

THE ANOMALOUS CHROMOMAGNETIC DIPOLE MOMENT OF THE TOP QUARK IN DIFFERENT FRAMEWORKS

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ABSTRACT

We give explicit formulae for the anomalous chromomagnetic dipole moment of the top quark in the framework of the standard model, the two Higgs doublet model and the minimal supersymmetric standard model. Finally, we compare the results for this coupling with the bound $-0.03 \leq \Delta\kappa \leq 0.01$ coming from analysis of $b \rightarrow s\gamma$ process with an on-shell gluon.

The top quark is the heaviest fermion in the standard model (SM) with a mass of 174 ± 5.2 GeV. Anomalous couplings between top quark and gauge bosons might affect top quark production and its decay at high energies. On the other hand, the $\bar{t}t\bar{g}$ coupling correction to the total top quark production cross section at Fermilab was calculated by Stange et al. [1], in the framework of the SM. Since the anomalous chromomagnetic dipole moment of the top quark appears in the top quark cross section, it is possible, due to uncertainties, to estimate the constraints that it would impose on the $\Delta\kappa$. For the LHC, the anomalous coupling is constrained to lie in the range $-0.09 \leq \Delta\kappa \leq 0.1$ [2]. Also the influence of an anomalous $\Delta\kappa$ on the cross section and associated gluon jet energy for $\bar{t}t\bar{g}$ has been analyzed, it leads to a bound of $-2.1 \leq \Delta\kappa \leq 0.6$.

Anomalous couplings of the top quark to on-shell gluons would modify the rate for $B \rightarrow X_s\gamma$ [3]. Using the recent data from CLEO collaboration for the branching fraction of the process $B(b \rightarrow s\gamma)$ [4], we update the previous analysis done in reference [3] and get the new allowed region for the anomalous chromomagnetic dipole moment of the top quark to be $-0.03 \leq \Delta\kappa \leq 0.01$.

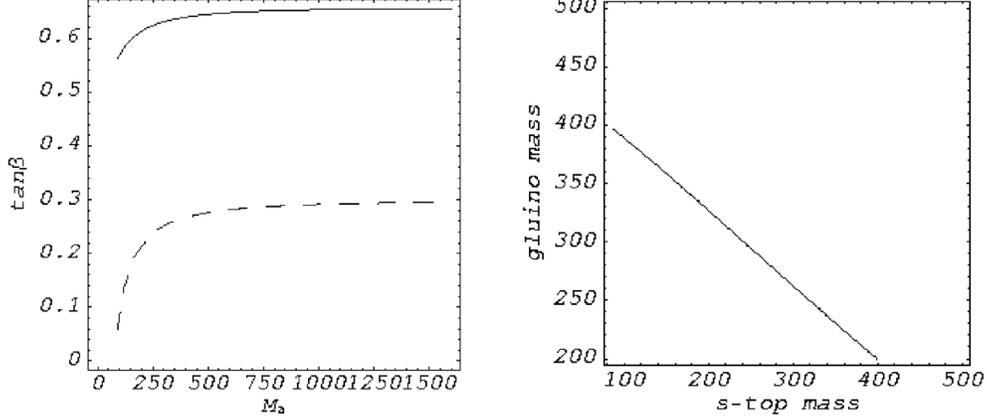


Figure 1: Contour plot for the plane $\tan\beta - m_A$ with the common scalar mass $m_h = m_H = 90(200)$ GeV for the solid line (dashed line). And Contour plot for the supersymmetric QCD contribution to the anomalous chromomagnetic dipole moment of the top quark using the bound from the $b \rightarrow s\gamma$ process.

Beginning with the SM, the typical QCD correction through gluon exchange implies two different Feynman diagrams. After the explicit calculation of the loops, the final result is,

$$\Delta\kappa = -\frac{1}{6} \frac{\alpha_s(m_t)}{\pi} \quad (1)$$

where we have a factor $-1/6$ coming from the color structure in the diagram, $T^a T^b T^a = -T^b/6$ with T^a the generators of $SU(3)_C$. The other possible contribution in the framework of the SM comes from electroweak interactions. This contribution reads

$$\Delta\kappa = -\frac{\sqrt{2}G_F m_t^2}{8\pi^2} [H_1(m_h) + H_2(m_Z)], \quad (2)$$

where $H_i(m)$ are defined in reference [3].

The contributions within a general 2HDM will be different from the SM contributions because of the presence of the virtual five physical Higgs bosons which appear in any two Higgs doublet model after spontaneous symmetry breaking: H^0 , A^0 , h^0 , H^\pm [5]. The expression for the contribution of the neutral Higgs bosons is given by

$$\Delta\kappa = \frac{\sqrt{2}G_F}{8\pi^2} [\lambda_{H^0 tt}^2 H_1(M_H^2) + \lambda_{h^0 tt}^2 H_1(M_h^2) + \lambda_{A^0 tt}^2 H_2(M_A^2) + \lambda_{G^0 tt}^2 H_2(M_Z^2)] \quad (3)$$

where λ_{itt} are the Yukawa couplings in the so-called models type I, II and III [5, 3]. We show in figure 1 the allowed region (top-right) for the plane $\tan\beta$ vs m_A with $m_H = m_h = 90(200)$ GeV for the solid (dashed) line. In this case we only find cuts with the upper limit for $\Delta\kappa$ from $b \rightarrow s\gamma$.

Our last step is to calculate the anomalous chromomagnetic dipole moment of the top quark in the framework of the MSSM. We only consider the SUSY QCD contribution which is generated from the exchange of gluinos and squarks top. In this framework the SUSY QCD contribution arises from the exchange of $\tilde{t}_{1,2}$ and gluinos. The contribution for the virtual \tilde{t}_1 is given in ref [3]. Again, we plot the points which are of the same order of the $\Delta\kappa$ from $b \rightarrow s\gamma$ in the figure 1, right side.

In conclusion, the anomalous chromomagnetic dipole moment of the top quark gets the wide bound $|\Delta\kappa| \leq 0.45$ from the Tevatron experiments under the assumption that it is the only non-zero anomalous coupling. On the other hand, we found a more stringent bound from the transition $b \rightarrow s\gamma$, recently measured with improved precision by CLEO collaboration [4], and the bound is $-0.03 \leq \Delta\kappa \leq 0.01$. Also, we have calculated the chromomagnetic dipole moment of the top quark in the framework of the SM, 2HDM and SUSY-QCD. We found that in SM the anomalous coupling is of the order of $\pm 10^{-2}$ and it is tending to -0.004 in the decoupling limit for the Higgs mass. Furthermore, the anomalous coupling is equal to -7×10^{-4} around a Higgs mass of 113 GeV that is the lower experimental limit from LEP2. Now if we keep in mind the sensitivity of future and current experiments to $\Delta\kappa$ [2] a measurement of this anomalous coupling would suggest the presence of physics beyond the SM. In the 2HDM the anomalous coupling of the top quark can reach $\sim 10^{-1}$ values, also gotten for the supersymmetric QCD corrections.

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