Theoretical estimation of Z' boson mass

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Introduction

The discovery of Higgs boson at the LHC brings a renewed perspective in particle physics. With the help of Higgs mechanism, standard model (SM) allows the generation of particle mass. The ATLAS and CMS experiments at the LHC have predicted the mass of Higgs boson as $m_H = 125$–126 GeV [1,2]. Recently, it is claimed that the Higgs boson might interact with dark matter [3,4] and there exists relation between the Higgs boson and dark matter (DM). Hertzberg [3] has predicted a correlation between the Higgs mass and the abundance of dark matter. His theoretical result is in good agreement with current data. He has predicted the mass of Higgs boson as 125.7 ± 0.6 GeV. The Higgs boson could be coupled to the particle that constitutes all or part of the dark matter in the universe [5]. Light Z' boson could have important implications in dark matter phenomenology. The Z' boson is known to exist in well-motivated extension of the SM. Theoretically the existence of Z' boson is predicted in grand unified theories (GUTs), left-right symmetric models, Little Higgs models and superstring theories. The Z' boson is considered as an excited state of the ordinary Z boson in models with extra dimensions at the weak scale. It is introduced as an additional $U(1)'$ group to the SM gauge group. Since the Z' boson has not been discovered so far, its accurate mass is not known. But from several theoretical and experimental observations we get a wide range of the mass of Z' boson. In this paper, we evaluate the mass of Z' boson considering the relation between mass squares of the particles like top quark, Higgs boson, W boson, Z boson and Z' boson in the $SU(2)\times U(1)\times U(1)$ model.

Theoretical Model

Here we consider $SU(2)\times U(1)\times U(1)$ model, which is a subgroup of SO(10). This model is discussed in detail in [6]. In this model, the authors have derived the relation between the mass squares of the particles in dimensional regularization (DREG) method at one loop in the SM as:

$$12\, m_t^2 = 3m_H^2 + 2m_W^2 + m_Z^2 + m_{Z'}^2 \quad \ldots\ldots (1)$$

where m_t, m_W, m_Z, m_H and $m_{Z'}$ are the masses of top quark, W boson, Z boson, Higgs boson and Z' boson respectively. As stated before the mass of Z' boson has a wide range of values. In [7], authors have studied the decays of B meson with Z'-mediated FCNCs, in the mass range of a few hundred GeV to 1 TeV. Recently in [8] authors have studied the genesis of DM by a Z' portal for a spectrum of Z' mass in the range 1 GeV – 1 TeV. The ATLAS collaboration [9] sets the lower mass limits for the sequential standard model (SSM) Z'_{SSM} as 2.90 TeV, for Z'_{ψ} as 2.51 TeV and for Z'_{χ} as 2.62 TeV. Recently Oda et al. [10] have found an upper bound on Z' boson mas, $M_{Z'} \leq 6$ TeV in classically conformal $U(1)'$ extended standard model. Following the above models, experiments and theories we study the variation of $m_{Z'}$ within the range 1 GeV – 6000 GeV.

Results and Discussions

We use the recent values of the parameters from [11] $m_t = 173.21 \pm 0.51 \pm 0.71$ GeV, $m_W = 80.385 \pm 0.015$ GeV, and $m_Z = 91.1876 \pm 0.0021$ GeV in eq.1 to study the variation of mass of Higgs boson with respect to Z' boson which is given in

Table1 and shown in Fig 1. From the graph we find that, in order to achieve experimental value of Higgs boson mass ~ 125 GeV, the mass of Z' boson should be around 545 GeV. Although the CMS and ATLAS collaborations have predicted the value of $m_{Z'}$ > 2.5 TeV, in [8] it is shown that the genesis of DM is possible with a light Z' boson. They have studied the genesis of DM through a Z' portal for a spectrum of Z' mass in the range 1 GeV – 1 TeV. Chen *et al*. [12] have studied Z' boson as a single DM candidate in the mass range 100 GeV < $m_{Z'}$ < 1 TeV. In future, we will look forward to get more data and analysis from different colliders or accelerators for the discovery of Z' boson and its mass. New physics beyond the SM will be known after its discovery.

Table 1:

$m_{Z'}$ (GeV)	m_H (GeV)
1	338.558
100	333.59
250	306.249
500	176.886
550	117.425
750	imaginary
1000	imaginary
3000	imaginary
6000	imaginary

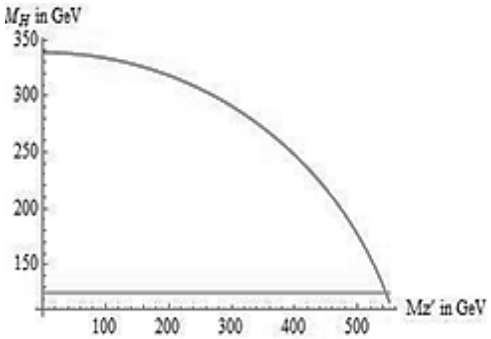

Fig. 1 $M_{Z'} \sim M_H$ Graph

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