# HIDDeN Paper of the Month: Test of lepton universality in beauty-quark decays

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The last 23rd of March, the LHCb collaboration presented an updated measurement of the ratio $R_K$, which is defined as the number of times a $B^+$ meson decays to a charged kaon and a muon-antimuon pair ($K^+\mu^+\mu^-$) divided by the number of times a $B^+$ meson decays to a charged kaon and a positron-electron pair ($K^+e^+e^-$). These decays involve the transition of a beauty antiquark into a strange antiquark ($\bar{b} \to \bar{s}$), a process that is highly suppressed within the Standard Model (SM), taking place only at the loop level (see Fig. 1). Furthermore, according to the SM, both the decay channel to muons and the decay channel to electrons must be equivalent, preserving a fundamental principle of the SM known as "lepton universality" (the mediator bosons of the SM couple to the three generations of charged leptons with the same strength). Therefore, $R_K$ is predicted to be 1, up to corrections of order 1% due to the different charged lepton masses.

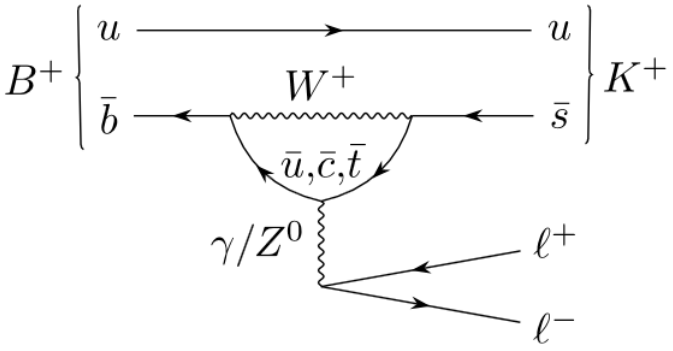



Figure 1: SM contribution to $R_K$. Figure taken from [1].

However, the updated measurement obtained by the LHCb collaboration is $R_K = 0.846^{+0.044}_{-0.041}$ [1], which deviates from the SM prediction with a statistical significance of 3.1 standard deviations ($\sigma$). This result indicates evidence of the breaking of lepton universality in beauty-quark decays, and is one of the stronger hints for new physics beyond the SM coming from LHC measurements. This updated measurement of $R_K$, shown as a black point with error bars in Fig. 2, is consistent with previous results and supersedes them, being the most precise measurement to date. However, in order to claim a discovery, the statistical significance must reach the $5\sigma$ level. Therefore, we must be cautious as there is still the possibility that this anomaly is due to fluctuations of the data.

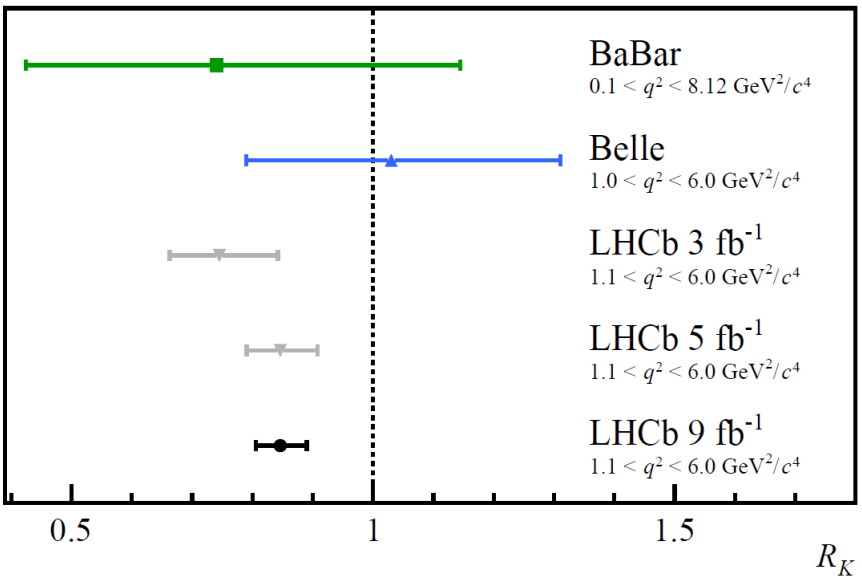
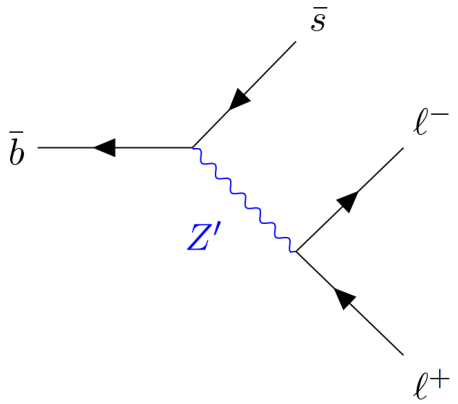
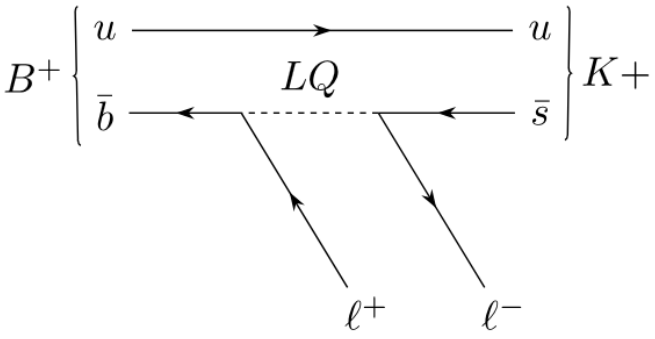



Figure 2: Comparison between $R_K$ measurements. Figure taken from [2].

There has been a strong theoretical effort in the last years aiming to explain the $R_K$ anomaly, and this effort will increase due to the new measurement. Up to now, some of the most promising candidates to explain the $R_K$ anomaly are tree-level exchange of a hypothetical, electrically neutral and flavourful $Z'$ boson (Fig. 3a), along with the contribution of a hypothetical leptoquark ($LQ$) coupling with different strengths to the different types of charged leptons (Fig. 3b).




(a) $Z'$ exchange diagram contributing to $R_K$.




(b) Leptoquark diagram contributing to $R_K$. Figure taken from [1].

Figure 3

Finally, the LHCb collaboration has also reported an improved measurement of the very rare $B_s \to \mu^+\mu^-$ decay. The measured branching fraction $\left(3.09^{+0.61}_{-0.54}\right)\times 10^{-9}$ [2] is in excellent agreement with the SM prediction of $(3.66 \pm 0.14)\times 10^{-9}$, with a statistical significance in the $10\sigma$ level. All candidate models of physics beyond the SM will have to demonstrate their compatibility with this important result, including models which propose explanations of hints for lepton universality anomalies, like $R_K$.

## References


[1] R. Aaij *et al.* [LHCb], "Test of lepton universality in beauty-quark decays", [arXiv:2103.11769 [hep-ex]].

[2] Forthcoming LHCb paper, results available in https://lhcb-public.web.cern.ch/Welcome.html#BsMuMU2021