SUSY 17

Minimal unified resolution to B anomalies with lepton mixing

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Outline

- Introduction
- Constraints
- Effective operators
- Results
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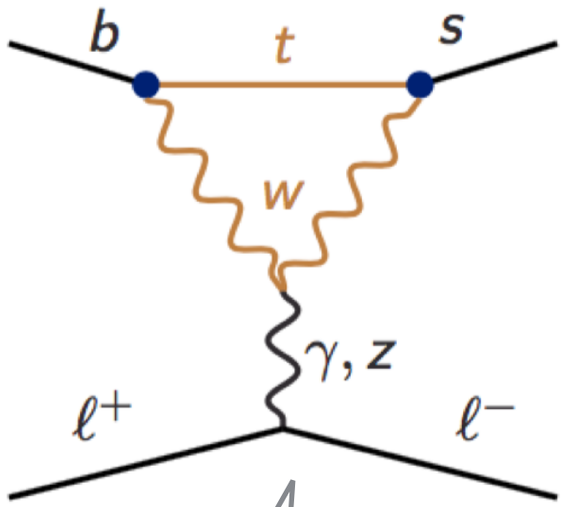
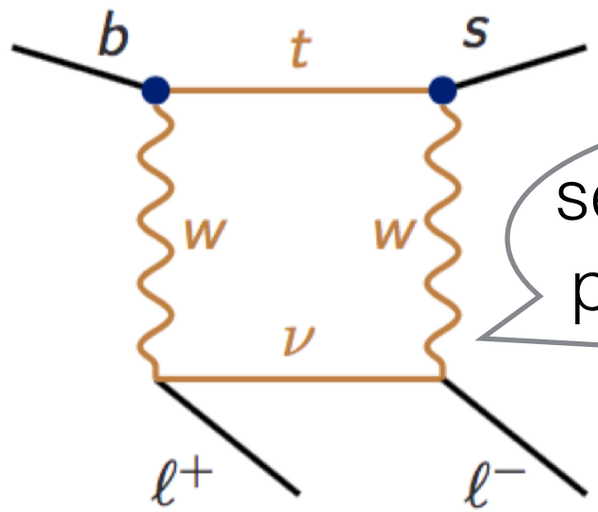
Introduction

loop and CKM suppressed SM amplitude





sensitive to new particle in loop

large no. of experimentally accessible observables

valuable probe for indirect search of NP

Introduction

- Discrepancies in neutral current B decays

$$R_{K^{(*)}} \equiv \frac{\mathrm{BR}(B \to K^{(*)}\mu\mu)}{\mathrm{BR}(B \to K^{(*)}ee)} \quad = 1 \text{ in SM}$$

[LHCb '14,'17]

$$R_K = 0.745^{+0.090}_{-0.074} \pm 0.036 \qquad q^2 \in [1:6]\,\mathrm{GeV}^2 \longrightarrow 2.6\sigma$$

$$R^{\mathrm{low}}_{K^*} = 0.660^{+0.110}_{-0.070} \pm 0.024 \qquad q^2 \in [0.045:1.1]\,\mathrm{GeV}^2 \longrightarrow 2.1\sigma$$

$$R^{\mathrm{cntr}}_{K^*} = 0.685^{+0.113}_{-0.069} \pm 0.047 \qquad q^2 \in [1.1:6]\,\mathrm{GeV}^2 \longrightarrow 2.4\sigma$$

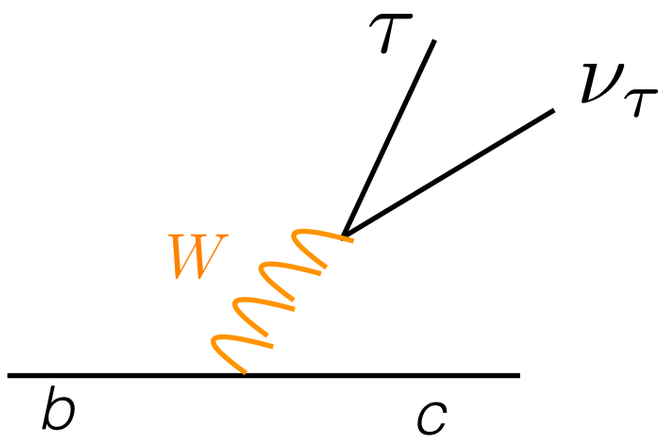
[LHCb '15]

$$\begin{aligned}\Phi &\equiv d\,\mathrm{BR}(B_s \to \phi\mu\mu)/dq^2\big|_{q^2\in[1:6]\,\mathrm{GeV}^2} \\ &= \left(2.58^{+0.33}_{-0.31} \pm 0.08 \pm 0.19\right) \times 10^{-8}\ \mathrm{GeV}^{-2} \quad (\mathrm{exp}) \\ &= (4.81 \pm 0.56) \times 10^{-8}\ \mathrm{GeV}^{-2} \quad (\mathrm{SM})\end{aligned}$$

3σ

Introduction

- Exciting discrepancies observed in charged current B decays also



$$\mathcal{H}^{\rm eff} = \frac{4G_F}{\sqrt{2}} V_{cb} \left(1 + C^{\rm NP}\right) \, (\bar{c}_L \gamma_\mu b_L)(\bar{\tau}_L \gamma^\mu \nu_{\tau L})$$

$$R(D^{(*)}) \equiv \frac{\mathrm{BR}(B \to D^{(*)} \tau \nu)}{\mathrm{BR}(B \to D^{(*)} \ell \nu)}\,, \quad \ell \in \{e, \mu\}$$

$$R(D) = (1.34 \pm 0.17) \times R(D)_{\rm SM}, \quad R(D^*) = (1.23 \pm 0.07) \times R(D^*)_{\rm SM}$$

2.2σ 3.3σ [HFAG]

combined deviation
$\sim 4\sigma$

Constraints

- Constraints from other modes [LHCb '17]

$$\mathrm{BR}(B_s \to \mu\mu) = \begin{array}{l} \left(3.0 \pm 0.6^{+0.3}_{-0.2}\right) \times 10^{-9} \quad (\mathrm{exp.}) \\ (3.65 \pm 0.23) \times 10^{-9} \quad (\mathrm{SM}) \end{array}$$

well in agreement

$$\mathrm{BR}(B \to K^{(*)} \nu\bar{\nu}) < 1.6\,(2.7) \times 10^{-5}$$

$$\mathrm{BR}(B^+ \to K^+ \mu^\pm \tau^\mp) < 4.5\,(2.8) \times 10^{-5}$$

$$\mathrm{BR}(B_s \to \tau\tau) < 6.8 \times 10^{-3}$$

$$\mathrm{BR}(B_c^- \to \tau^- \bar{\nu}) \lesssim 5\% \quad \text{[Grinsten } et.al \text{ '16]}$$

Quite challenging to explain all anomalies together by evading all the bounds.

Effective operators

- NP operators with 2nd & 3rd generation fields

$$\mathcal{H}^{\rm NP} = A_1 \left(\bar{Q}_{2L}\gamma_\mu L_{3L}\right)\left(\bar{L}_{3L}\gamma^\mu Q_{3L}\right) + A_2 \left(\bar{Q}_{2L}\gamma_\mu Q_{3L}\right)\left(\bar{\tau}_R\gamma^\mu \tau_R\right)$$

- Directly contributes to $R(D^{(*)})$

- Diagonalisation of Hamiltonian for lepton part through small mixing angle θ : interaction basis → mass basis

$$\tau = \cos\theta\,\tau' + \sin\theta\,\mu'$$

Contribution to $b \to s\mu\mu$ is generated

Effective operators

- Hamiltonian and relevant operators for $b \to s\mu\mu$

$$\mathcal{H}^{\rm eff} = \frac{-4G_F}{\sqrt{2}}\, V_{tb}\, V_{ts}^* \sum_i C_i(\mu)\mathcal{O}_i(\mu)\,,$$

$$\mathcal{O}_7 = \frac{e}{16\pi^2} m_b\, (\bar{s}\sigma_{\mu\nu} P_R b)\, F^{\mu\nu}$$

$$\mathcal{O}_9 = \frac{e^2}{16\pi^2}\, (\bar{s}\gamma_\mu P_L b)\, (\bar{\mu}\gamma^\mu \mu)$$

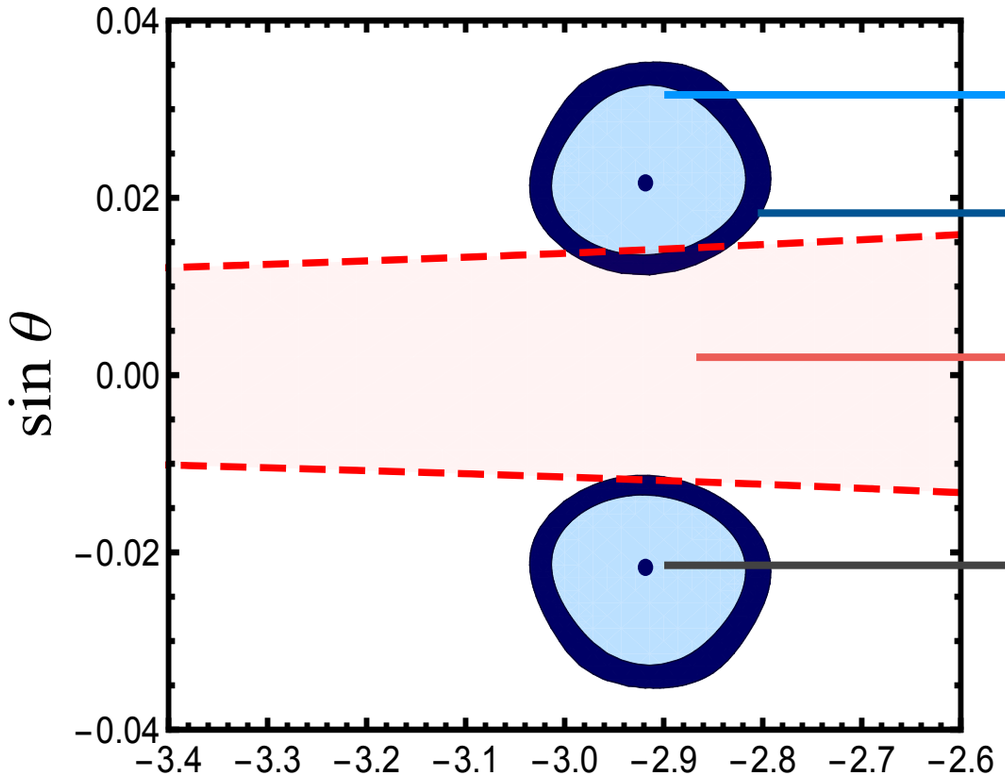
$$\mathcal{O}_{10} = \frac{e^2}{16\pi^2}\, (\bar{s}\gamma_\mu P_L b)\, (\bar{\mu}\gamma^\mu \gamma_5 \mu)$$

New contribution to (axial)vector currents

$$C_9 \to C_9 + C_9^{\rm NP}$$

$$C_{10} \to C_{10} + C_{10}^{\rm NP}$$

Results



95% C.L.

99% C.L.

Allowed by $B^+ \to K^+\mu^-\tau^+$

$$A_1(=A_2) = -2.92\,\mathrm{TeV}^{-2}$$

$$\sin\theta = \pm 0.022$$

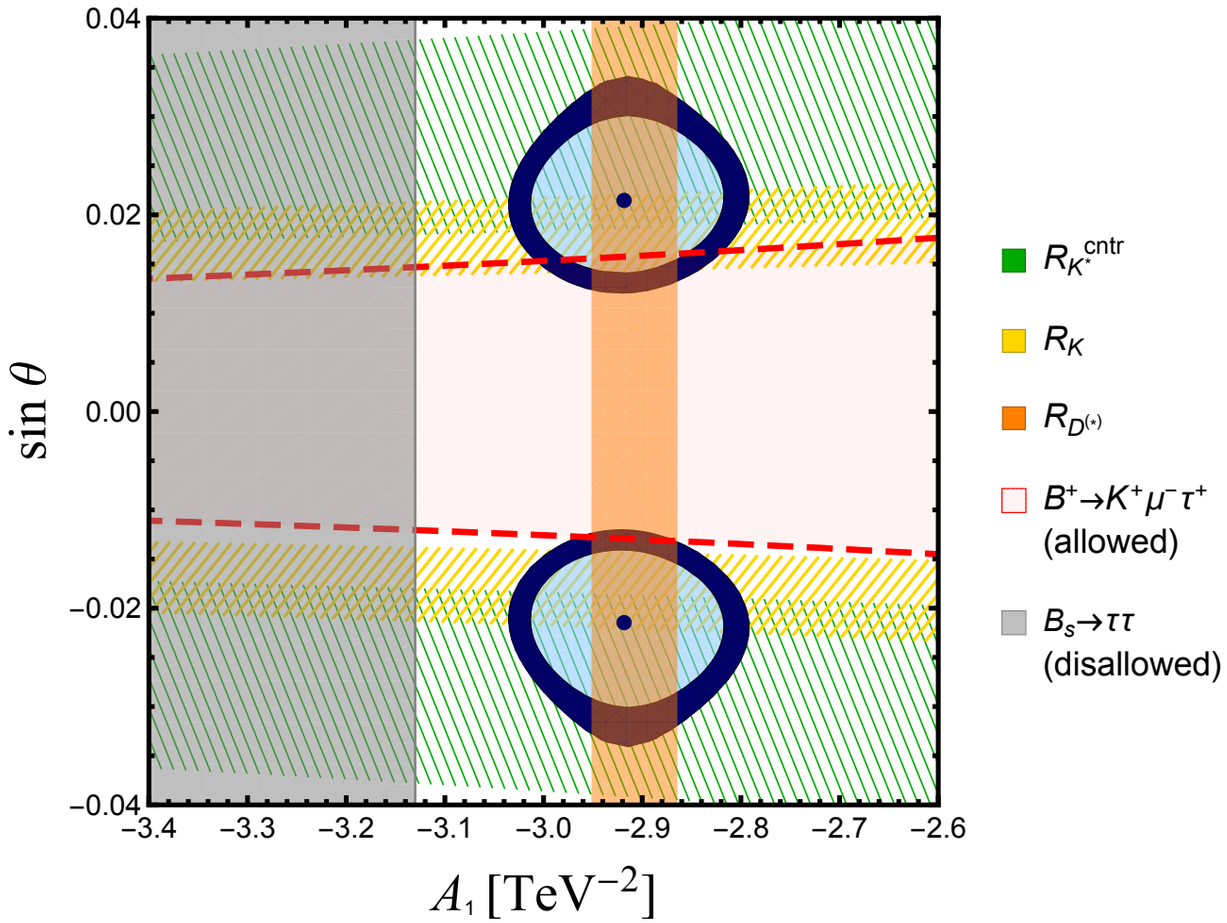
$$\chi^2_{\mathrm{SM}} \simeq 46 \quad \Rightarrow \quad \chi^2_{\text{allowed region}} \simeq 15$$

agreement within 2σ level

$$R_K \simeq 0.86,\ R_{K^*}{}^{\mathrm{cntr}} \simeq 0.88,\ R^{\mathrm{low}}_{K^*} \simeq 0.90,$$

$$R(D^{(*)}) \simeq 1.25 \times R(D^{(*)})_{\mathrm{SM}}, \Phi \simeq 4.1 \times 10^{-8}\mathrm{GeV}^{-2}.$$

Results



Allowing 20% breaking

$$A_2 = 4A_1/5$$

from quantum corrections or unknown dynamics of the UV completion of the model

$$\chi^2_{\rm SM} \simeq 46 \quad \Rightarrow \quad \chi^2_{\text{allowed region}} \simeq 10$$

agreement within 1σ level

$$R_K \simeq 0.80,\ R_{K^*}{}^{\rm cntr} \simeq 0.83,\ R^{\rm low}_{K^*} \simeq 0.88,$$
$$R(D^{(*)}) \simeq 1.24 \times R(D^{(*)})_{\rm SM}, \Phi \simeq 3.8 \times 10^{-8}{\rm GeV}^{-2}$$

Summary & Outlook

- Another discrepancy at $b \to c$ charged current [LHCb '17]

$$R_{J/\psi} \equiv \frac{\mathrm{BR}(B_c \to J/\psi\, \tau\nu)}{\mathrm{BR}(B_c \to J/\psi\, \mu\nu)}$$

$$= (2.5 \pm 0.97\,) \times R^{\mathrm{SM}}_{J/\psi} \longrightarrow < 2\sigma$$

In the same direction as of $R(D^{(*)})$

→ considered operators can also explain

- $SU(2)_L$ triplet type operators are also explored [1712:01593]

Summary & Outlook

- ☑ Several hints of lepton non universality are observed by various experimental groups

- ☑ In terms of effective operators we show a possible explanation to all the anomalies together

  - The model has only two new parameters
  - It predicts some interesting signatures in the context of B decays such as $B_s \to \tau\tau,\ B \to K^{(*)}\mu\tau$

- ☑ Opens up way to construct UV complete theory

- ☑ Fluctuation? Wait for more data to be accumulated!

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