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Lepton polarization asymmetry in excited b-meson

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Recently, some unexpected phenomena in various B meson decays are being observed in several experiments. Few of the observables are branching ratio of $B_s \to ^{+-}$ decay, angular observable P_5ˆ' in $B \to K^{*+-}$ decay, lepton flavour non-universality parameters $R_{K^{(*)}}$,$R_{D^{(*)}}$ etc. The fact that these observables show significant deviation around 3σ from their standard model (SM) values declares them as anomalies in recent time. To find the possible solutions scientists extend their ideas beyond the SM which points towards the presence of new physics (NP). There are various NP models like leptoquark, 2HDM, non-universal Z', fermion fourth generation etc which are being examined to see whether they could explain the recent anomalies. Here, we are interested to study the heavy-light systems like the $(b\bar{q})$ mesons which have a rich spectrum of excited states. We are mainly concerned about the decay $B^*_{(s,d)} \to l^+l^-(l = e, ,)$ which includes $b \to sll$ flavor-changing neutral-current (FCNC) transition. The excited mesons $B^*_{(s,d)}$ are unstable under electromagnetic and strong interactions and possess narrow width with corresponding lifetime of the order of 10^{-17} s. The $B^*_{(s,d)} \to l^+l^-$ decays are sensitive to short-distance structure of $B = 1$ transitions. Some theoretical studies are being done in ref. [1, 2]. The authors of ref. [1] have proposed a novel method to study FCNCs in the $B^*_{(s,d)} \to e^+e^-$ transition and predicted the branching ratio [1] $BR(B^*_{(s,d)} \to e^+e^-) = 0.98 \times 10^{-11}$. In ref. [2] $B^*_{(s.d)} \to l^+l^-$ decay modes have been studied in the SM and the branching ratio has been predicted as $BR^{SM}(B_{(s,d)})^* \to l^+l^-) = (0.7 - 2.2) \times 10^{-11}$ for decay width $= 0.10(5)$ keV, irrespective of the lepton flavor. We have recently studied [3] $B^*_{(s,d)} \to l^+l^-(l = , e)$ decay in Z' model and predicted the branching ratio as $BR(B^*_s \to l^+l^-) = (1.5 - 2.2) \times 10^{-11}$ and $BR(B^*_d \to l^+l^-) = (1.7 - 2.2) \times 10^{-13}$.
Theoretical investigation of longitudinal lepton polarization asymmetry (A_{P_L}) is found to be more clean compared to the branching ratio of this decay channel as the observable A_{P_L} is independent of the total width of B^* meson which is not confirmed theoretically or experimentally. In this work, we first calculate the SM prediction of A_{P_L} and then analyse its sensitivity to the non-universal Z' model [4] which is an extension of SM with an extra U(1)' symmetry. The main attraction of this NP model is that FCNC transitions could occur at tree level due to the off-diagonal couplings of non-universal Z' with fermions, which is not allowed under SM consideration. The relation between the electroweak interaction eigenstates and mass eigenstates induces GIM mechanism within SM due to which flavor changing neutral interaction (FCNI) becomes forbidden at tree level. However, the relation between the interaction eigenstates of NP and the mass eigenstates is not same as of the SM. In such a situation, Z' model could allow the tree level FCNC $b \to sll$ transitions. As, $B^*_{(s,d)} \to l^+l^-$ decay modes are not observed experimentally till now, so these decays are expected to be used to test the flavour sector of the SM and search for NP.

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