$B^+ \to K^+\ell^+\ell^-$ to probe physics beyond standard model

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1. Introduction

The rare decays $B^+ \to K^+\ell^+\ell^-$, $\ell = e, \mu$ involving $b \to s$ flavour changing loop induced transition at the quark level makes it an attractive mode to search for physics beyond the standard model (SM) [1].
The $B^+ \to K^+\ell^+\ell^-$ decay occurs at tree level in standard model (SM) and via one loop excitations at high energies providing new physics (NP) beyond standard model. The important observable in the case $\ell = e, \mu$ is the ratio of two branching ratios i.e. $R_k = BR(B^+ \to K^+\mu^+\mu^-)/BR(B^+ \to K^+e^+e^-)$. In the standard model calculations where the decay can only occur by tree level diagram, R_k reduces to unity. However, various experiments at different energy scale have reported different results for R_k as listed in Table I.
The descripencies in the experimental observations and standard model predictions can be used to test physics beyond SM where excitations of more energetic particles is possible.

2. Methodology

The QCD hamiltonian for B^+ can be parametrized by heavy quark effective theory in terms of short distance wilson coefficients and large distance operators around mass scale μ_b. In this case the effective hamiltonian is given as:

$$H = C_9(\mu_b) \times O_9(\mu_b) \quad (1)$$

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TABLE I: Ratio R_k and Wilson Coefficient C_9^{NP} at different energy bins

Experiment	Energy bins	R_k	ΔC_9^{NP}
LHCb[2]	$1 < q^2 < 6$	$0.745^{+0.090}_{-0.074}$	-1.2
BaBar[3]	$0.1 < q^2 < 8.12$	$0.74^{0.40}_{-0.31}$	-1.1
Belle[4]	$1 < q^2 < 25$	1.03 ± 0.19	+0.1

Where,

$$O_9(\mu_b) = \frac{4G_f}{\sqrt{2}} V_{tb}V_{ts}^* \frac{e^2}{16\pi^2}(\bar{s}\gamma_\mu b)(\bar{\ell}\gamma_\mu \ell) \quad (2)$$

The branching ratios then can be calculated by Fermi's Golden rule. The basic needed input parameters are taken from PDG 2018 [5]. The coefficient C_9 is first fit to get best results for R_k in the case of SM. Python based flavio package is adopted to get fit for C_9. The weak effective theory and standard flavio basis are used. Our best fitted values are listed in Table I. The SM prediction $R_k = 1$ gives the best fit for wilson coefficient as $C_9 = 4.349$ at scale $\mu_b = 4.2$ GeV as in [6].
The deviation of R_k from unity governs change in the Wilson coefficient from SM prediction to meet the scale invariant QCD Hamiltonian. To get contribution for New Physics C_9 is then tuned to vary from its SM value to get experimental fit. The deviation $\Delta C_9 = C_9^{NP} - C_9^{SM}$ are listed in Table I.

3. Results and Conclusion

Our results show the negative NP contribution in C_9 in addition to the standard model. The model independent results in effective Hamiltonian ca be interpreted to put constrain on new physics model.
We look forward for further experimental results to establish possibility of new physics in these transitions.

References

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