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# B-meson Anomalies and New Physics for Flavor Violation

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The LHCb experiment has recently provided several new measurements to test the lepton flavor universality in the Standard Model (SM) and confirmed some of the prevailing anomalies from the B-meson decays in BaBar and/or Belle experiments. We consider the setup where scalar leptoquarks have flavor-dependent couplings to the SM. In this work, we discuss the flavor structure for quarks and leptons and various constraints on the model and propose a natural candidate for dark matter.

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In the Standard Model, lepton flavor universality for weak interactions is confirmed by $\tau$ decay and $Z^0$ decay, etc. But, recent measurements on the semi-leptonic decays of $B$-mesons at BaBar, Belle and LHCb experiments raise intriguing anomalies, $R_{K^{(*)}}$ and $R_{D^{(*)}}$. The reported values of $R_{K^{(*)}} = \mathscr{B}(B \to K^* \mu^+ \mu^-)/\mathscr{B}(B \to K^* e^+ e^-)$ are deviated from the SM prediction by $2.1 - 2.5\sigma$. The results for $R_{D^{(*)}} = \mathscr{B}(B \to D^* \tau^- \nu_\tau)/\mathscr{B}(B \to D^* l^- \nu_l)$ with $l = e,\ \mu$ also show derivations from the SM prediction by $4\sigma$ [2].

We consider the Lagrangian for an $SU(2)_L$ singlet scalar leptoquark $S_1$ with $Y = +\frac{1}{3}$, and an $SU(2)_L$ triplet scalar leptoquark $S_3 \equiv \Phi_{ab} = \begin{pmatrix} \sqrt{2}\phi_3 & -\phi_2 \\ -\phi_2 & -\sqrt{2}\phi_1 \end{pmatrix}$ with $Y = +\frac{1}{3}$,

$$\mathscr{L}_{LQ} = -\lambda_{ij}\overline{(Q^C)^a_{Ri}}\left(i\sigma^2\right)_{ab} S_1 L^b_{Lj} - \kappa_{ij}\overline{(Q^C)^a_{Ri}}\Phi_{ab}L^b_{Lj} + \text{h.c.} \tag{1}$$

By integrating out the leptoquarks $S_1$ and $S_3$, we obtain the effective Hamiltonian relevant for $b \to c\tau\overline{\nu}_\tau$ and $b \to s\mu^+\mu^-$ as

$$\mathscr{H}^{S_1,S_3}_{b\to c\tau\overline{\nu}_\tau,\, b\to s\mu^+\mu^-} = -\frac{\lambda^*_{33}\lambda_{23}}{2m^2_{S_1}}\left(\overline{b}_L\gamma^\mu c_L\right)\left(\overline{\nu}_{\tau L}\gamma_\mu\tau_L\right) - \frac{\kappa^*_{32}\kappa_{22}}{m^2_{\phi_1}}\left(\overline{b}_L\gamma^\mu s_L\right)\left(\overline{\mu}_L\gamma_\mu\mu_L\right) + \text{h.c.} \tag{2}$$

which explains the B-anomalies in the parameter space shown in figure. 1 (first and second plots).

We introduce a singlet real scalar dark matter $S$ with leptoquark $S_{LQ}$ and Higgs couplings,

$$\begin{aligned}\mathscr{L}_S &= |D_\mu S_{LQ}|^2 - m^2_{LQ}|S_{LQ}|^2 + \frac{1}{2}(\partial_\mu S)^2 - \frac{1}{2}m^2_S S^2 \\ &\quad -\frac{1}{4}\lambda_1 S^4 - \lambda_2|S_{LQ}|^4 - \frac{1}{2}\lambda_3 S^2|S_{LQ}|^2 - \frac{1}{2}\lambda_4 S^2|H|^2 - \lambda_5|H|^2|S_{LQ}|^2. \end{aligned} \tag{3}$$

In this model, we determine the dark matter relic density by the direct and cascade annihilations with leptoquarks. We show various constraints in the parameter space, $\lambda_4$ vs $m_S$, in figure 1 (third and fourth plots) [3]: direct detection bound (XENON1T) and indirect detection bound (Fermi-LAT, HESS and AMS-02). Additionally, Higgs data can constrain by using diphoton signal strength and Higgs invisible decay.

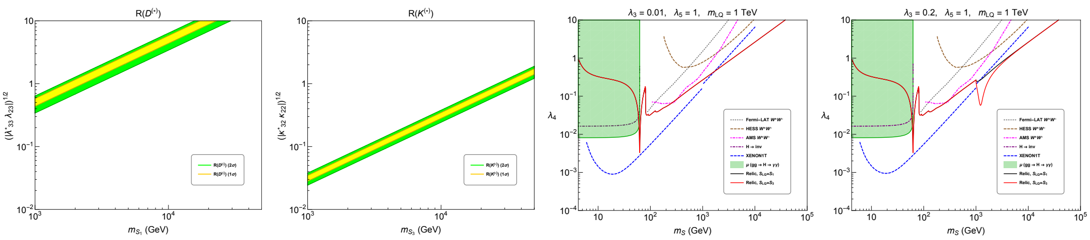

**Figure 1:** $R_{D^{(*)}}$ and $R_{K^{(*)}}$ anomalies (first and second), Parameter space, $\lambda_4$ vs $m_S$ (third and fourth)

## References


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