PRAMANA
— journal of
physics

© Indian Academy of Sciences

Vol. 79, No. 5
November 2012
pp. 1293–1296

Anomalous top magnetic couplings

G GONZÁLEZ-SPRINBERG[1], R MARTINEZ[2,*] and JORGE VIDAL[3]
[1]Instituto de Física, Facultad de Ciencias, Universidad de la República, Montevideo, Uruguay
[2]Departamento de Física, Universidad Nacional, Bogotá, Colombia
[3]Departament de Física Teòrica Universitat de València, Burjassot,València, Spain
*Corresponding author. E-mail: remartinezm@unal.edu.co

Abstract. The real and imaginary parts of the one-loop electroweak contributions to the left and right tensorial anomalous couplings of the tbW vertex in the Standard Model (SM) are computed.

Keywords. Top; anomalous.

PACS Nos 14.65.Ha; 12.15.Lk

Top quark physics at the Large Hadron Collider (LHC) is an important scenario for testing physics above the electroweak scale [1,2]. Some effects related to the top anomalous couplings, both in the $t \to bW^+$ polarized branching fractions and in single top production at the Tevatron and at the LHC, have already been studied in recent years. One-loop QCD and electroweak contributions to the tbW vertex have been studied in the frame of the Standard Model (SM) [3]. The explicit dependence of the polarized branching fractions on the anomalous couplings have been computed in refs [4,5].

We compute the electroweak SM contribution to the left and right 'magnetic' tensorial couplings of the *tbW* vertex. We found that the electroweak contribution is also at the level of 10% with respect to the leading gluon exchange. For on-shell particles, the amplitude $\mathcal{M}_{tbW}$ can be written in the following way:

$$\mathcal{M}_{tbW^+} = -\frac{e}{\sin\theta_W\sqrt{2}}\,\epsilon^{\mu *}\,\bar{u}_b\left[\frac{i\sigma_{\mu\nu}q^\nu}{m_W}\,(g_L P_L + g_R P_R)\right]u_t. \tag{1}$$

One-loop QCD gluon exchange contribution to g_R was computed in ref. [6], $g_R^{\rm QCD} = -6.61 \times 10^{-3}$. The sensitivity to g_R will be accessible to the LHC experiments [2,5]. The left tensorial term couples a right b-quark and thus it is proportional to m_b. Then, constraints on g_L are stronger than g_R due to the chiral m_t/m_b factor.

Indirect limits on g_L and g_R can be obtained from $b \to s\gamma$ [7]. The results from the analysis given in refs [8] and [9] are given in the first line of table 1; the second and third lines show g_L and g_R limits predicted for the future LHC data [5]. The LHC will improve the sensitivity to g_R by an order of magnitude compared to bounds from $b \to s\gamma$. In the same way as it is done in Tau physics [10], new asymmetry observables derived from

DOI: 10.1007/s12043-012-0443-x; ***e*Publication: 9 November 2012**

Table 1. Bounds on g_R and g_L.

Reference		g_R Bound	g_L Bound
$bs\gamma$	95% CL	$-0.15 < g_R < 0.57$	$-0.0015 < g_L < 0.0004$
Future LHC data	2σ	$-0.026 \leq g_R \leq 0.031$	$-0.058 \leq g_L \leq 0.026$
Future LHC data	1σ	$-0.012 \leq g_R \leq 0.024$	$-0.16 \leq g_L \leq 0.16$
		g_R Discovery limit	g_L Discovery limit
Helicity fractions of the W	3σ	$\lvert\mathrm{Re}(g_R)\rvert \geq 0.056$	$\mathrm{Re}(g_L) \geq 0.051$ or $\mathrm{Re}(g_L) \leq -0.083$
$bs\gamma$	3σ	$\lvert\mathrm{Im}(g_R)\rvert \geq 0.115$	$\lvert\mathrm{Im}(g_L)\rvert \geq 0.065$
		$\mathrm{Re}(g_R) \geq 0.76$ or	$\mathrm{Re}(g_L) \geq 0.0009$ or
		$\mathrm{Re}(g_R) \leq -0.33$	$\mathrm{Re}(g_L) \leq -0.0019$
			$\lvert\mathrm{Im}(g_L)\rvert \geq 0.006$

helicity fractions for polarized W were defined for polarized top decays; the exclusion intervals derived from these observables are shown in the fourth line of table 1. As a reference for the comparison with the LHC, they also derived as 3σ discovery limits from $b \to s\gamma$ in ref. [9]; this is shown in the last line of table 1.

At one loop in the SM, there is only one topology for the diagrams that contribute to the anomalous g_R and g_L: this is shown in figure 1a. For g_R there are two diagrams that have a leading m_t-mass. They are the ones in figure 1b with thW and tw_0W circulating in the loop, where h is the Higgs boson and w_0 is the unphysical Z-boson. These two diagrams have top mass insertions that give a mass dependence which is of the order $1/r_W^2 = 1/(m_W/m_t)^2$ with respect to the other diagrams. Some diagrams, like bWZ for example, contribute to the imaginary part of g_R.

The result for each contribution of the diagrams to g_R and g_L is given in table 2, with $m_h = 150$ GeV. The final result for the one-loop electroweak correction is

$$g_R^{\mathrm{EW}} = -(0.56 + 1.23i) \times 10^{-3}, \qquad g_L^{\mathrm{EW}} = -(0.92 + 0.14i) \times 10^{-4}. \quad (2)$$

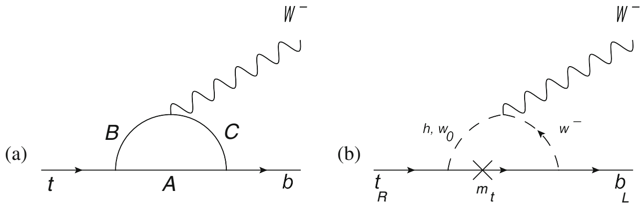

Figure 1. (**a**) Topology of the one-loop SM Feynman diagrams for the quantum correction to the $t \to bW^+$ decay. (**b**) Leading order diagrams for g_R in the large m_t limit.

Table 2. Electroweak contributions to g_{R} and g_{L}.

Diagram	$g_{\mathrm{R}} \times 10^3$	$g_{\mathrm{L}} \times 10^3$
tZW	-1.176	-0.0141
thW	0.220	0
tw^0w^-	0.344	0.0051
hw^-	0.462	-0.0088
tZw^-	-0.050	-0.0012
$t\gamma W + t\gamma w^-$	0.572	-0.0094
bWZ	$-0.623 - 0.664i$	$-0.0201 - 0.0214i$
bWh	0	$0.0086 - 0.0120i$
bw^+w^0	$(1.5 + 11.0i) \times 10^{-4}$	$-0.0029 - 0.0167i$
bw^+h	$(-4.3 + 8.6i) \times 10^{-4}$	$-0.0019 + 0.0111i$
bw^+Z	$-0.088 - 0.062i$	$-0.00039 - 0.00028i$
$bW\gamma + bw^+\gamma$	$0.114 - 0.509i$	$-0.0270 + 0.0250i$
Ztb	-0.397	-0.0067
γtb	0.068	0.0115
w^0tb	-6.8×10^{-4}	-0.0109
htb	-6.2×10^{-4}	-0.0135
$\Sigma(EW)$	$-0.56 - 1.23i$	$-(0.092 + 0.014i)$
gtb	-6.61	-1.12

We note that for $g_{\mathrm{L}}^{\mathrm{EW}}$ is 8% of g_{L}^{g}, and also that the CP violation has its origin in the electroweak diagrams. These values are to be compared with the gluon contribution that is the dominant one:

$$g_{\mathrm{R}}^{\mathrm{g}} = -6.61 \times 10^{-3}, \qquad g_{\mathrm{L}}^{\mathrm{g}} = -1.12 \times 10^{-3}. \tag{3}$$

The final result for the one-loop computation in the SM is the sum of eqs (2) and (3):

$$g_{\mathrm{R}}^{\mathrm{SM}} = -(7.17 + 1.23i) \times 10^{-3}, \qquad g_{\mathrm{L}}^{\mathrm{SM}} = -(1.21 + 0.01i) \times 10^{-3}. \tag{4}$$

The real part for the one-loop electroweak quantum correction for g_{R} is 8% of the leading gluon-exchange contribution. Note that the imaginary part is 17% of the one-loop $\mathrm{Re}(g_{\mathrm{R}}^{\mathrm{SM}})$.

Acknowledgements

This work was supported by ANII-FCE-2986-Uruguay, COLCIENCIAS-Colombia, the Spanish Ministry of Science and Innovation, under grants FPA2008-03373, FPA2008-02878, and by Generalitat Valenciana under grant PROMETEO 2009/128.

References

[1] M Beneke *et al*, hep-ph/0003033

[2] W Bernreuther, *J. Phys.* **GG35**, 083001 (2008)
E Boos, L Dudko and T Ohl, *Eur. Phys. J.* **C11**, 473 (1999)
J A Aguilar-Saavedra, *Nucl. Phys.* **B804**, 160 (2008)

[3] H S Do *et al*, *Phys. Rev.* **D67**, 091501 (2003)
[4] C R Chen, F Larios and C P Yuan, *Phys. Lett.* **B631**, 126 (2005)
Gabriel A Gonzalez-Sprinberg, Roberto Martinez and Jorge Vidal, *J. High Energy Phys.* **1107**, 094 (2011)
[5] F del Águila and J A Aguilar-Saavedra, *Phys. Rev.* **D67**, 014009 (2003)
J A Aguilar-Saavedra *et al*, *Eur. Phys. J.* **C804**, 160 (2008)
J A Aguilar-Saavedra *et al*, *Eur. Phys. J.* **C53**, 689 (2008)
J Bernabéu and J A Aguilar-Saavedra, *Nucl. Phys.* **B840**, 349 (2010)
[6] C S Li, R J Oakes and T C Yuan, *Phys. Rev.* **D43**, 3759 (1991)
[7] M Jezabek and J H Kuhn, *Phys. Rev.* **D48**, 1910 (1993)
A Czarnecki, *Phys. Lett.* **B252**, 467 (1990)
C S Li, R J Oakes and T C Yuan, *Phys. Rev.* **D43**, 3759 (1991)
[8] J Alwall *et al*, *Eur. Phys. J.* **C49**, 791 (2007)
[9] B Grzadkowski and M Misiak, *Phys. Rev.* **D78**, 077501 (2008)
[10] J Bernabéu, G A González-Sprinberg and J Vidal, *Phys. Lett.* **B326**, 168 (1994)
J Bernabéu *et al*, *Nucl. Phys.* **B436**, 474 (1995)