# Abstract

There are several measurements in the decays of $B$ mesons which show discrepancy with the predictions of the Standard Model (SM) of electro-weak interactions. Many such measurements are in the decays induced by the quark level transition $b \to s\, l^+\, l^-$ ($l = e,\, \mu$). In order to discriminate between various new physics solutions and pin down the type of new physics responsible for anomalies in $b \to s\, l^+\, l^-$ transition, one should look for alternative observables. The purely leptonic decay of $B_s^*$ meson is considered to be a golden channel to probe beyond SM Physics in $b \to s\, l^+\, l^-$ sector as it is theoretically very clean. Assuming new physics only in $b \to s\, \mu^+\, \mu^-$, we perform a model independent analysis of new physics in $B_s^* \to \mu^+\mu^-$ decay to identify operator(s) which can provide large enhancement in the branching ratio of $B_s^* \to \mu^+\mu^-$ above its SM value. We find that a significant enhancement in $Br(B_s^* \to \mu^+\mu^-)$ is not allowed by any of the allowed solutions. In fact, the present $b \to s\mu^+\mu^-$ data indicates that the future measurements of $Br(B_s^* \to \mu^+\mu^-)$ is expected to be suppressed in comparison to the SM. We then consider a new observable, the longitudinal polarization asymmetry of muons in $B_s^* \to \mu^+\mu^-$ decay. We find that this observable is a good discriminant between the new physics solutions if it can be measured to a precision of $10\%$. We also investigate the potential impact of $b \to c\tau\bar{\nu}$ anomalies on $B_s^* \to \tau^+\tau^-$ decay in a model where the new physics contributions to these two transitions are strongly correlated. We find that the branching ratio of $B_s^* \to \tau^+\tau^-$ can be enhanced by three orders of magnitude.

We then consider new physics only in $b \to s\, e^+\, e^-$ decay. Including all measurements in $b \to se^+e^-$ sector along with lepton-universality violating ratios $R_{K^{(*)}}$, we perform a model independent analysis of new physics by considering effective operators in the form of vector/axial-vector (V/A), scalar/pseudoscalar (S/P) and tensors (T). We find that S/P operators cannot account for the anomalous measurements of $R_{K^{(*)}}$ due to tight constraints coming from the upper bound on the branching ratio of $B_s \to e^+e^-$. On the other hand, various V/A scenarios can alleviate the tension between $R_{K^{(*)}}$ data and the SM predictions. This includes generating values for $R_{K^*}$ within $1\sigma$ of its measured values in the low-$q^2$ bin ($0.045\,\mathrm{GeV}^2 \le q^2 \le 1.1\,\mathrm{GeV}^2$). Further, we identify angular observables in $B \to K^*e^+e^-$ which can discriminate between the allowed V/A solutions. Moreover, it was previously shown that various combinations of V/A and T new physics operators can also explain $R_{K^{(*)}}$ measurements. We find that $K^*$ longitudinal polarization fraction, $F_L$, in $B \to K^*e^+e^-$ decay can discriminate against pure V/A and (V/A+T) scenarios. A measurement of $F_L$ in $(1-6)$ GeV$^2$ bin with an absolute uncertainty of 0.05 can either confirm or rule out any combination of V/A and T new physics scenarios by more than $2\sigma$.

Finally, we study the impact of $B$ anomalies on rare top quark decay $t \to c\,Z$. Top quarks are particularly important for hunting new physics as it is the heaviest of all the SM particles. In particular, the flavour changing neutral current top quark decay $t \to c\,Z$ has immense potential to probe new physics as it is highly suppressed in the SM. The SM prediction for its branching ratios is $\sim 10^{-14}$ and is probably immeasurable at the LHC until new physics enhances its branching ratio up to the current detection level which is $10^{-4}$-$10^{-5}$. Using relevant constraints from the $B$ and $K$ sectors, we show that the anomalous $tcZ$ couplings can enhance the branching ratio of $t \to c\,Z$ at the level of $10^{-4}$ provided the couplings are complex.