Charming new physics in rare B decays and mixing

6th workshop: "Implications of LHCb measurements and future prospects" 2016

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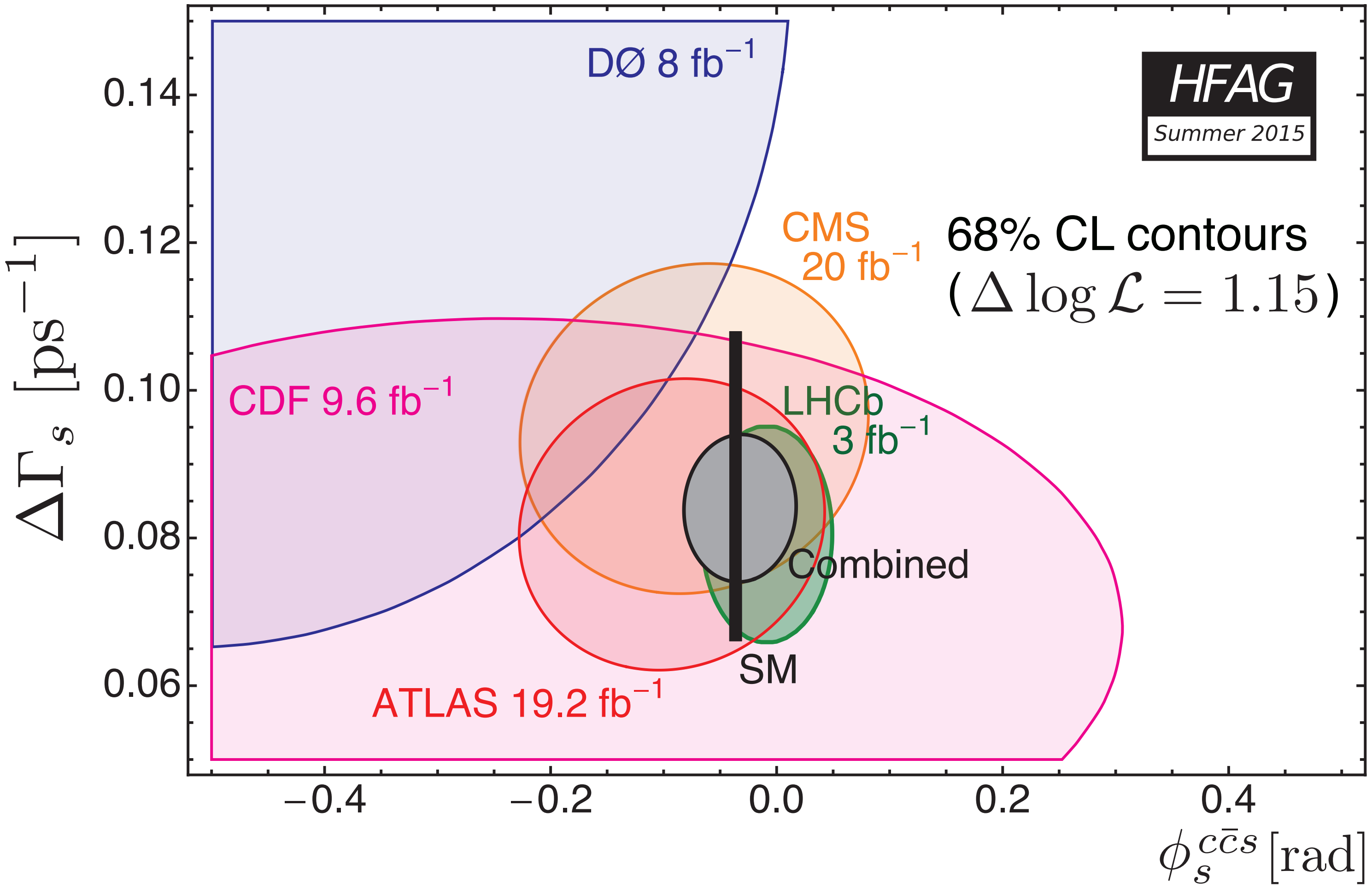
Outline of talk

- Correlating mixing and rare decays : Motivation
- Methodology
- Phenomenology
- Conclusions

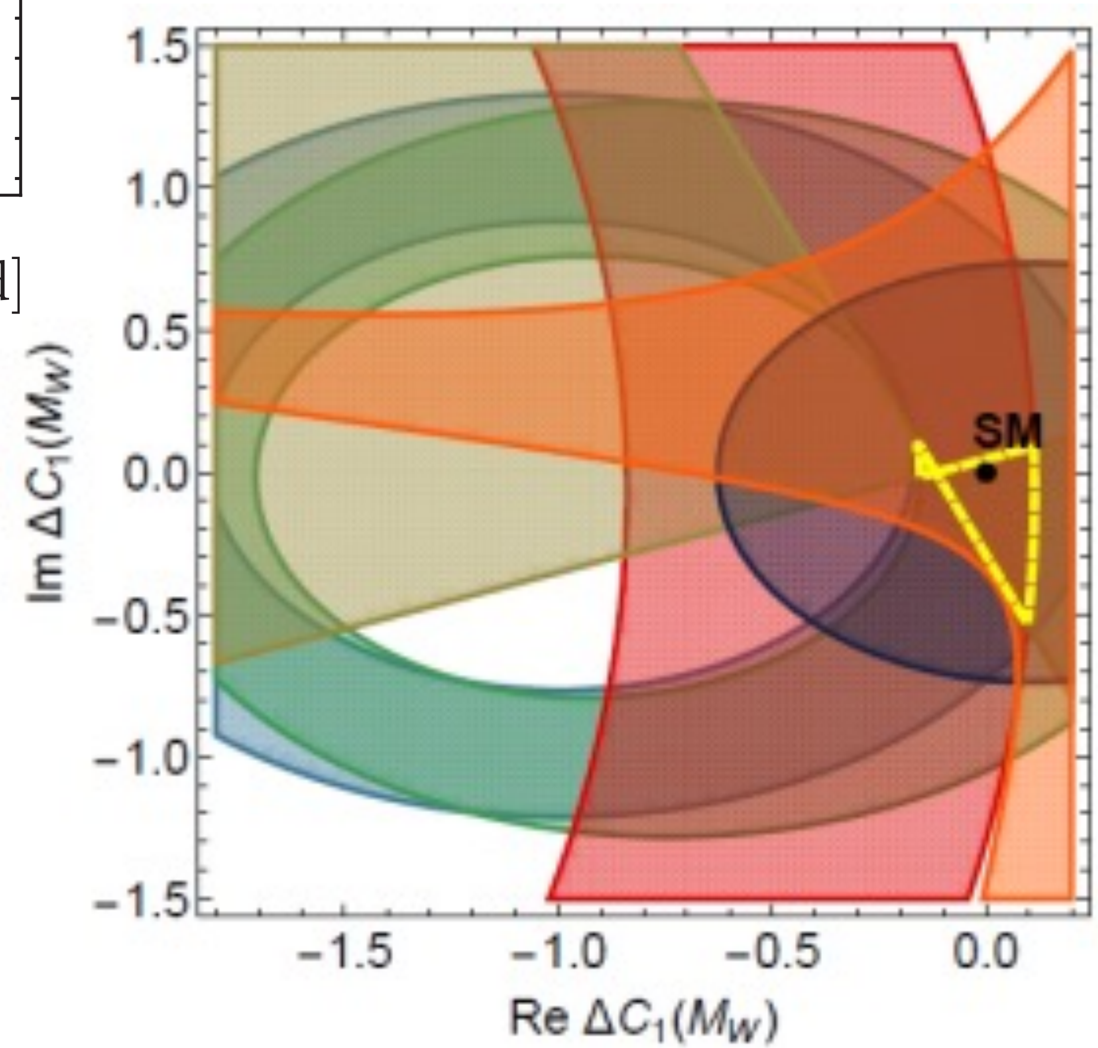
Motivation: B_s Mixing



http://www.slac.stanford.edu/xorg/hfag/osc/spring_2016/#DG

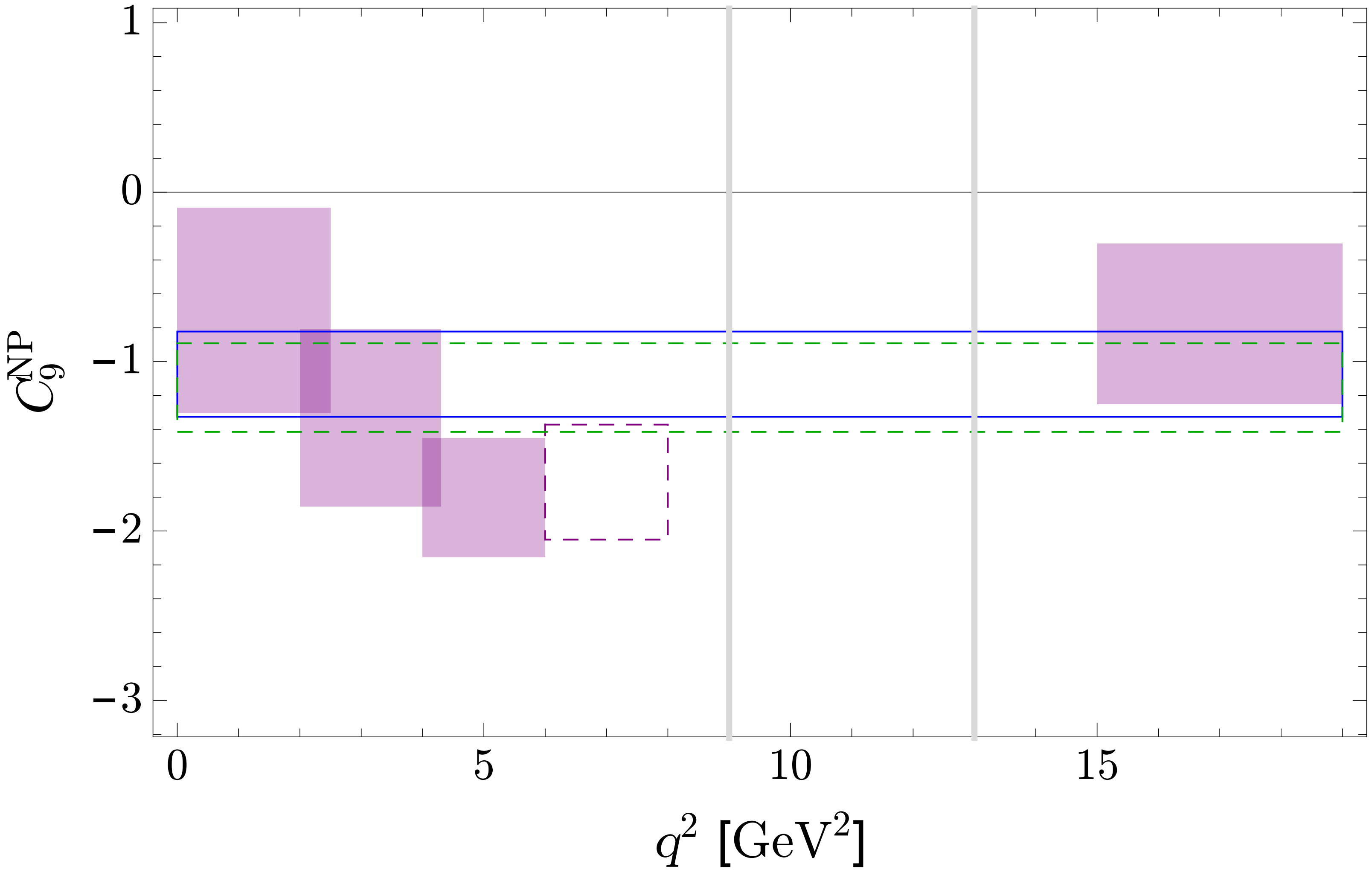
- Mixing related observables such as the decay rate difference and the semi leptonic asymmetry show consistency with the SM

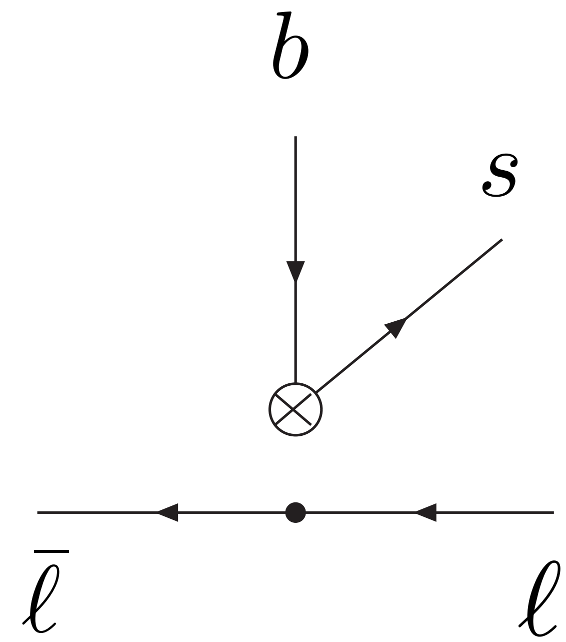
Brod, Lenz, Tetlalmatzi-Xolocotzi, Wiebusch, 1412.1446v1



- However mixing observables may not be very constraining, and if sizeable new physics contributions to b->ccs couplings are present, could also effect b->sll

Motivation: Rare Decays





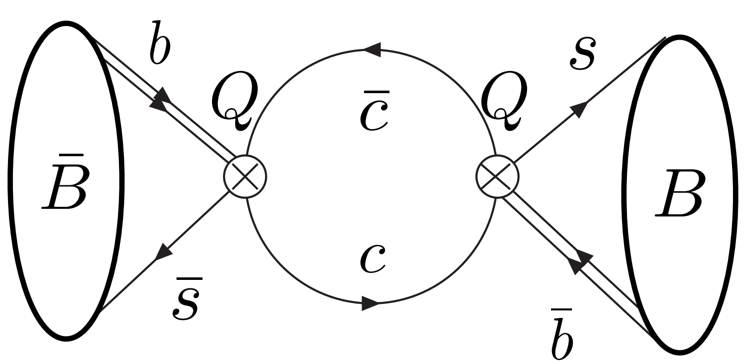
$$Q_9^l = \frac{\alpha}{4\pi}(\bar{s}_L\gamma_\mu b_L)(\bar{\ell}\gamma^\mu \ell)$$

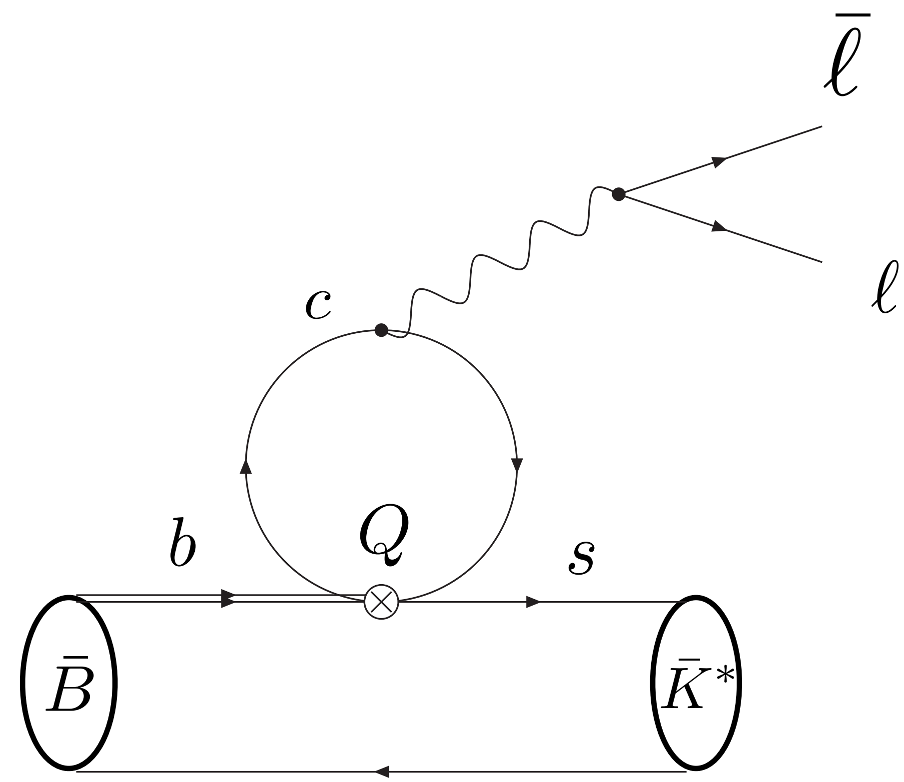
Altmannshofer, Straub, 1503:06199,
(see also Descotes,Hofer,Matias,Virto 1605:06059)

- Recent analysis of LHCb data suggests negative contribution to Wilson coefficient C_9
- Possible explanation for tensions in rare decays such as B->K*ll
- We assume there is a negative shift to C_9, and ask: could this be attributable to virtual charm effects?

Set up: Basic idea

- Effective operators with charm content give correlated effects in both mixing and rare B decays





$\Delta\Gamma_q \quad , a_{sl}^q$

A_{FB}, R_K, P_5' etc

Methodology: Weak Effective Hamiltonian

$$\mathcal{H}^{cc}_{eff} = \frac{4G_F}{\sqrt{2}} \left[\lambda_c \left(\Sigma_{i=1}^{10} C_i Q_i + C'_i Q'_i\right) + h.c\right]$$

SM

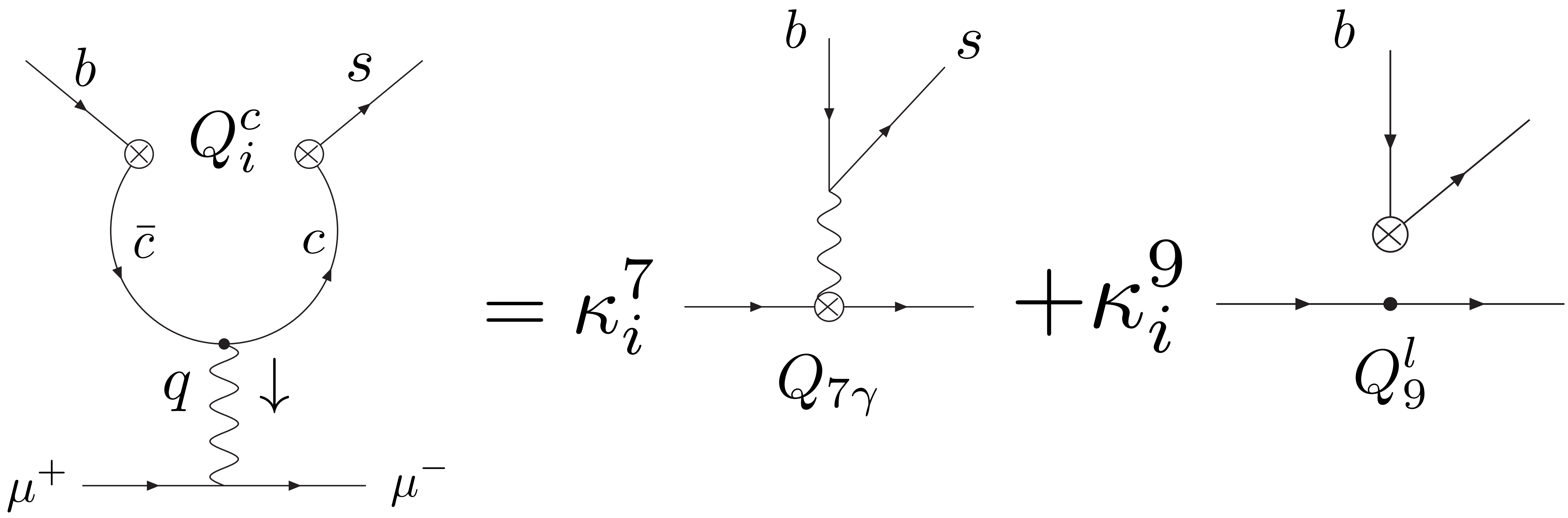
$$Q^c_1 = (\bar{c}^i_L \gamma_\mu b^j_L)(\bar{s}^j_L \gamma^\mu c^i_L), \qquad Q^c_2 = (\bar{c}^i_L \gamma_\mu b^i_L)(\bar{s}^j_L \gamma^\mu c^j_L),$$

BSM

$$\begin{aligned}
Q^c_3 &= (\bar{c}^i_R b^j_L)(\bar{s}^j_L c^i_R), & Q^c_4 &= (\bar{c}^i_R b^i_L)(\bar{s}^j_L c^j_R), \\
Q^c_5 &= (\bar{c}^i_R \gamma_\mu b^j_R)(\bar{s}^j_L \gamma^\mu c^i_L), & Q^c_6 &= (\bar{c}^i_R \gamma_\mu b^i_R)(\bar{s}^j_L \gamma^\mu c^j_L), \\
Q^c_7 &= (\bar{c}^i_L b^j_R)(\bar{s}^j_L c^i_R), & Q^c_8 &= (\bar{c}^i_L b^i_R)(\bar{s}^j_L c^j_R), \\
Q^c_9 &= (\bar{c}^i_L \sigma_{\mu\nu} b^j_R)(\bar{s}^j_L \sigma^{\mu\nu} c^i_R), & Q^c_{10} &= (\bar{c}^i_L \sigma_{\mu\nu} b^i_R)(\bar{s}^j_L \sigma^{\mu\nu} c^j_R),
\end{aligned}$$

Plus 10 more parity conjugate operators Q'^c_i

Rare Decay: Calculation

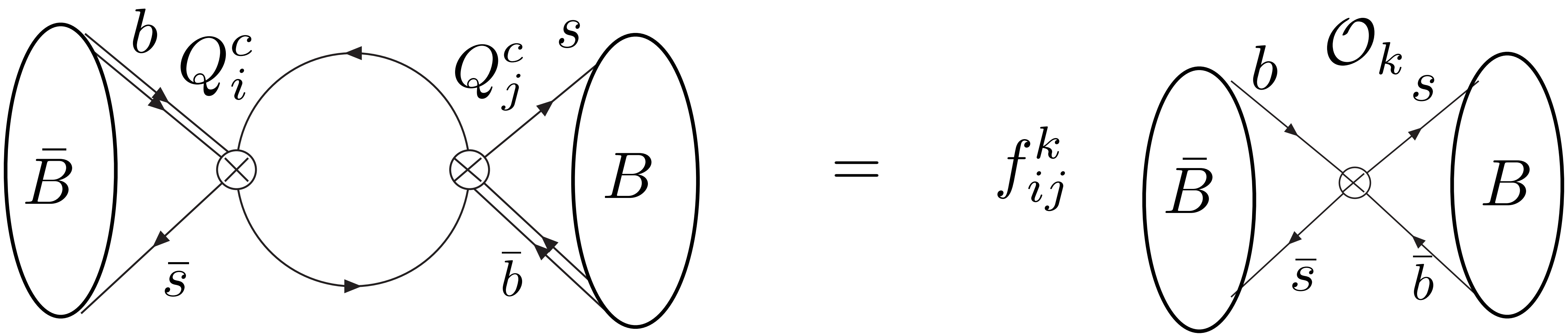


$$\langle \mu^+ \mu^- s | \mathcal{H}_{eff}^{charm} | b \rangle = \underbrace{\Delta C_{eff}^7}_{\Sigma_i C_i \kappa_i^9}(q^2) \langle Q_{7\gamma} \rangle^{tree} + \underbrace{\Delta C_{eff}^9}_{\Sigma_i C_i \kappa_i^7}(q^2) \langle Q_9^l \rangle^{tree} + \mathcal{O}(\alpha \alpha_s)$$

$$\Delta C_9^{eff}(q^2) = [4(3\Delta C_1 + \Delta C_2)\left(h(q^2, m_c) + \frac{2}{27}\right) - 2(3\Delta C_3 + \Delta C_4)\left(h(q^2, m_c) + \frac{5}{27}\right)]$$

- Only shifts in Wilson coefficients C_1, C_2, C_3, C_4 are present - no sensitivity to C_5-C_{10}
- Delta C_9' also obtained

$B-\bar{B}$ Mixing: Calculation



$$\Gamma_{12}^{cc} = \Sigma_{i,j} C_i C_j f_{ij}^k \langle \bar{B} | \mathcal{O}_k | B \rangle$$

OPE reduces original basis to the standard $\Delta F = 2$ basis

$B-\bar{B}$ Mixing observables

$$\frac{\Delta\Gamma_s}{\Delta M_s} = -Re\left(\frac{\Gamma_{12}}{M_{12}}\right)$$

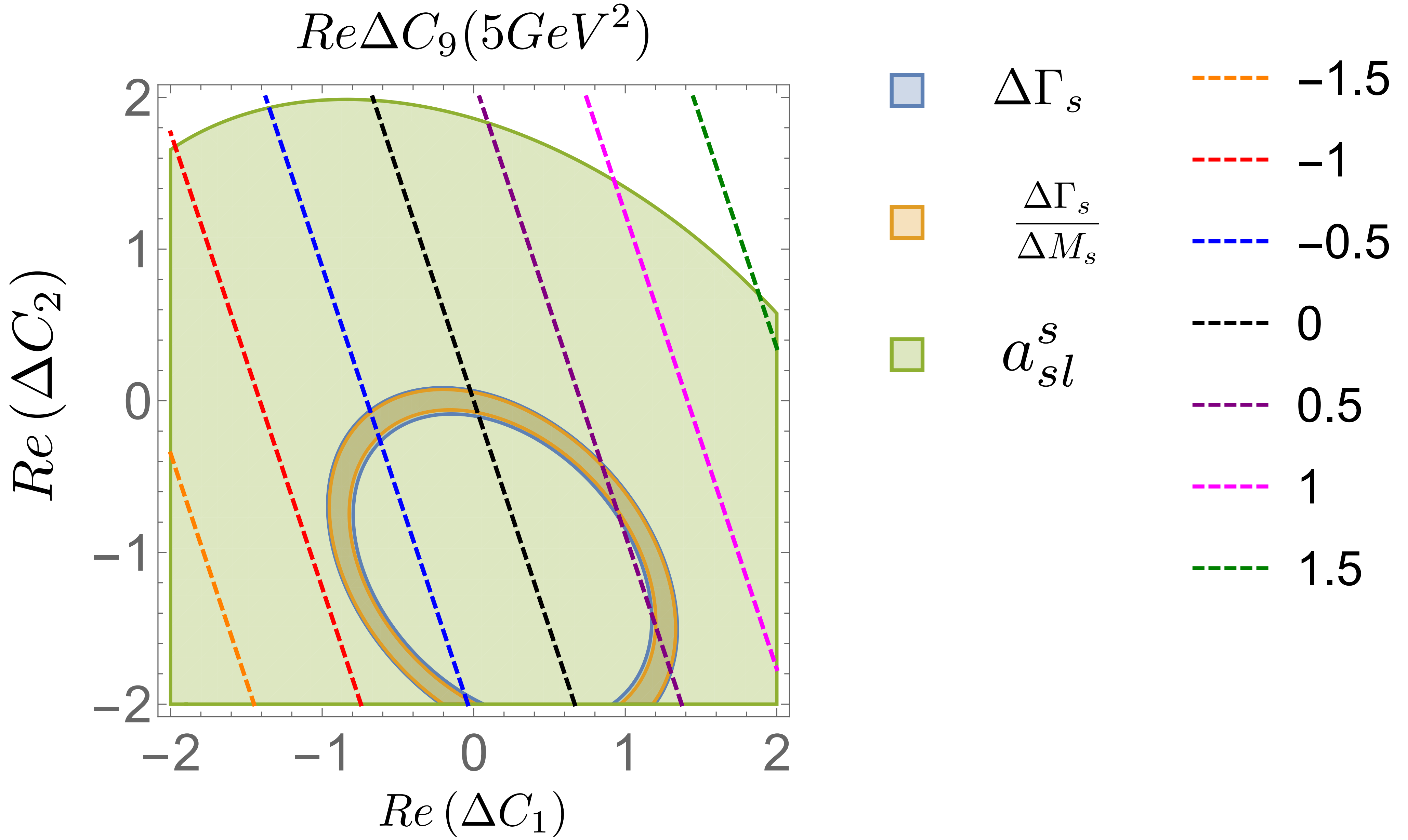
Width difference /Mass difference

$$a_s^l = Im\left(\frac{\Gamma_{12}}{M_{12}}\right)$$

Semileptonic Asymmetry

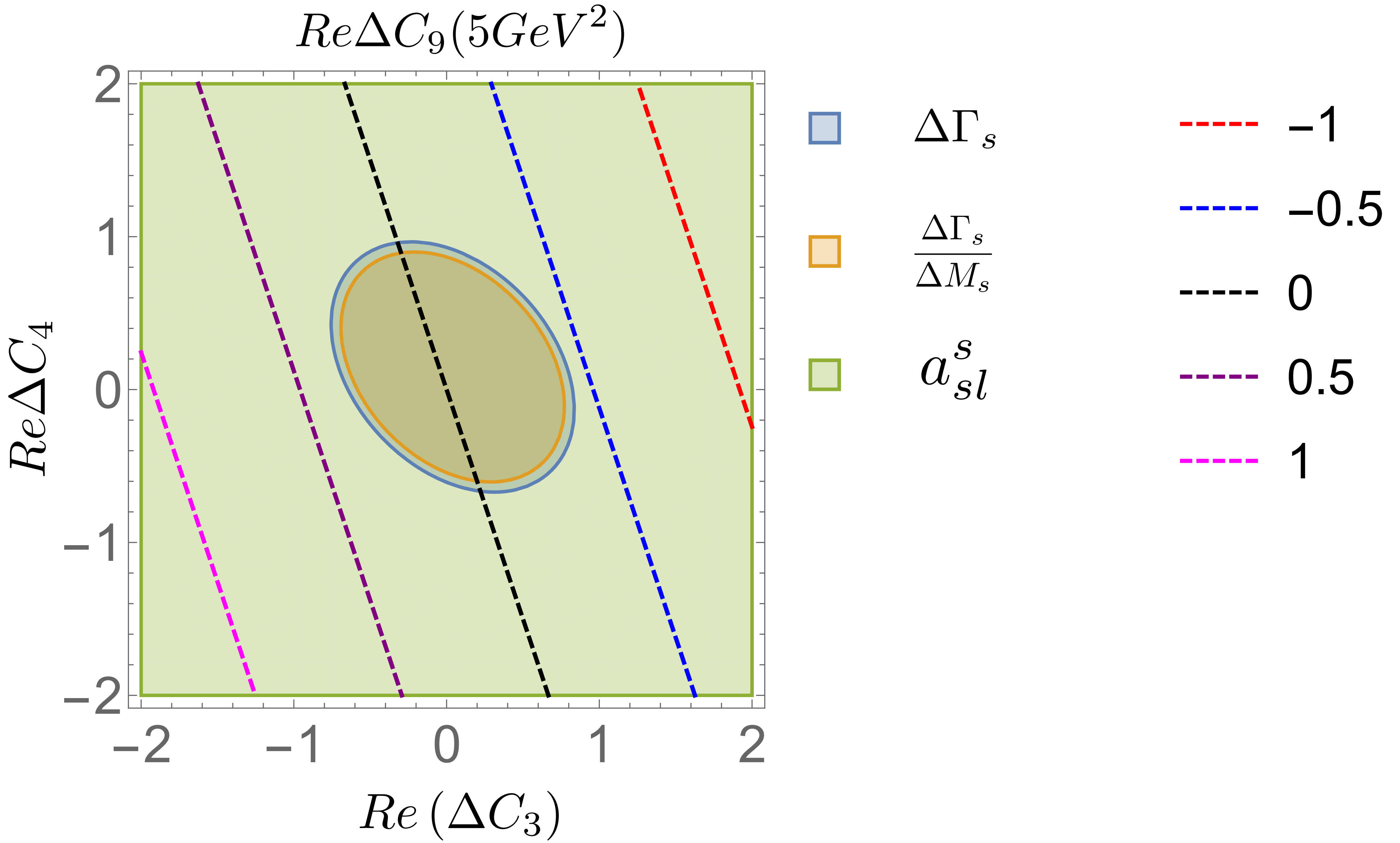
Phenomenology

Results: Bounds on ΔC_9^{eff} from mixing observables



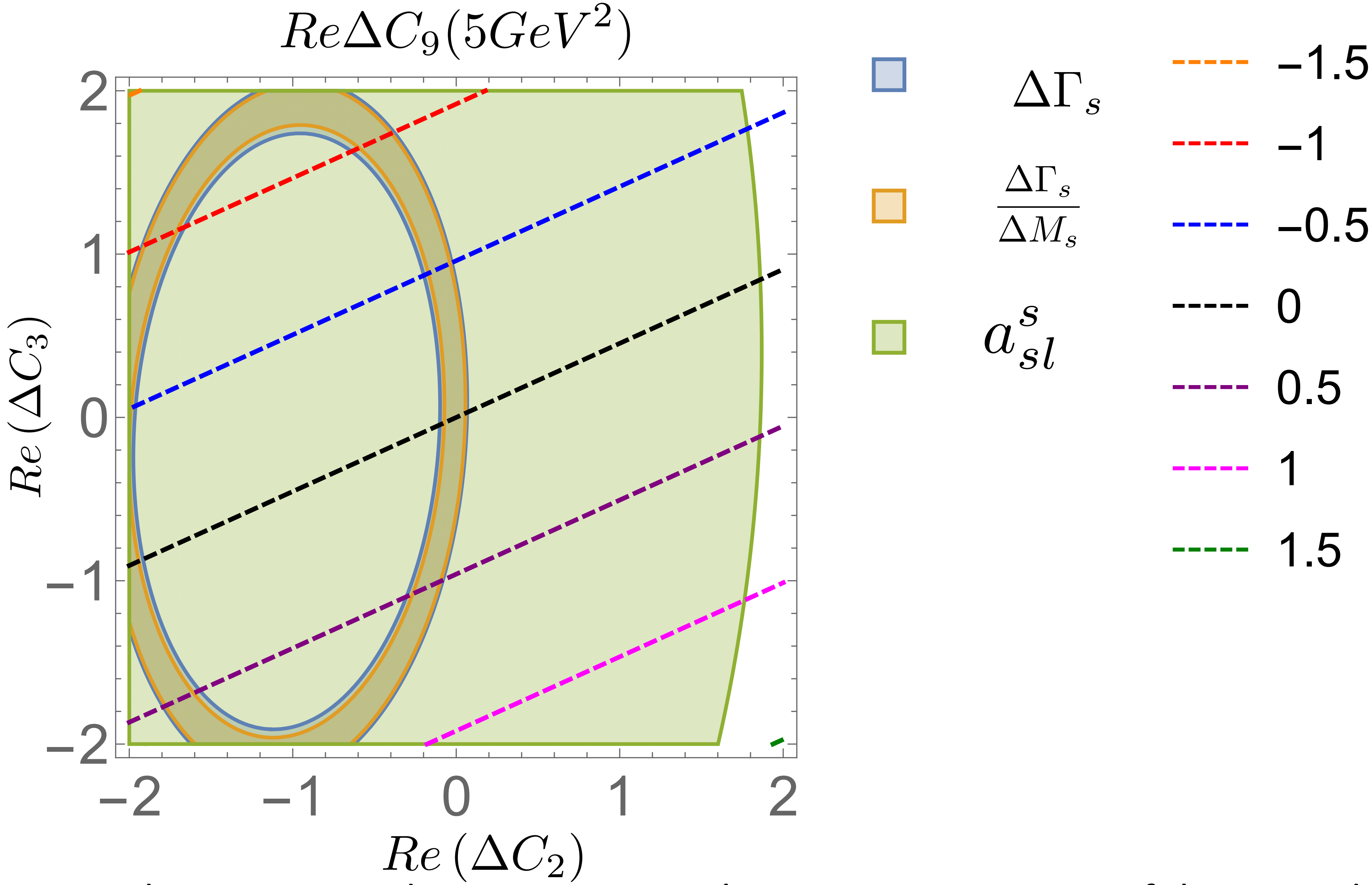
- Negative shift to C_9 can be consistent with the mixing data
- C_1 is more effective in shifting the C_9 contour due to larger weighting in solution

Results: Bounds on ΔC_9^{eff} from mixing observables



- Again, mixing data allows sizeable contribution to ΔC_9^{eff}
- Effects appear less pronounced than in the $\Delta C_1, \Delta C_2$ case

Results: Bounds on ΔC_9^{eff} from mixing observables



- Mixing data accommodates a scenario where C_3 contains most of the NP and C_2 can have a very small shift

- In all of the cases, improved accuracy in measurements of the width difference and semileptonic CP asymmetry may lead to more stringent constraints on charm effects in ΔC_9

Conclusions

- Deviations of experimental data from SM theory predictions could possibly be explained by a negative shift in C_9
- Charmed new physics in $b \to c\bar{c}s$ transitions could offer an explanation, but will affect mixing
- Bounds from mixing observables allow a negative NP contribution to C_9 for several different combinations of Wilson coefficients
- Improved accuracy in the measurement of the width difference and semileptonic CP asymmetry may lead to tighter constraints on a "charming ΔC_9 scenario"

back up slides

$\Delta B = 2$ SUSY Basis

$$\begin{aligned}
\mathcal{O}_1^q &= \bar{b}^\alpha \gamma_\mu L q^\alpha \, \bar{b}^\beta \gamma_\mu L q^\beta, \\
\mathcal{O}_2^q &= \bar{b}^\alpha L q^\alpha \, \bar{b}^\beta L q^\beta, \\
\mathcal{O}_3^q &= \bar{b}^\alpha L q^\beta \, \bar{b}^\beta L q^\alpha, \\
\mathcal{O}_4^q &= \bar{b}^\alpha L q^\alpha \, \bar{b}^\beta R q^\beta, \\
\mathcal{O}_5^q &= \bar{b}^\alpha L q^\beta \, \bar{b}^\beta R q^\alpha, \\
\tilde{\mathcal{O}}_1^q &= \bar{b}^\alpha \gamma_\mu R q^\alpha \; \bar{b}^\beta \gamma_\mu R q^\beta, \\
\tilde{\mathcal{O}}_2^q &= \bar{b}^\alpha R q^\alpha \; \bar{b}^\beta R q^\beta, \\
\tilde{\mathcal{O}}_3^q &= \bar{b}^\alpha R q^\beta \; \bar{b}^\beta R q^\alpha,
\end{aligned}$$

See **Bazakov et al arXiv:1602.03560**