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Anomalous top magnetic couplings

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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.

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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:

$$\mathcal{M}_{tbW^+} = -\frac{e}{\sin\theta_{\mathrm{W}}\sqrt{2}}\,\epsilon^{\mu *}\,\bar{u}_{\mathrm{b}}\left[\frac{\mathrm{i}\sigma_{\mu\nu}q^{\nu}}{m_{\mathrm{W}}}\,(g_{\mathrm{L}}P_{\mathrm{L}} + g_{\mathrm{R}}P_{\mathrm{R}})\right]u_{\mathrm{t}}. \quad (1)$$

One-loop QCD gluon exchange contribution to g_{R} was computed in ref. [6], $g_{\mathrm{R}}^{\mathrm{QCD}} = -6.61 \times 10^{-3}$. 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 $m_{\mathrm{t}}/m_{\mathrm{b}}$ 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

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Table 1. Bounds on $g_{\rm R}$ and $g_{\rm L}$.

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

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 $g_{\rm R}$ and $g_{\rm L}$: this is shown in figure 1a. For $g_{\rm R}$ there are two diagrams that have a leading $m_{\rm t}$-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 $1/r_{\rm W}^2 = 1/(m_{\rm W}/m_{\rm t})^2$ with respect to the other diagrams. Some diagrams, like bWZ for example, contribute to the imaginary part of $g_{\rm R}$.

The result for each contribution of the diagrams to $g_{\rm R}$ and $g_{\rm L}$ is given in table 2, with $m_{\rm h} = 150$ GeV. The final result for the one-loop electroweak correction is

$$g_{\rm R}^{\rm EW} = -(0.56 + 1.23i) \times 10^{-3}, \qquad g_{\rm L}^{\rm EW} = -(0.92 + 0.14i) \times 10^{-4}. \quad (2)$$

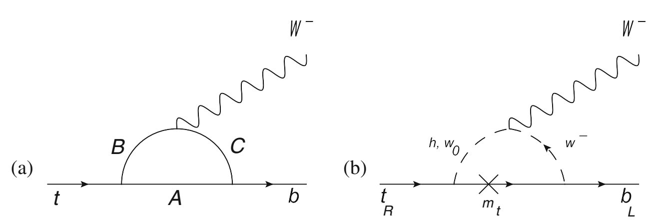

Figure 1. (**a**) Topology of the one-loop SM Feynman diagrams for the quantum correction to the $t \to bW^+$ decay. (**b**) Leading order diagrams for $g_{\rm R}$ in the large $m_{\rm t}$ limit.

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 $\mathrm{Re}(g_{\mathrm{R}}^{\mathrm{SM}})$.

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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)