Signal of light Z' boson from the study of $B^0_{s,d} \to \mu^+\mu^-$ decays

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Introduction

Rare leptonic decays of the neutral B mesons play a vital role in the precision test of the standard model (SM) of particle physics and provide important constraints on models of new physics (NP) [1]. The $B_s^0 \to \mu^+\mu^-$ and $B_d^0 \to \mu^+\mu^-$ rare decays induced by flavor-changing neutral current (FCNC) transitions are very important to probe the flavor sector of the SM. These decays are highly suppressed by loop and helicity factors in the SM. Therefore, their branching ratios are small in the SM. However, one-loop FCNC processes can be enhanced by orders of magnitude in some theories beyond the SM. Presence of extra one or more extra gauge boson (such as Z'-boson) are predicted theoretically in many extensions of the SM [2]. The Z'- mediated FCNC transitions offers an important base to understand the new physics beyond the SM . In this paper, we study the $B^0_{s,d} \to \mu^+\mu^-$ decays in flavor changing Z'- model and estimate the mass of Z' boson. using the recent experimental value of branching ratios for $B^0_{s,d} \to \mu^+\mu^-$ decays. Finally we compare our result with that of others.

Theoretical model

The $B^0_{s,d} \to \mu^+\mu^-$ decays [1] are potentially sensitive to new physics beyond the SM. These decays involve $b \to s, d$ transitions respectively. In extended quark sector model [3], besides the three standard generations of the quarks, there is an $SU(2)_L$ singlet of charge $-1/3$. This model allows Z-mediated FCNCs. The same idea can be applied for a Z' boson. Here, we consider a model (as given in [3-6]) with an extra $U(1)'$ gauge symmetry. The Z' boson is associated with the additional $U(1)'$ gauge symmetry. Here, we have assumed that there is no mixing between Z and Z' boson. In this model, the branching ratio of $B^0_{s,d} \to \mu^+\mu^-$ decay is given by [4, 5]:

$$B\left(B^0_{s,d} \to \mu^+\mu^-\right) = \frac{G_F^2}{4\pi}\tau_{B_{s,d}} f^2_{B_{s,d}} m^2_{\mu} m_{B_{s,d}} \sqrt{1-\frac{4m^2_{\mu}}{m^2_{B_{s,d}}}} \left|V^*_{tb}V_{ts}\right|^2 \times \left[\left|\frac{\alpha}{2\pi \sin^2\theta_W} Y\left(\frac{m_t^2}{M_W^2}\right) + 2\frac{\rho_L^{bs}\rho_L^{\mu\mu}}{V^*_{tb}V_{ts}}\right|^2 + \left|2\frac{\rho_L^{bs}\rho_R^{\mu\mu}}{V^*_{tb}V_{ts}}\right|^2\right]$$

We use above equation for the calculation of $M_{Z'}$ for Z'- mediated rare decays $B_s^0 \to \mu^+\mu^-$ and $B_d^0 \to \mu^+\mu^-$ in the next section.

Results and Discussions

In this section, we estimate the mass of Z' boson using the experimental value [7] $B\left(B_s^0 \to \mu^+\mu^-\right) = \left(2.8^{+0.7}_{-0.6}\right)\times 10^{-9}$ and $B\left(B_d^0 \to \mu^+\mu^-\right) = \left(3.9^{+1.6}_{-1.4}\right)\times 10^{-10}$. Here we use all the recent data from particle data

group [8], we find that the values of branching ratios for $B_s^0 \to \mu^+\mu^-$ and $B_d^0 \to \mu^+\mu^-$ decays in Z' model are consistent with the mass of Z' boson $M_{Z'} \approx 108$ GeV and $M_{Z'} \approx$ 99 GeV respectively. The variation of branching ratio B($B_{s,d}^0 \to \mu^+\mu^-$) with $M_{Z'}$ is shown in Fig. 1. Since $M_{Z'}$ has not yet been discovered, its mass is unknown. The variation of branching ratio B($B_{s,d}^0 \to \mu^+\mu^-$) with $M_{Z'}$ is shown in Figure 1.

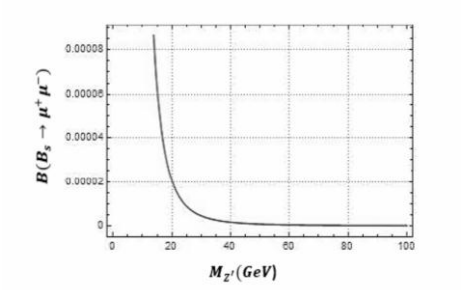

Fig-1(a) Blue line represents the variation of branching ratio B $\left(B_s^0 \to \mu^+\mu^-\right)$ with $M_{Z'}$

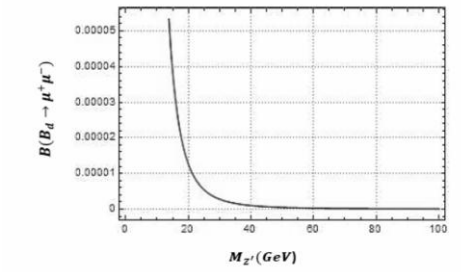

Fig-1(b) Blue line represents the variation of branching ratio B $(B_s^0 \to \mu^+\mu^-)$ with $M_{Z'}$

In a study of *B* meson decays with Z'-mediated FCNCs [9], they study the Z' boson in the mass range of a few hundred GeV to 1 TeV. The existence of light Z' boson has been predicted in dark matter (DM) phenomenology. In [10] it is shown that the genesis of DM is possible with a Z' portal for a spectrum of Z' mass in the range 1 GeV –1 TeV. In [11] it is shown that the strong first order electroweak phase transition (EWPT) can be realized in the light of Z' boson region, $M_{Z'} <$ 220 GeV. The Z' boson is also considered as dark matter candiadate in many cosmological survey, such as in [12] it is reported that dark Z' boson mass lies within the low energy region of 100 GeV. More interestingly, our estimation of the mass of Z' boson is around 100 GeV. These facts lead to enrichment in the phenomenology of both Z' boson and $B_{s,d}^0 \to \mu^+\mu^-$ rare decays. A detailed and more precise study of these decays are needed to know the phenomena. So, we look forward to get more data and analysis of these decays as well as some more similar decays at the LHC Run-2 or any of the future colliders.

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