

Vacuum Polarization Effects From Dark Fermion Loops in Z' Mediator Models and Their Impact on Angular Observables in Rare B Meson Decays

Gupta, Suhani (School: Amity International School, Gurugram)

Rare flavour-changing neutral current decays such as $B \rightarrow K\mu^+\mu^-$ are a sensitive probe of beyond Standard Model (SM) Physics. The angular observable P_5' has exhibited a persistent deviation from SM predictions, remaining at approximately 3σ in the central q^2 bin of $[1.1, 6.0] \text{ GeV}^2$. In this work, I investigated whether vacuum polarization (VP) effects from a dark fermion χ coupled via a Z' portal, can induce a nontrivial q^2 -dependent shifts in C_9 , potentially improving agreement with experimental data. I derived the loop-corrected Z' propagator, incorporated the resulting correction into the effective weak Hamiltonian, and computed bin-averaged angular observables using Flavio. A systematic parameter scan over 34,997 configurations was performed across three chiral realizations of the Z' (left-handed, left-right asymmetric, and left-right symmetric). The preferred solutions are vector-dominant but chirally asymmetric, yielding a best-fit point that reduces the central-bin C_9 deviation from the SM expectation to approximately 0.12σ , an approximately 96% improvement. The model produces an effective shift in C_9 which matches with global EFT fits and the VP term is highly loop-suppressed but introduces a non-negligible momentum-dependent structure in the propagator. The model is compatible with complementary angular observables and decays. I extended the Z' couplings to neutrinos, and investigated the optimal chiral structure of Z' -lepton couplings by jointly constraining C_9 and C_{10} . Overall, this study suggests that energy-dependent effects arising from dark-sector dynamics may provide a viable and phenomenologically consistent contribution to the P_5' tension and is a useful benchmark that motivates future experimental studies through finer q^2 binning.

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