A gauged horizontal SU(2) symmetry and R_K

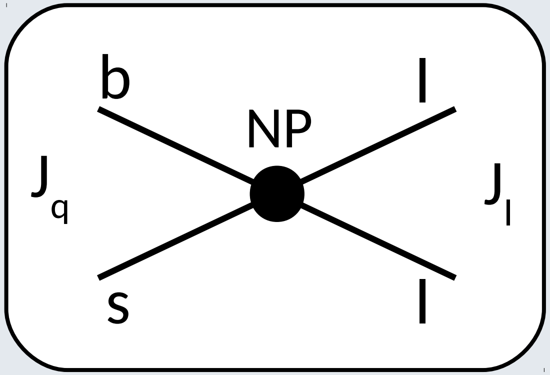
GDR-InF annual workshop – 11/05/2018

Méril Reboud

Diego Guadagnoli & Olcyr Sumensari

Introduction

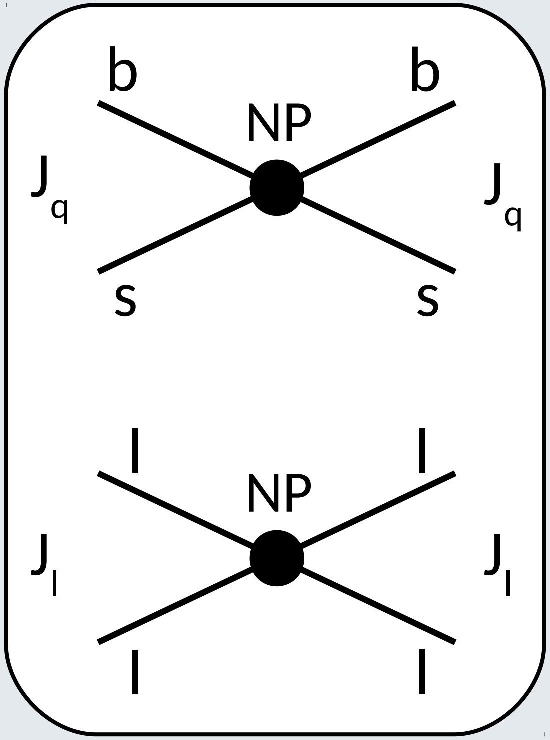
B anomalies can be explained by a **shift in C_9 and C_{10}**
→ **15-20% correction** to $J_q \times J_l$



But:

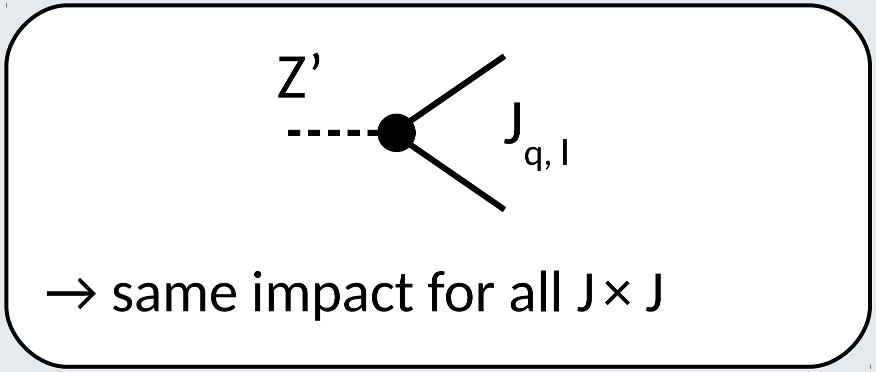
- $\Delta M_s \sim (\Delta M_s)_{SM}$
  → **small correction** to $J_q \times J_q$

- Lepton decays < experimental limit
  → **small correction** to $J_l \times J_l$

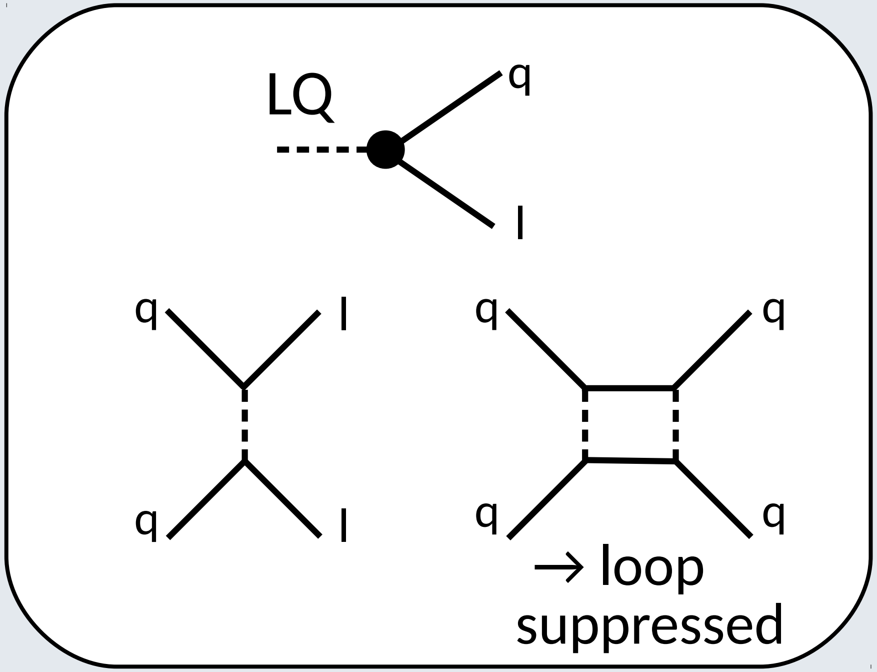


Introduction – LQ

This can be **challenging for Z' models…**

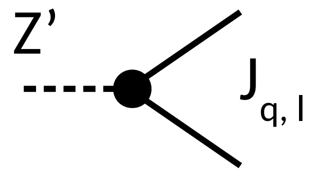


…but it makes **leptoquark** solutions very **appealing**



Introduction – Question

This can be **challenging for Z' models…**



→ same impact for all J × J

… Can we get the same suppression **within gauge extension?**

A gauged horizontal SU(2)

1) Add a **horizontal group** G_H, e.g. SU(2), acting on the **2^{nd} and 3^{rd} generations**

$$G_{SM} = SU(3)_c \times SU(2)_L \times U(1)_Y \times SU(2)_H$$

$$\delta L = \sum_{F,a} \bar{F} \gamma_\mu \left(g_L P_L G_L^{\mu a} + g_R P_R G_R^{\mu a} \right) \tau^a F$$

with $F = \begin{pmatrix} f_2 \\ f_3 \end{pmatrix}$ i.e. $\begin{pmatrix} s_L \\ b_L \end{pmatrix}, \begin{pmatrix} \mu_L \\ \tau_L \end{pmatrix}, \begin{pmatrix} s_R \\ b_R \end{pmatrix} \dots$

2) Integrate out heavy degrees of freedom

$$\delta L_{eff} = \sum_{F_1, F_2, a} \frac{g_L^2}{2 M_{G_{La}}^2} \left(\overline{F_1} \gamma_\mu P_L \tau_a F_1 \right) \left(\overline{F_2} \gamma^\mu P_L \tau_a F_2 \right)$$

Basic argument

3) Rotate the field to the mass basis $F = U_F \hat{F}$

$$\delta L_{eff} = \sum_{F_1, F_2, a} \frac{g_L^2}{2 M_{G_{L a}}^2} \left(\overline{\hat{F}}_1 U_{F_1}^{+} \gamma_{\mu L} \tau_a U_{F_1} \hat{F}_1 \right) \left(\overline{\hat{F}}_2 U_{F_2}^{+} \gamma_L^{\mu} \tau_a U_{F_2} \hat{F}_2 \right)$$

For $\mathbf{F_1 = F_2}$, if masses are degenerate, $\mathbf{U_F}$ **can be absorbed in a G basis redefinition**

→ **Only flavor diagonal terms!**

Minimal setup

But:

Rotation also involve the **first generation**

→ Small **corrections** to K-$\overline{\text{K}}$ mixing, μ → 3e… wich are **very constrained**

Generalize to 3 generations: $F = \begin{pmatrix} u_L \\ s_L \\ b_L \end{pmatrix} \ldots \qquad F = U_F \hat{F}$

Apply all constraints:

- CKM $= U_{uL}^{+} U_{dL}$
- meson mixings
- lepton decays
- R_K

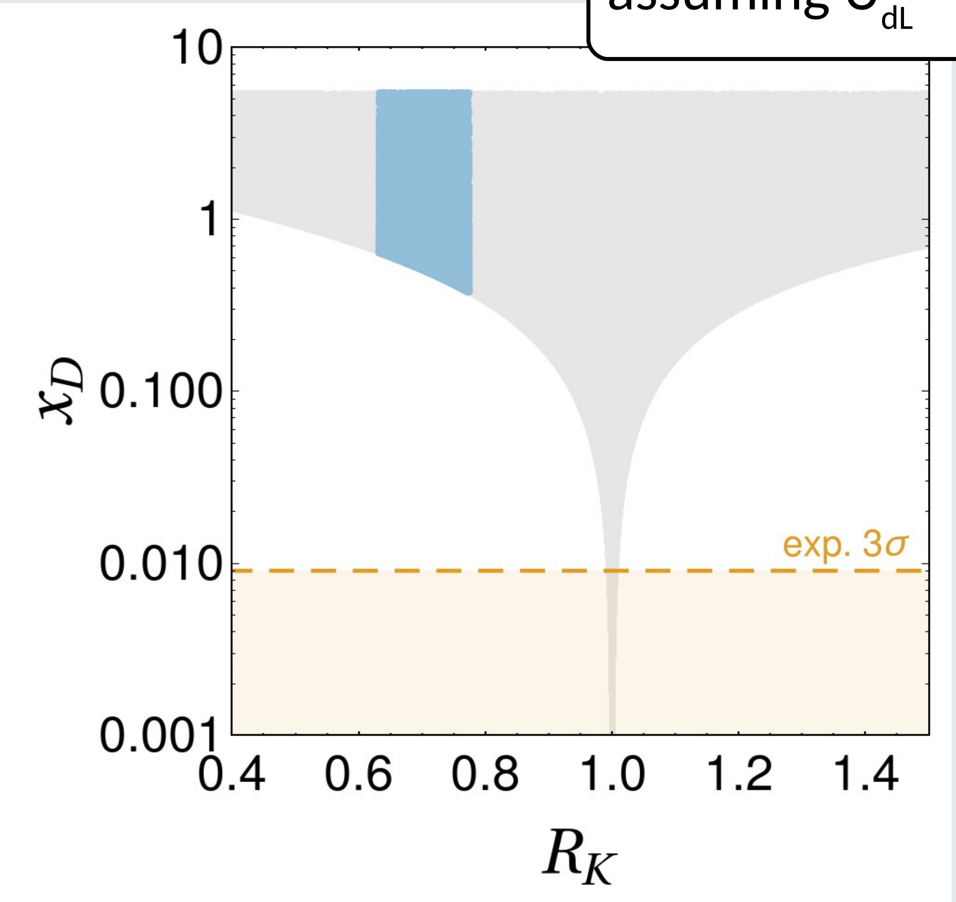
Minimal setup

But:

Rotation also involve the **first generation**

→ Small **corrections** to K-$\overline{K}$ mixing, μ → 3e… wich are **very constrained**

assuming $U_{dL} = 1$



Generalize to 3 generations:

Apply all constraints:

- CKM $= U_{uL}^{+} U_{dL}$
- meson mixings
- lepton decays
- R_K

Non-degenerate masses

A direct generalization is obtained with **non-degenerate masses**:

$$M_{G_{L1}} = M_{G_{L2}} \ll M_{G_{L3}}$$

[–] This breaks the original SU(2) symmetry

[+] It passes all the experimental constraints:

- $b \to sll$ measurements
- Meson mixings
- Small shift to $B \to K\nu\nu$ (due to underlying SU(2) symmetry)
- Small shifts to $\tau \to l\nu\nu$ and $D^0 \to \mu\mu$

Non-degenerate masses

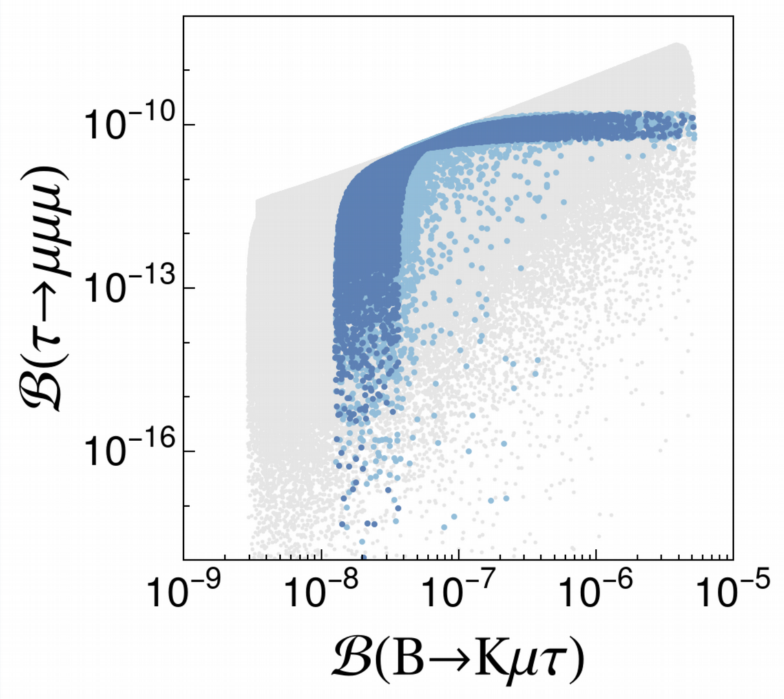
A direct generalization is obtained with **non-degenerate masses**:

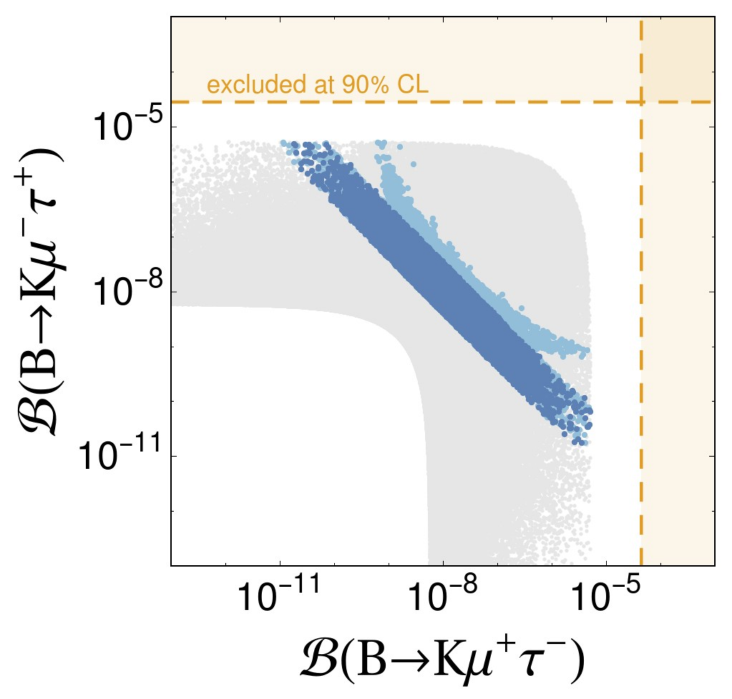
$$M_{G_{L1}} = M_{G_{L2}} \ll M_{G_{L3}}$$

[–] This breaks the original SU(2) symmetry

[+] It passes all the experimental constraints

[+] $\delta C_{9,10}^{\tau\tau} = -\delta C_{9,10}^{\mu\mu}$ and LFV predictions





Outlook

Adding a **SU(2) horizontal symmetry** allows

- sizeable correction to $\mathbf{J_q \times J_l}$
- while keeping $\mathbf{J_q \times J_q}$ and $\mathbf{J_l \times J_l}$ small enough

The choice of SU(2) is motivated by the **absence of anomalies**, but one can consider a larger group

- Require **extra matter**
- May solve **other problems**

Thank you!

Back-up

Fermion masses

Accommodating quark masses and the SU(2) symmetry can be done by adding heavy fermions that mixes with the SM ones.

$$\psi_U^{L,R} = (3, 1, 2/3; 2) \qquad F_Q = \begin{pmatrix} Q_L^2 \\ Q_L^3 \end{pmatrix}$$

$$\psi_D^{L,R} = (3, 1, -1/3; 2)$$

$$\Phi_{1,2} = (1, 1, 0; 2)$$

$$L_{mass} = m_U \overline{\psi_U^L} \psi_U^R + m_D \overline{\psi_D^L} \psi_D^R$$

$$L_{mix} = \sum_{a=1,2} \left[(y_a^U)_i \overline{\psi_U^L} \Phi_a (u_R)_i + (u \Leftrightarrow d) \right] + c_U \overline{F_Q} \widetilde{H} \psi_U^R + c_D \overline{F_Q} H \psi_D^R + \text{h.c.}$$