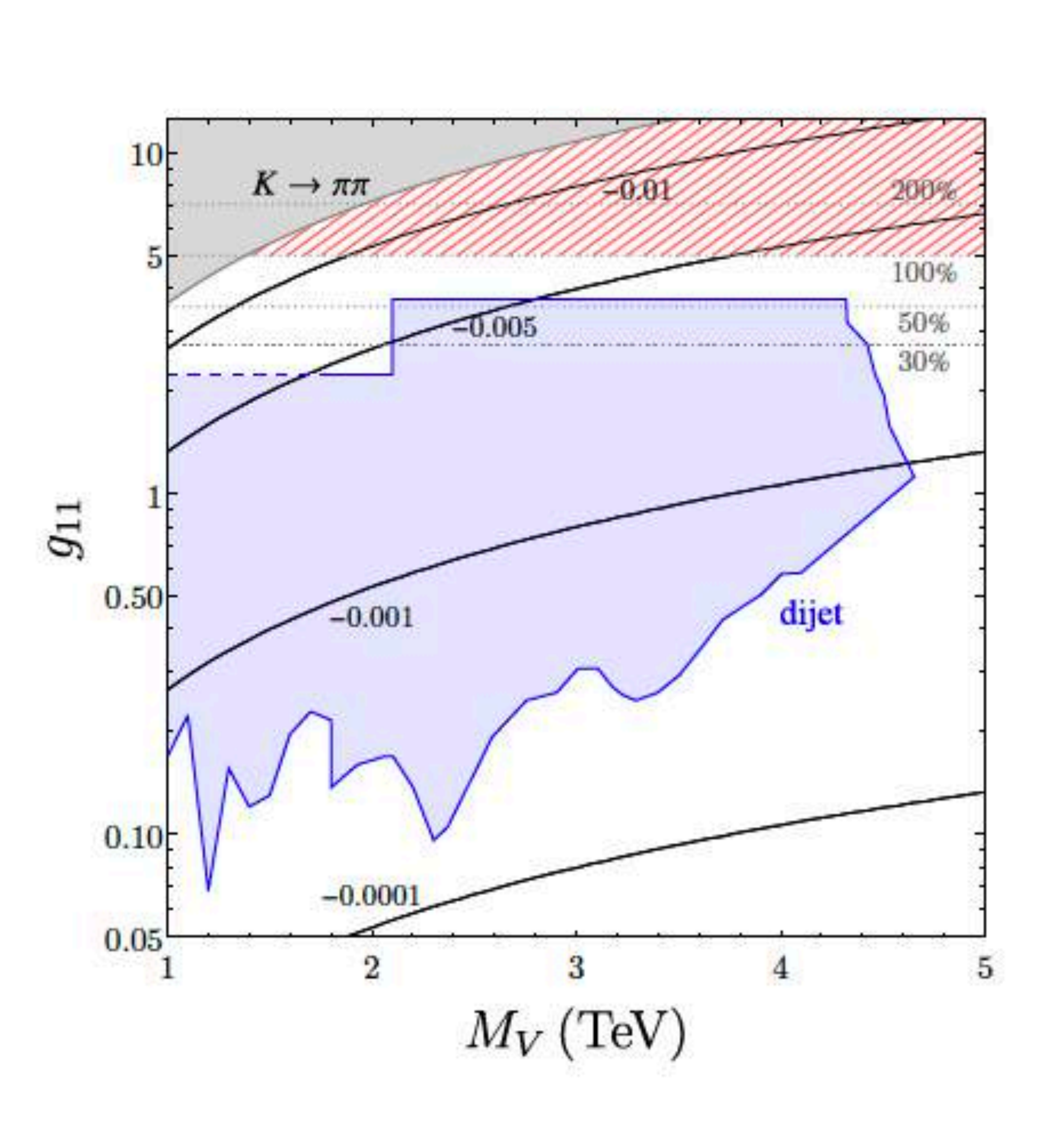
Scenario I:



Anomaly: $\frac{2.6}{\text{TeV}} \lesssim \frac{\sqrt{|g_{11}\, g_{23}|}}{M_V} \lesssim \frac{3.8}{\text{TeV}}$

$\to$ Disfavoured by B-mixing

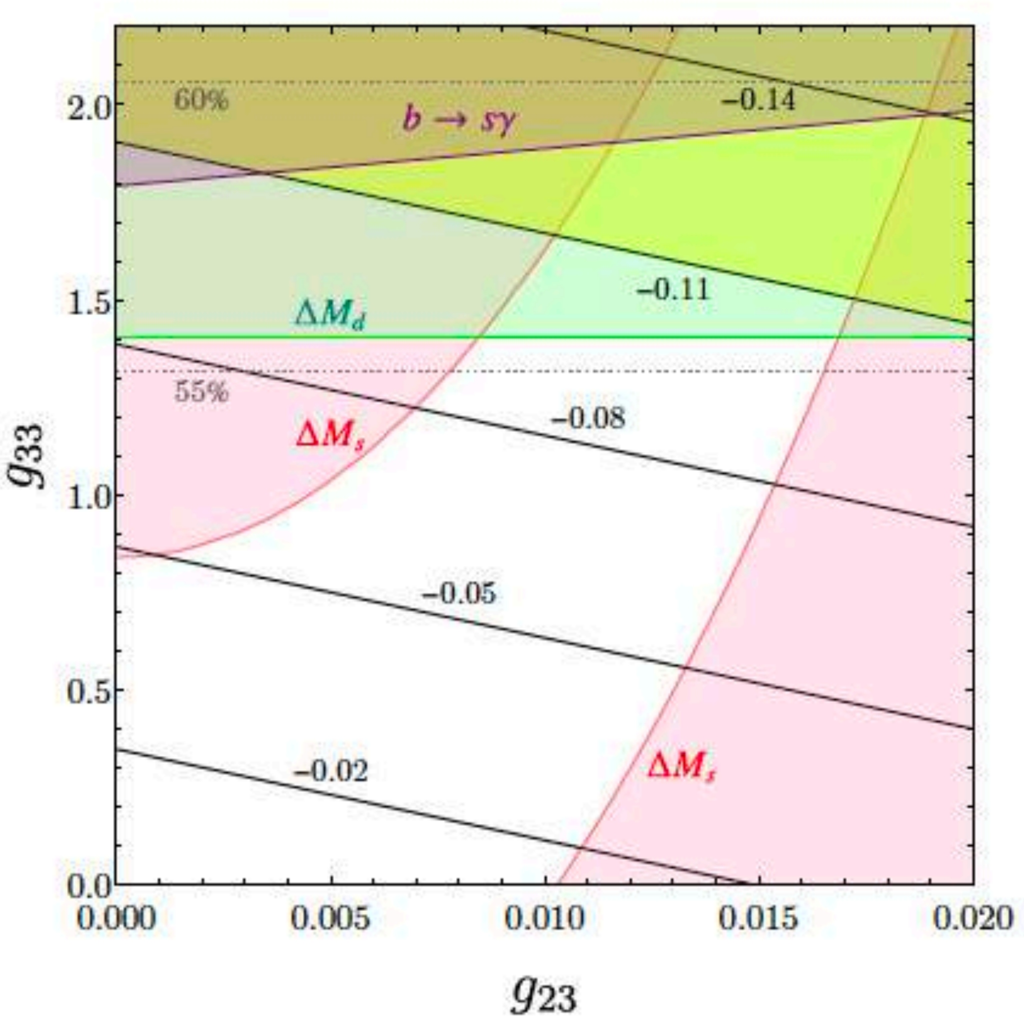
Scenario II:



Anomaly: $\frac{0.54}{\text{TeV}} \lesssim \frac{\sqrt{|g_{11}\, g_{23}|}}{M_V} \lesssim \frac{0.78}{\text{TeV}}$

→ Excluded by B-mixing: tree-level Z'

Scenario III :



$\Rightarrow$ 10% contribution to amplitude can be achieved without violating different bounds from Flavour & collider

$\Rightarrow$ $g_{11} = g_{22}$ $\Rightarrow$ also $\not{S}\not{L}$ in $b \to c\bar{c}s$

Why bounds from Kaon sector?

2) new Dirac structures arise

2103.04138

Probing new physics in class-I B-meson decays into heavy-light final states

Fang-Min Cai,[a] Wei-Jun Deng,[a] Xin-Qiang Li[a,1] and Ya-Dong Yang[a]

[a] *Institute of Particle Physics and Key Laboratory of Quark and Lepton Physics (MOE), Central China Normal University, Wuhan, Hubei 430079, China*

E-mail: caifangmin@mails.ccnu.edu.cn, dengweijun@mails.ccnu.edu.cn, xqli@mail.ccnu.edu.cn, yangyd@mail.ccnu.edu.cn

ABSTRACT: With updated experimental data and improved theoretical calculations, several significant deviations are observed between the Standard Model predictions and the experimental measurements of the branching ratios of $\bar{B}^0_{(s)} \to D^{(*)+}_{(s)} L^-$ decays, where L is a light meson from the set $\{\pi, \rho, K^{(*)}\}$. Especially for the two channels $\bar{B}^0 \to D^+K^-$ and $\bar{B}^0_s \to D^+_s \pi^-$, which are free of the weak annihilation contribution, the deviation can even reach 4-5σ. Here we exploit possible new-physics effects in these class-I non-leptonic B-meson decays within the framework of QCD factorization. Firstly, we perform a model-independent analysis of the effects from twenty linearly independent four-quark operators that can contribute, either directly or through operator mixing, to the quark-level $b \to c\bar{u}d(s)$ transitions. Under the combined constraints from the current experimental data, we find that the observed deviations could be well explained at the 2σ level by the new-physics four-quark operators with $\gamma^\mu(1-\gamma_5) \otimes \gamma_\mu(1-\gamma_5)$, $(1+\gamma_5) \otimes (1-\gamma_5)$ and $(1+\gamma_5) \otimes (1+\gamma_5)$ structures, while the ones with other Dirac structures fail to provide a consistent interpretation. Then, as two examples of model-dependent considerations, we discuss the case where the new-physics four-quark operators are generated by either a colorless charged gauge boson or a colorless charged scalar, with their masses fixed both at 1 TeV. Constraints on the effective coefficients describing the couplings of these mediators to the relevant quarks are obtained by fitting to the current experimental data.

Include all possible Dirac structures (=20) for new $b \to c\bar{u}d,s$ transitions

Assume: * $C_i^{BSM, c\bar{u}d} = C_i^{BSM, c\bar{u}s}$

* $C_i^{BSM, c\bar{u}d} \in \mathbb{R}$

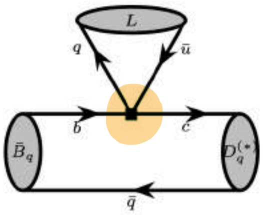


Figure 2. Leading-order Feynman diagram contributing to the hard kernels $T_{ij}(u)$, where the local four-quark operators are represented by the black square.

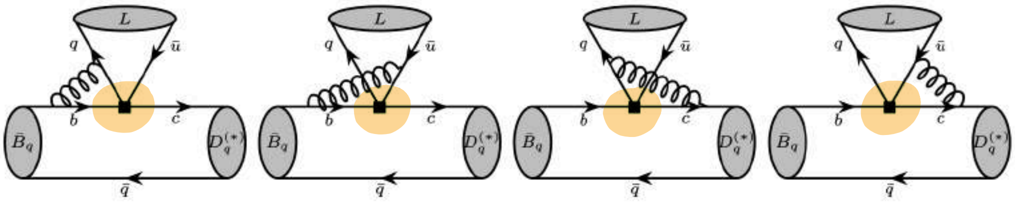


Figure 3. "Non-factorizable" vertex corrections to the hard kernels $T_{ij}(u)$ at NLO in α_s, where the other captions are the same as in Fig. 2.

I) SM update

3.26 ± 0.13

Decay mode	LO	NLO	NNLO	Ref. [36]	Exp. [7, 8]
$\bar{B}^0 \to D^+\pi^-$	4.07	$4.32^{+0.23}_{-0.42}$	$4.43^{+0.20}_{-0.41}$	$3.93^{+0.43}_{-0.42}$	2.65 ± 0.15
$\bar{B}^0 \to D^{*+}\pi^-$	3.65	$3.88^{+0.27}_{-0.41}$	$4.00^{+0.25}_{-0.41}$	$3.45^{+0.53}_{-0.50}$	2.58 ± 0.13
$\bar{B}^0 \to D^+\rho^-$	10.63	$11.28^{+0.84}_{-1.23}$	$11.59^{+0.79}_{-1.21}$	$10.42^{+1.24}_{-1.20}$	7.6 ± 1.2
$\bar{B}^0 \to D^{*+}\rho^-$	9.99	$10.61^{+1.35}_{-1.56}$	$10.93^{+1.35}_{-1.57}$	$9.24^{+0.72}_{-0.71}$	6.0 ± 0.8
$\bar{B}^0 \to D^+K^-$	3.09	$3.28^{+0.16}_{-0.31}$	$3.38^{+0.13}_{-0.30}$?	$3.01^{+0.32}_{-0.31}$	2.19 ± 0.13
$\bar{B}^0 \to D^{*+}K^-$	2.75	$2.92^{+0.19}_{-0.30}$	$3.02^{+0.18}_{-0.30}$	$2.59^{+0.39}_{-0.37}$	2.04 ± 0.47
$\bar{B}^0 \to D^+K^{*-}$	5.33	$5.65^{+0.47}_{-0.64}$	$5.78^{+0.44}_{-0.63}$	$5.25^{+0.65}_{-0.63}$	4.6 ± 0.8
$\bar{B}_s^0 \to D_s^+\pi^-$	4.10	$4.35^{+0.24}_{-0.43}$	$4.47^{+0.21}_{-0.42}$?	$4.39^{+1.36}_{-1.19}$	3.03 ± 0.25
$\bar{B}_s^0 \to D_s^+K^-$	3.12	$3.32^{+0.17}_{-0.32}$	$3.42^{+0.14}_{-0.31}$	$3.34^{+1.04}_{-0.90}$	1.92 ± 0.22

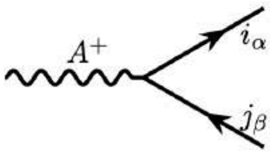
$3.27^{+0.39}_{-0.34}$ 4.42 ± 0.21

II) BSM analysis

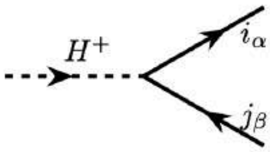
look at 8 vertices $\quad \dfrac{\Gamma(B_{(s)} \to D_{(s)}^{(*)+} L^-)}{d\Gamma_{SE}/dq^2}$

$\Longrightarrow$ $\gamma^\mu(1-\gamma_5) \otimes \gamma_\mu(1-\gamma_5)$: colorless charged gauge boson

$$\left.\begin{aligned}(1+\gamma_5) &\otimes (1-\gamma_5)\\ (1+\gamma_5) &\otimes (1+\gamma_5)\end{aligned}\right\} \text{colorless charged scalar}$$



$$i\frac{g_2}{\sqrt{2}}V_{ij}\gamma^\mu\delta_{\alpha\beta}\left[\Delta^L_{ij}(A)P_L + \Delta^R_{ij}(A)P_R\right]$$



$$i\frac{g_2}{\sqrt{2}}V_{ij}\delta_{\alpha\beta}\left[\Delta^L_{ij}(H)P_L + \Delta^R_{ij}(H)P_R\right]$$

Improved Flavour Constraints

A) BSM effects only in $b \to c\bar{u}d,s$

Lifetime ratios:

$$\frac{\tau_{B_s}}{\tau_{B_d}} = \frac{\Gamma_{B_d}}{\Gamma_{B_s}} = 1 + \left(\Gamma_{B_d} - \Gamma_{B_s}\right)\tau_{B_s}$$

$$= 1 + \Gamma_5 \frac{\langle O_5\rangle_{B_d} - \langle O_5\rangle_{B_s}}{m_b^2}$$

chromomagnetic
kinetic
small

$$+ \Gamma_6 \frac{\langle O_6\rangle_{B_d} - \langle O_6\rangle_{B_s}}{m_b^3}$$

Darwin
large

AL, Piscopo, Rusov 2004.09527
Mannel, Moreno, Pivovarov 2004.09485

$$+ \dots$$

$$+ 16\pi^2 \left[\frac{\tilde{\Gamma}_6^{B_d} \langle \tilde{O}_6\rangle_{B_d} - \tilde{\Gamma}_6^{B_s} \langle \tilde{Q}_6\rangle_{B_s}}{m_b^3} \right.$$

1st. calc.

King, AL, Rauh
soon...

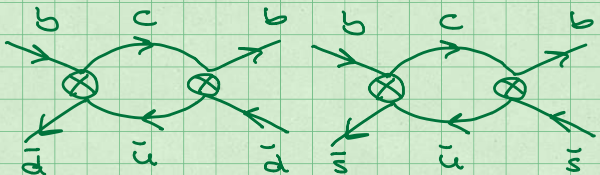
$$+ \frac{\tilde{\Gamma}_7^{B_d} \langle \tilde{O}_7\rangle_{B_d} - \tilde{\Gamma}_7^{B_s} \langle \tilde{Q}_7\rangle_{B_s}}{m_b^4}$$

$$+ \dots$$

new contributions stemming from $b \to c\bar{u}d,s$

1) for Q_1, Q_2 known

2) for new operators ✗



τ_{B_d} CKM leading τ_{B_s} CKM suppressed

1) for Q_1, Q_2 known

2) for new operators ✗

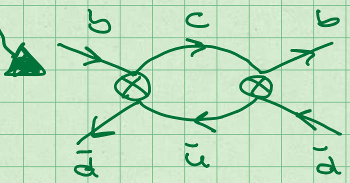
$$\frac{\tau_{B^+}}{\tau_{B_d}} = \frac{\Gamma_{B_d}}{\Gamma_{B^+}} = 1 + \left(\Gamma_{B_d} - \Gamma_{B^+}\right)\tau_{B^+}$$

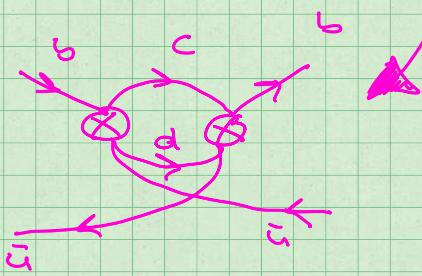
$$\left.\begin{aligned} &= 1 + \Gamma_5 \frac{\langle Q_5\rangle_{B_d} - \langle O_5\rangle_{B^+}}{m_b^2} \\ &+ \Gamma_6 \frac{\langle Q_6\rangle_{B_d} - \langle O_6\rangle_{B^+}}{m_b^3} \end{aligned}\right\} \text{vanishes due to isospin}$$

$$+ \ldots$$

$$+ 16\pi^2 \Big[\frac{\tilde{\Gamma}_6^{B_d} \langle \tilde{O}_6\rangle_{B_d} - \tilde{\Gamma}_6^{B^+} \langle \tilde{Q}_6\rangle_{B^+}}{m_b^3} + \frac{\tilde{\Gamma}_7^{B_d} \langle \tilde{O}_7\rangle_{B_d} - \tilde{\Gamma}_7^{B^+} \langle \tilde{Q}_7\rangle_{B^+}}{m_b^4} + \ldots$$

new contributions stemming from $b \to c\bar{u}ds$





τ_{B_d}

CKM leading

1) for Q_1, Q_2 known

2) for new operators ?

τ_{B^+}

CKM leading

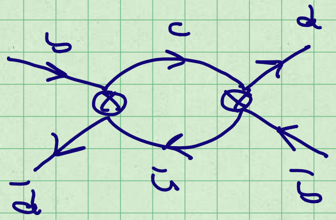
1) for Q_1, Q_2 known

2) for new operators ?

Mixing

$$\frac{\Gamma_{12}}{M_{12}} = \underbrace{\frac{\Gamma_{12}^{cc}}{\tilde{M}_{12}} + \underbrace{2\frac{\lambda_u}{\lambda_t}\frac{\Gamma_{12}^{cc}-\Gamma_{12}^{uc}}{\tilde{M}_{12}} + \left(\frac{\lambda_u}{\lambda_t}\right)^2\frac{\Gamma_{12}^{cc}-2\Gamma_{12}^{uc}+\Gamma_{12}^{uu}}{\tilde{M}_{12}}}_{a_{sl}^q = \mathrm{Im}\left(\frac{\Gamma_{12}}{M_{12}}\right)}}_{\frac{\Delta\Gamma_q}{\Delta M_q} = \mathrm{Re}\left(\frac{\Gamma_{12}}{M_{12}}\right)}$$

new contributions stemming from $b \to c\bar{u}d\,s$

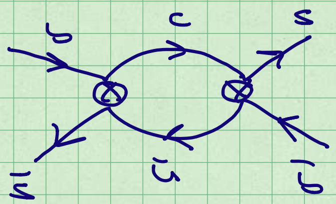


a_{sl}^d CKM leading (breaks SM)

$\Delta\Gamma_d$ CKM suppressed

1) for Q_1, Q_2 known

2) for new operators ↯



a_{sl}^s CKM leading (breaks SM)

$\Delta\Gamma_s$ CKM suppressed

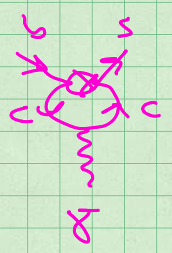
1) for Q_1, Q_2 known

2) for new operators ↯

3) BSM in all non-leptonic channels (univ.)

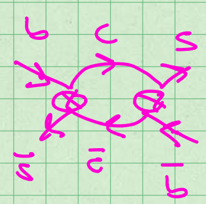
e.g. also new physics in $b \to c\bar{c}s$

$\Longrightarrow$



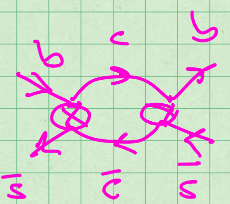
$b \to s\gamma$

anomalies but not R_K, R_{K^*}



CKM leading to $\Delta\Gamma_s$ ($\Delta\Gamma_d$)

cancels in a_{sl}^s (a_{sl}^d)



CKM leading

c) ...