New Physics in $\Delta\Gamma_d$

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- Conclusions

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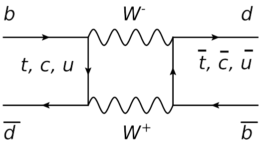

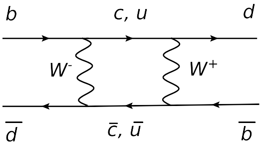

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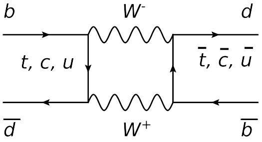

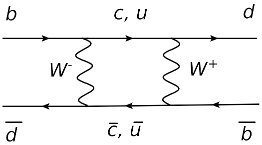

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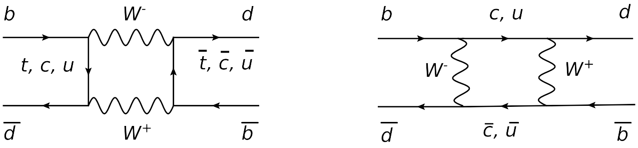

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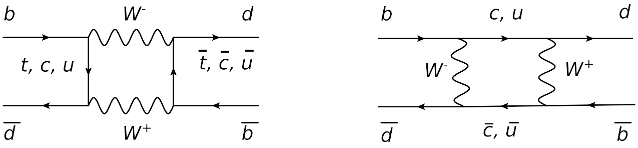

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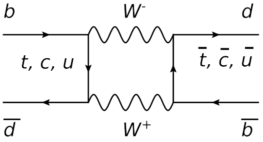

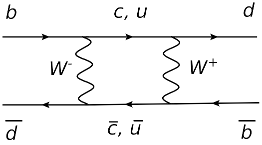

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Γ_{12}	On-shell
M_{12}	Off-shell

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$$\begin{aligned} \Delta M &\approx 2|M_{12}| \\ a_{sl} &= \left|\frac{\Gamma_{12}}{M_{12}}\right| sin(\phi) \\ \Delta\Gamma &\approx 2|\Gamma_{12}| cos(\phi) \end{aligned}$$

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New Physics at tree level decays.

The effective Hamiltonian approach

$$\left(\frac{g_2}{2\sqrt{2}}\right)^2 \frac{1}{k^2 - M_W^2} \quad \approx \quad -\left(\frac{g_2}{2\sqrt{2}}\right)^2 \frac{1}{M_W^2} \equiv \frac{G_F}{\sqrt{2}}$$

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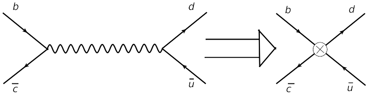

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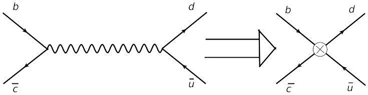

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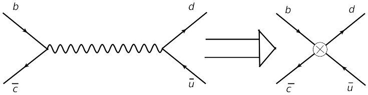

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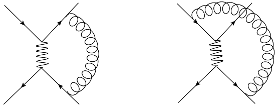

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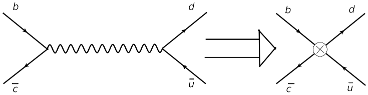

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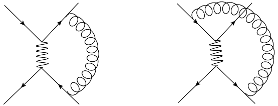

After integrating out the W boson we get: $Q_1^{qq'} = \left(\bar{d}_j \gamma_\mu P_L q_i\right)\left(\bar{q}'_i \gamma^\mu P_L b_j\right)$

New Physics at tree level decays.

$$H_{eff} = \frac{4G_F}{\sqrt{2}} \sum_{q,q'=u,c} \lambda_{qq'} \sum_{i=1,2} C_i^{q,q'}(M_W, \mu) Q_i^{qq'} + h.c.$$

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Wilson Coefficients

$$\begin{aligned} C_1(\mu) &= -\frac{3\alpha_s(\mu)}{4\pi} Ln\left(\frac{M_W^2}{\mu^2}\right) \\ C_2(\mu) &= 1 + \frac{3}{N_c}\frac{\alpha_s(\mu)}{4\pi} Ln\left(\frac{M_W^2}{\mu^2}\right) \end{aligned}$$

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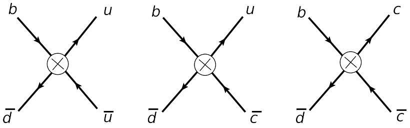

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- $B \to X_d \gamma \Longrightarrow$ Operator Mixing
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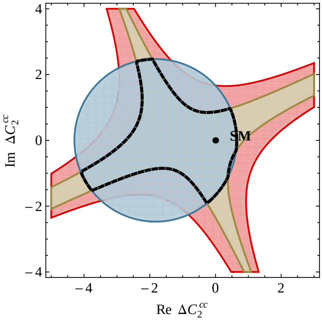
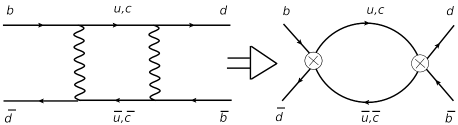
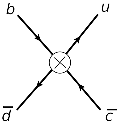
- $a_{sl}^d = Im\left(\frac{\Gamma_{12}^d}{M_{12}^d}\right)$



New Physics at tree level decays.

Calculation of $\Delta\Gamma_{d,s}$





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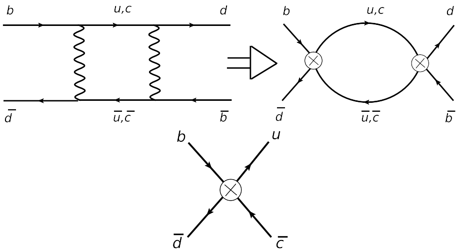

$$H_{eff}^{\Delta B=1} = \frac{4G_F}{\sqrt{2}} \sum_{q,q'=u,c} \lambda_{qq'} \sum_{i=1,2} C_i^{q,q'}(M_W,\mu) Q_i^{qq'} + h.c.$$

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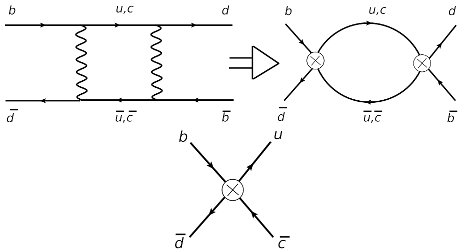

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$$\begin{aligned}\Gamma_{12}^{d} &= \frac{1}{2M_{B_d}} < \bar{B}_d | Im \left(i \int d^4x \hat{T} \left[H_{eff}^{\Delta B=1}(x) H_{eff}^{\Delta B=1}(0) \right] \right) | B_d > \\ &= -\left(\lambda_c^2 \Gamma_{12}^{cc,d}(C_1^{cc}, C_2^{cc}) + 2\lambda_c \lambda_u \Gamma_{12}^{uc,d}(C_1^{uc}, C_2^{uc}) + \lambda_u^2 \Gamma_{12}^{uu,d}(C_1^{uu}, C_2^{uu}) \right) ,\end{aligned}$$

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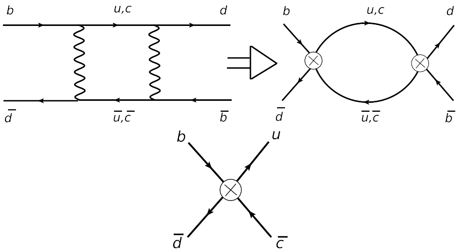

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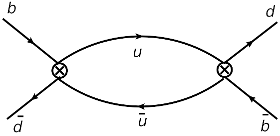
$$\Delta\Gamma_d \approx 2|\Gamma_{12}^d| cos(\phi_d)$$

Effect of C_1, C_2 on $\Delta\Gamma$



Up to an enhancement of 1.5 possible.

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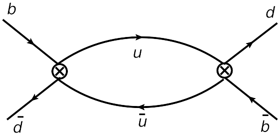

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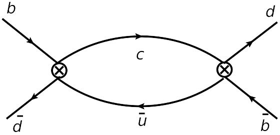
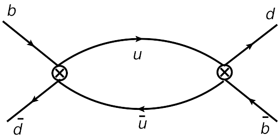


Up to an enhancement of 1.6 possible.

Effect of C_1, C_2 on $\Delta\Gamma$



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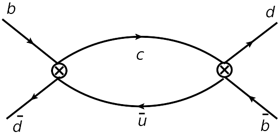

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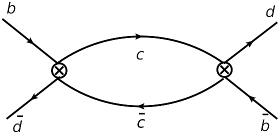

Up to an enhancement of 16 posssible

How big can $\Delta\Gamma_d$ be?

Enhancements in $\Delta\Gamma_d$ arise from:

1. CKM Unitarity violations.
2. New Physics at tree level decays.
3. $(\bar{d}b)(\bar{\tau}\tau)$ operators.

$(b\bar{d})\ (\bar{\tau}\tau)$ Operators

The contributions from NP on $\Delta\Gamma_d$ can be estimated by analyzing effective operators well suppressed in the SM.

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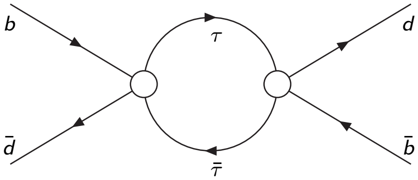

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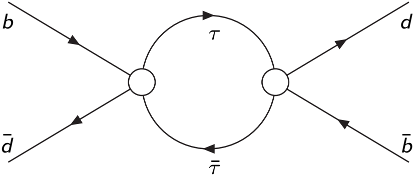

$$
\begin{aligned}
Q_{S,AB} &= \left(\bar{d}\, P_A\, b\right) \left(\bar{\tau}\, P_B\, \tau\right) , \\
Q_{V,AB} &= \left(\bar{d}\, \gamma^{\mu} P_A\, b\right) \left(\bar{\tau}\, \gamma_{\mu} P_B\, \tau\right) , \\
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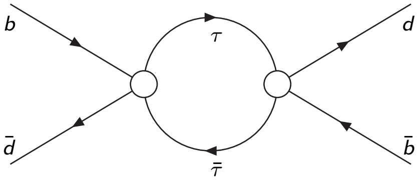

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\end{aligned}
$$

The effective Hamiltonian involving these operators is

$$H_{\text{eff}} = -\frac{4G_F}{\sqrt{2}}\lambda_t^d \sum_{i,j} C_{i,j}(\mu) Q_{i,j}$$

$(b\bar{d})\,(\bar{\tau}\tau)$ Operators

Example: Vector contribution $Q_{V,AB} = \left(\bar{d}\,\gamma^{\mu} P_A\, b\right)\left(\bar{\tau}\,\gamma_{\mu} P_B\, \tau\right)$

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$$Q_9 = \frac{e^2}{(4\pi)^2}\,(\bar{d}\,\gamma^{\mu} P_L\, b)\,(\bar{\ell}\,\gamma_{\mu}\,\ell)\ ,$$

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$$C_{9,A}(m_b) = \left(0.1 - 0.2\,\eta_6^{-1}\right)\left(C_{V,AL}(\Lambda) + C_{V,AR}(\Lambda)\right)$$

$(b\bar{d})\,(\bar{\tau}\tau)$ Operators

$$\Gamma_{12}^{d} = \Gamma_{12}^{d,SM}\tilde{\Delta}_d$$

$$\frac{\Delta\Gamma_d}{\Delta\Gamma_d^{SM}} \leq |\tilde{\Delta}_d|$$

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Dependence of $\tilde{\Delta}_d$ on the Wilson coefficients

$$\begin{aligned}|\tilde{\Delta}_d|_{S,AB} &< 1 + (0.41^{+0.13}_{-0.08})|C_{S,AB}(m_b)|^2 \leq 1.6 \\ |\tilde{\Delta}_d|_{V,AB} &< 1 + (0.42^{+0.13}_{-0.08})|C_{V,AB}(m_b)|^2 \leq 3.7 \\ |\tilde{\Delta}_d|_{T,AB} &< 1 + (3.81^{+1.21}_{-0.74})|C_{T,A}(m_b)|^2 \leq 1.2\end{aligned}$$

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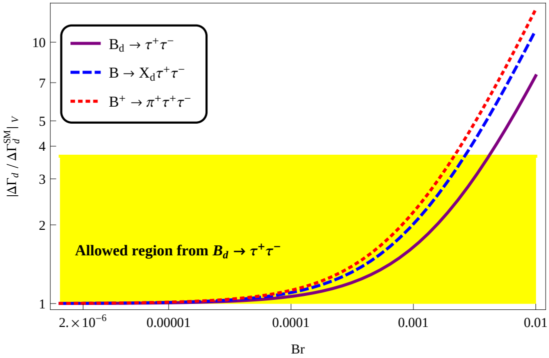
Expected values for $Br\left(B \to \pi^+\tau^+\tau^-\right)$
and
$Br\left(B \to X_d\tau^+\tau^-\right)$ in order to compete against $Br\left(B_d \to \tau^+\tau^-\right)$



$$|\tilde{\Delta}_d|_{V,AB} \quad \leq \quad 3.7 \Longrightarrow Br(B \to X_d\tau^+\tau^-) \leq 2.6 \times 10^{-3}$$

Like-sign dimuon asymmetry

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CP violation in mixing+

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CP violation in mixing+CP violation in interference between mixing and decay.

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$a^d_{sl} = (-0.62 \pm 0.43)\%$ $a^s_{sl} = (-0.82 \pm 0.99)\%$ $\frac{\Delta\Gamma_d}{\Gamma_d} = (0.50 \pm 1.38)\%$ D0 (2014)

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Phys. Rev. D 89, 012002 (2014)

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Borissov and Hoeneisen $A_{CP} \propto C_d a^d_{sl} + C_s a^s_{sl} + C_{\Gamma_d} \frac{\Delta\Gamma_d}{\Gamma_d} + C_{\Gamma_s} \frac{\Delta\Gamma_s}{\Gamma_s}$ Phys. Rev. D 87, 074020

CP violation in mixing+CP violation in interference between mixing and decay.

$a^d_{sl} = (-0.62 \pm 0.43)\%$ $a^s_{sl} = (-0.82 \pm 0.99)\%$ $\frac{\Delta\Gamma_d}{\Gamma_d} = (0.50 \pm 1.38)\%$ D0 (2014)

Phys. Rev. D 89, 012002 (2014)

3.0 σ deviation from the SM

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There are different phases

$$Sin(2\beta + 2\theta_{\lambda_c})$$

attached with the components of $\Delta\Gamma_d$.

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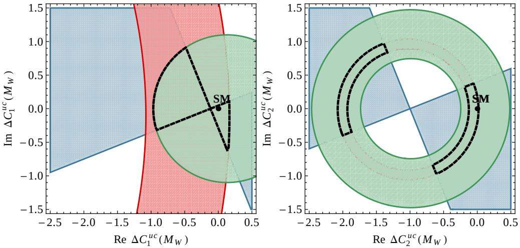

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