Space for New Physics in Neutral B mixing observables

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April 30, 2014

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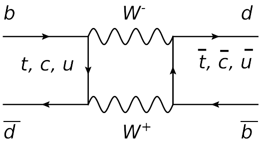

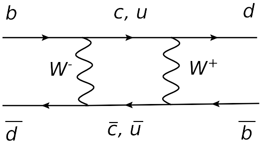

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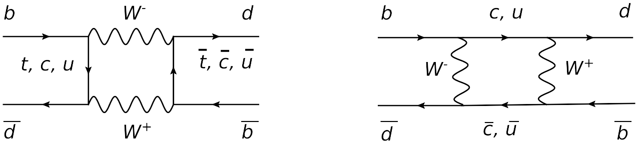

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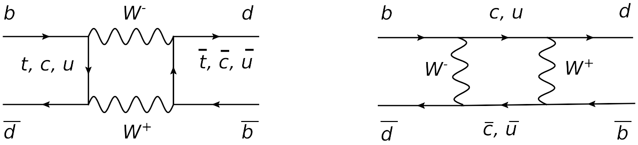

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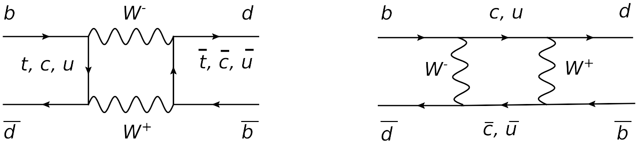

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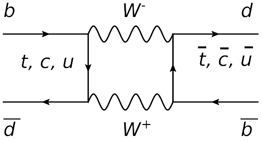

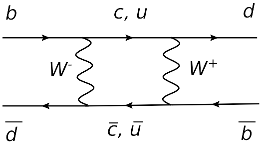

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Γ_{12}	On-shell
M_{12}	Off-shell

Mixing of neutral B mesons

Eigenvalues of Σ:

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

Calculation of ΔM_q

$\Delta M_{d,s}$

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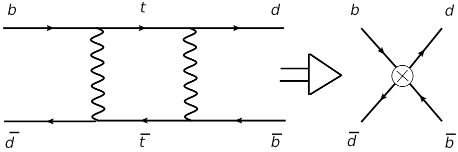

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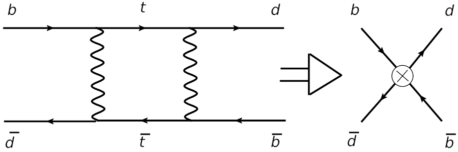

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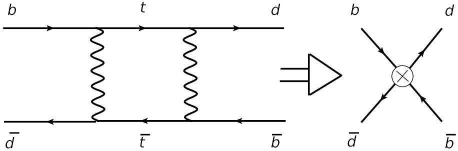

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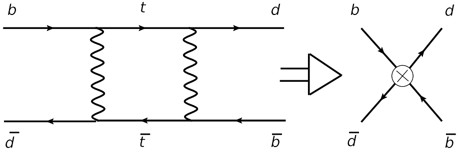

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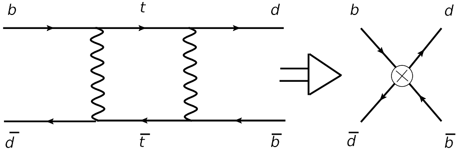

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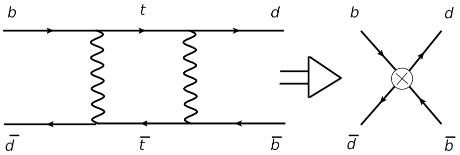

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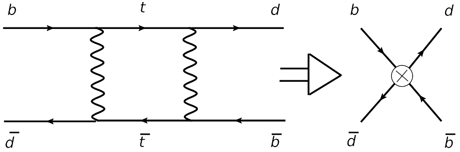

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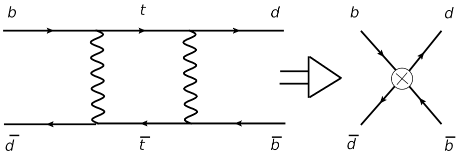

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Theoretical predictions vs experimental results for the mass splittings:

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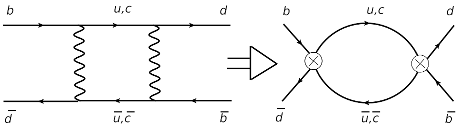
The hadronic uncertainties allow space for new physics.

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



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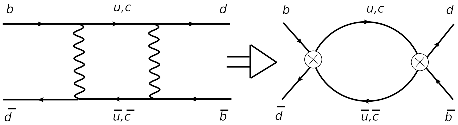

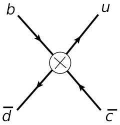

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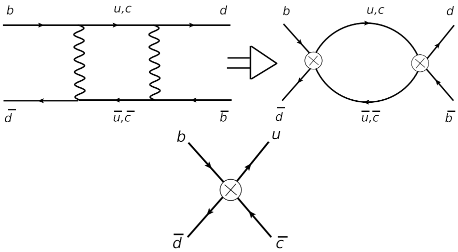

$$H_{eff}^{\Delta B=1} = \frac{4G_F}{\sqrt{2}} \sum_{q,q'=u,c} \lambda_{qq'} \sum_{i=1,2} C_i^{q,q'}(M_W,\mu) Q_i^{qq'} + h.c.$$

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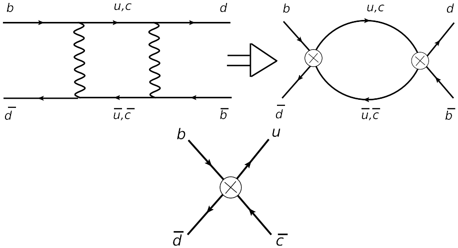

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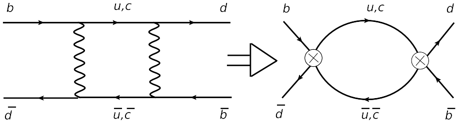

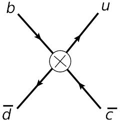

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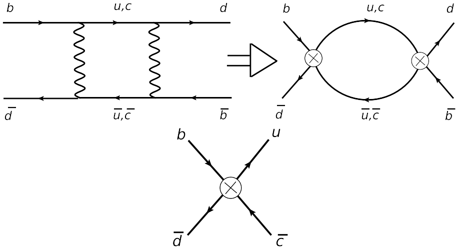

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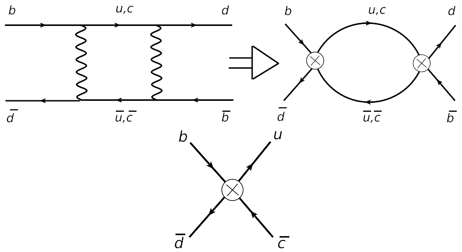

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$\Delta\Gamma_{d,s}$

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Room for new physics in $\Delta\Gamma_d$

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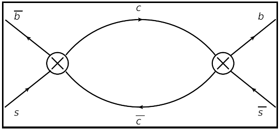

$\Delta\Gamma_s$ triggered by $b \to c\bar{c}s$

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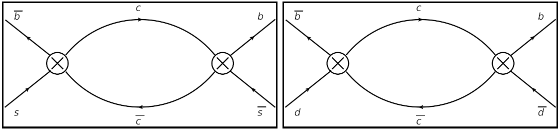

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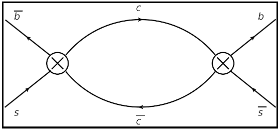

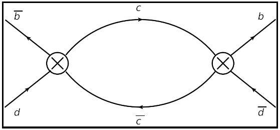

$\Delta\Gamma_s$ triggered by $b \to c\bar{c}s$ $\Delta\Gamma_d$ triggered by $b \to c\bar{c}d$

$$Br(b \to c\bar{c}s) = (23.7 \pm 1.3)\% \,||\, Br(b \to c\bar{c}d) = (1.31 \pm 0.07)\%$$

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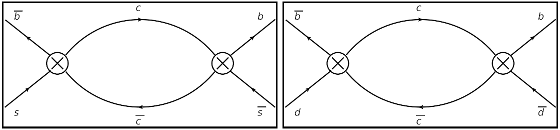

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Room for new physics in $\Delta\Gamma_d$

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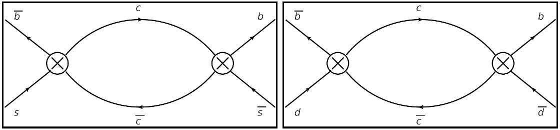

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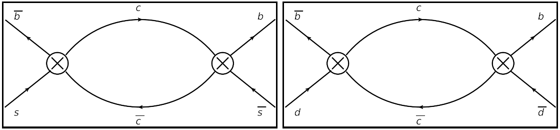

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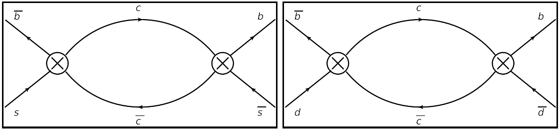

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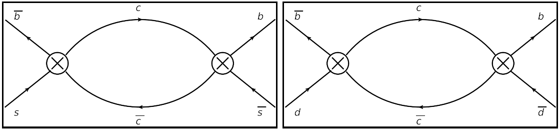

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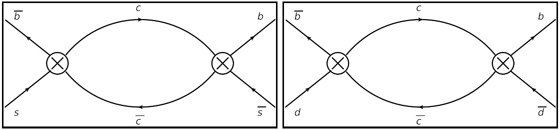

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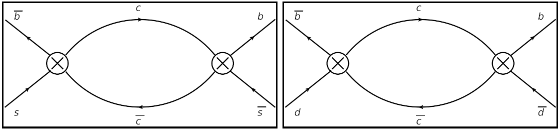

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Bobeth, Haisch, Lenz, Pecjak and Tetlalmatzi-Xolocotzi, arXiv:1404.2531.

Room for new physics in $\Delta\Gamma_d$

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CKM Unitarity violations

Let $\lambda_u = V_{ud}^* V_{ub}$, $\lambda_c = V_{cd}^* V_{cb}$, $\lambda_t = V_{td}^* V_{tb}$.

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Enhancement factors: 4 for $\Delta\Gamma_d$ and 1.4 for $\Delta\Gamma_s$.

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Room for New Physics at SM tree level decays.

Room for new physics in $\Delta\Gamma_d$

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Room for New Physics at SM tree level decays.

Calculation of the effects of $C_{1,2}^{qq^{'},SM} \Longrightarrow C_{1,2}^{qq^{'},SM} + \Delta C_{1,2}^{qq^{'}}$ on $\Delta\Gamma_d$

Room for new physics in $\Delta\Gamma_d$

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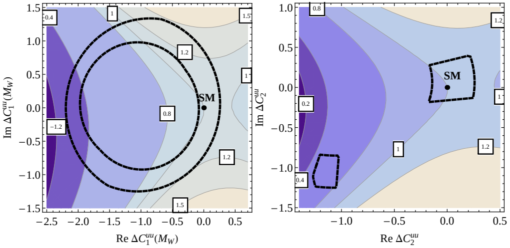

The contours show the ratio $\Delta\Gamma_d^{SM+NP}/\Delta\Gamma_d^{SM}$ for $qq' = uu$

Room for new physics in $\Delta\Gamma_d$

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Room for New Physics at SM tree level decays.

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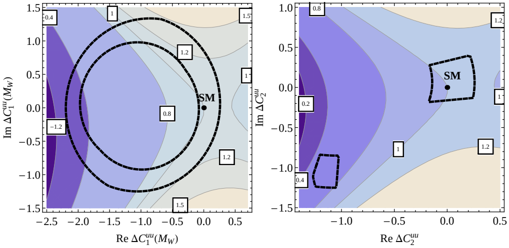
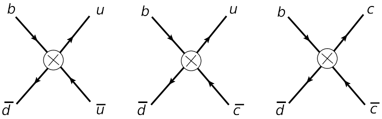


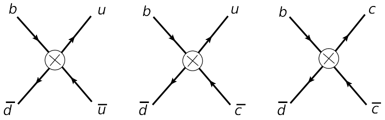
The contours show the ratio $\Delta\Gamma_d^{SM+NP}/\Delta\Gamma_d^{SM}$ for $qq' = uu$

Enhancement factor: 16 for $\Delta\Gamma_d$.

Room for new physics in $\Delta\Gamma_d$



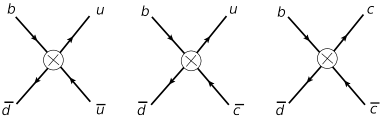
Room for new physics in $\Delta\Gamma_d$



C^{uu} bounds from:

$$
\begin{array}{rcl}
B^0 & \to & \pi^+\pi^- \\
B^- & \to & \pi^-\pi^0 \\
B^0 & \to & \rho^+\rho^- \\
B^0 & \to & \rho^{+/-}\pi^{-/+}
\end{array}
$$

Room for new physics in $\Delta\Gamma_d$



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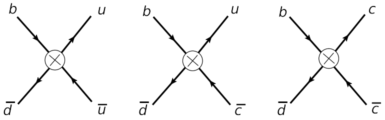
C^{uc} bounds from:

$$\begin{array}{rcl} \bar{B}_d & \to & D^{*+}\pi^- \\ \Gamma(B_d) & & \end{array}$$

Room for new physics in $\Delta\Gamma_d$



C^{uu} bounds from:

$$\begin{aligned} B^0 &\rightarrow \pi^+\pi^- \\ B^- &\rightarrow \pi^-\pi^0 \\ B^0 &\rightarrow \rho^+\rho^- \\ B^0 &\rightarrow \rho^{+/-}\pi^{-/+} \end{aligned}$$

C^{uc} bounds from:

$$\begin{aligned} \bar{B}_d &\rightarrow D^{*+}\pi^- \\ \Gamma(B_d) & \end{aligned}$$

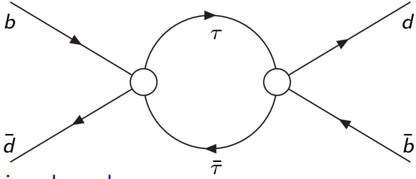
C^{cc} bounds from:

$$\begin{aligned} B &\rightarrow X_d\gamma \\ sin(2\beta) & \\ a_{sl}^d & \end{aligned}$$

Room for new physics in $\Delta\Gamma_d$

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

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



Bounds from the following channels

Room for new physics in $\Delta\Gamma_d$

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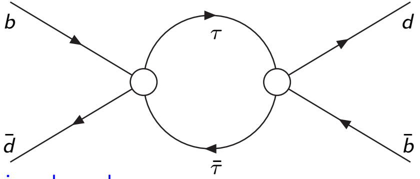

Bounds from the following channels

- $B_d \to \tau^+\tau^-$

Room for new physics in $\Delta\Gamma_d$

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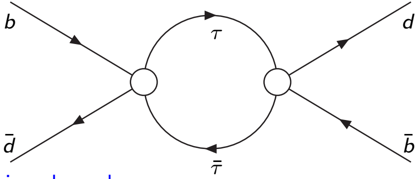
$$



Bounds from the following channels

- $B_d \to \tau^+\tau^-$
- $B \to X_d\tau^+\tau^-$ and $B^+ \to \pi^+\tau^+\tau^-$

Room for new physics in $\Delta\Gamma_d$

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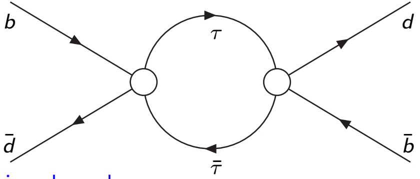
$$\begin{aligned} Q_{S,AB} &= \left(\bar{d}\, P_A\, b\right)(\bar{\tau}\, P_B\, \tau)\ , \\ Q_{V,AB} &= \left(\bar{d}\,\gamma^\mu P_A\, b\right)(\bar{\tau}\,\gamma_\mu P_B\, \tau)\ , \\ Q_{T,A} &= \left(\bar{d}\,\sigma^{\mu\nu} P_A\, b\right)(\bar{\tau}\,\sigma_{\mu\nu} P_A\, \tau)\ , \end{aligned}$$



Bounds from the following channels

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- $B \to X_d\tau^+\tau^-$ and $B^+ \to \pi^+\tau^+\tau^-$
- $B^+ \to \pi^+\mu^+\mu^-$

Enhancement factor: 3.7 for $\Delta\Gamma_d$.

Semileptonic asymmetries a_{sl}^q

$$a_{sl}^q \quad = \quad \frac{\Gamma(\bar{B}(t)_q \to f) - \Gamma(B(t)_q \to \bar{f})}{\Gamma(\bar{B}(t)_q) \to f) + \Gamma(B(t)_q \to \bar{f})} = |\frac{\Gamma_{12}^q}{M_{12}^q}| sin(\phi_q)$$

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$$a_{sl}^{d,D0} = (0.68 \pm 0.45 \pm 0.14)\% (2012) \qquad a_{sl}^{s,D0} = (-1.12 \pm 0.74 \pm 0.17)\% (2013)$$

$$a_{sl}^{d,BaBar} = (0.06 \pm 0.17 \pm 0.17^{+0.38}_{-0.23})\% (2013) \qquad a_{sl}^{s,LHCb} = (-0.06 \pm 0.050 \pm 0.36)\% (2014)$$

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Phys. Rev. D 89, 012002 (2014)

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3.0 σ deviation from the SM

β and β_s

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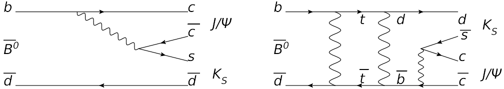

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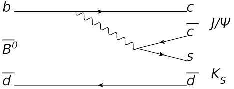

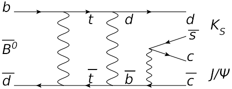

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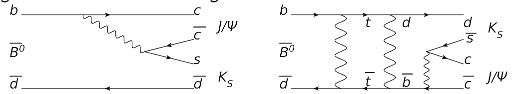

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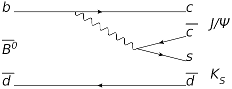

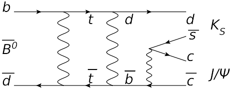

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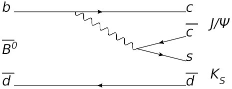

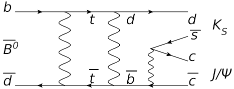

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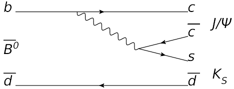

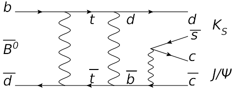

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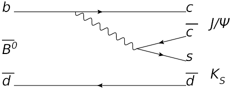

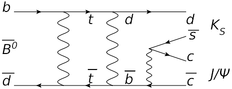

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New Physics in M_{12}^d and M_{12}^s

$$M_{12}^q = M_{12}^{q,SM} \Delta_q = M_{12}^{q,SM} |\Delta_q| e^{i\phi_q^\Delta}$$

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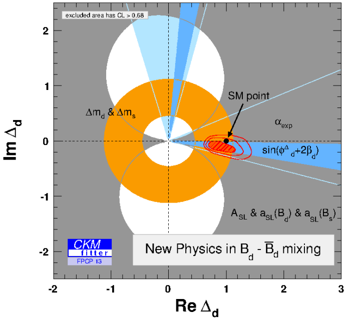

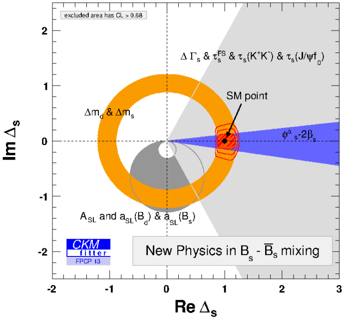

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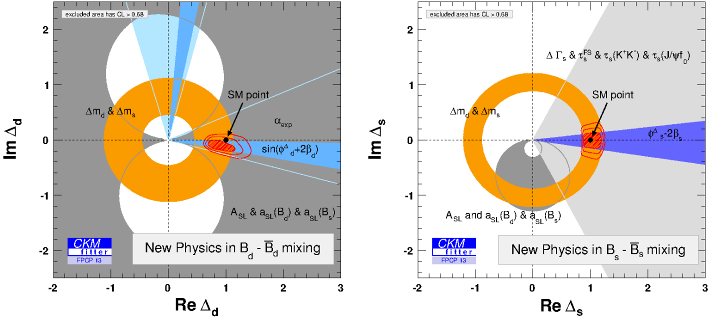

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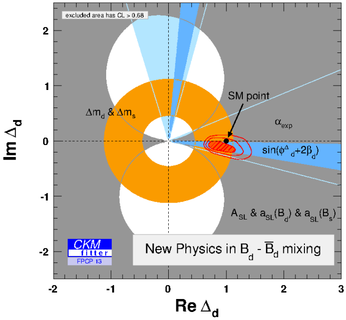

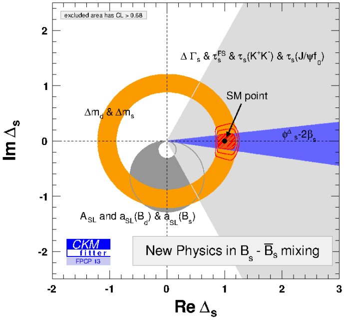

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