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Conclusions

The Standard Model (SM), which explains the fundamental interactions of nature excluding gravity, is the most successful theory of particle physics. The discovery of the Higgs Boson at the LHC marked the completion of the SM. However, despite its success, many important questions remain unanswered in SM. Such as, what is the origin of observed difference between matter and antimatter? What is the origin of dark matter and dark energy? Why are there exactly three generations of quarks and leptons? These unanswered questions suggest that SM cannot be the ultimate theory of fundamental interactions of nature and hence one needs to go beyond the SM.

Flavor physics is an elegant way to probe physics beyond SM by performing a detailed study of properties of particles such as K, D and B mesons as well as top quarks. The experiments in flavor physics are now approaching precession era and hence have the potential to probe new physics at a scale much above the direct search experiments. In fact, the currently running LHC experiments have already provided several tantalizing hints of beyond SM physics. Most of these observables are related to the decays induced by the quark level transition $b \to s\, l^+\, l^-$ ($l = e,\, \mu$) [40–49]. These include deviations from LFU [42, 47, 49] which are indication of new physics in $b \to s\, e^+\, e^-$ and/or $b \to s\, \mu^+\, \mu^-$. Further, there are anomalies independent of LFU violation. These are in decays $B^0 \to K^{0*}\, \mu^+\, \mu^-$ and $B_s \to \phi\, \mu^+\, \mu^-$ [40, 41, 43–46, 48] which can be attributed to possible new physics in $b \to s\, \mu^+\, \mu^-$ transition. In order to identify the Lorentz structure of this possible new physics, several groups across the globe performed model independent analyses of $b \to s\, l^+\, l^-$ data within the framework of effective field theories [62–86]. These analyses suggest various new physics solutions, mainly in the form of vector (V) and axial-vector (A) operators.

In order to discriminate between various new physics solutions and pin down the type of new physics responsible for anomalous measurements in $b \to s\, l^+\, l^-$ sector, one should look for alternative observables. The purely leptonic decay of B_s^* meson is considered to be one such channel. The fact that this decay mode is theoretically very clean, it is considered to be a golden channel to probe new physics. Assuming new physics only in the muon sector, we perform a model independent analysis of new physics in $B_s^* \to \mu^+\mu^-$ decay to identify operator(s) which can provide a large enhancement in $Br(B_s^* \to \mu^+\mu^-)$ above its SM value. We find that

- the scalar (S) and pseudo-scalar (P) operators do not contribute to the branching ratio of $B_s^* \to \mu^+\mu^-$.
- a significant enhancement in the branching ratio of $B_s^* \to \mu^+\mu^-$ is not allowed by any of the allowed new physics solutions.
- 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 prediction.

As $Br(B_s^* \to \mu^+\mu^-)$ can not distinguish between new physics solutions that can explain all the anomalies in $b \to s\mu^+\mu^-$ sector, we consider a new observable, the longitudinal polarization asymmetry of muons in $B_s^* \to \mu^+\mu^-$ decay. We show that the longitudinal polarization asymmetry of the muons in $B_s^* \to \mu^+\mu^-$ decay is a good discriminant between the two solutions if it can be measured to a precision of 10%, provided the new physics Wilson coefficients are real. If they are complex, the theoretical uncertainties in this asymmetry are too large to provide effective discrimination. Moreover, 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 current data in $b \to c\tau\bar{\nu}$ allows three orders of magnitude enhancement in the branching ratio of $B_s^* \to \tau^+\tau^-$.

We then consider new physics only in $b \to s\,e^+\,e^-$ decay. By including all measurements in $b \to se^+e^-$ sector along with LFU violating ratios $R_{K^{(*)}}$, we perform a first complete model independent analysis of new physics in $b \to se^+e^-$ within the framework of EFT. We show 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 $B_s \to e^+e^-$.
- various V/A scenarios can alleviate the tension between $R_{K^{(*)}}$ data and the SM predictions. This includes generating values for R_{K^*} within 1σ of its measured values in the low-q^2 bin ($0.045\,\text{GeV}^2 \leq q^2 \leq 1.1\,\text{GeV}^2$).
- tensor (T) operators, by itself, cannot account for the anomalous measurements of $R_{K^{(*)}}$.
- various combinations of V/A and T new physics operators can 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 2σ.
- the azimuthal angular observable P_1 in $B \to K^*e^+e^-$decay is most suited to discriminate between the different allowed V/A solutions.

Finally, we study the imprints of B anomalies on rare top quark decay $t \to c\,Z$. The top quark is particularly important for hunting physics beyond the SM. As it is the heaviest of all the SM particles, it is expected to feel the effect of new physics most. 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} with an integrated luminosity of 10 fb^{-1}. 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. We also study the impact of such complex couplings on several CP-violating observables in $B \to K^*\mu^+\mu^-$ decay and the branching ratio of $K_L \to \pi^0\nu\bar{\nu}$.