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Radiative Contributions to TGC in the MSSM [1]

A. Arrhib [a], J.-L. Kneur [b,2] and G. Moultaka [a]

[a] Physique Mathématique et Théorique, U.R.A. du CNRS N^o 040768,
Université Montpellier II, F-34095 Montpellier France

[b] Theory Division, CERN,
CH-1211 Geneva 23, Switzerland

Abstract

We give a brief account of recent calculations of radiative contributions to the Triple Gauge Couplings (TGC) from the Minimal Supersymmetric Standard Model (MSSM), at a 500 GeV e^+e^- collider. Our results indicate that, although these MSSM virtual contributions indeed are of the order of the expected accuracy on TGC measurements, the generally neglected box contributions to TGC also are likely to be relevant at such high energies.

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[2] On leave from U.R.A. 768 du C.N.R.S., F34095 Montpellier France.

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A. Arhrib [a], J.-L. Kneur [b,1] and G. Moultaka [a]

[a] LPM, U.R.A. du CNRS N^o 040768, Univ. Montpellier II, France

[b] Theory Division, CERN, Geneva, Switzerland

1 Radiative Contributions to TGC

With an expected accuracy of O(10^{-3}) or better [1], the measurement of Triple Gauge Couplings (TGC) at a 0.5–2 TeV e^+e^- collider will truly constitute a *precision* experiment. Therefore, apart from testing possible departures from the SM $WW\gamma$, WWZ vertices at tree-level, with an accuracy improved by more than an order of magnitude with respect to LEP2 [2], it is legitimate to expect detectable loop-level TGC contributions from different models of New Physics. Actually, one-loop TGC contributions are certainly present in any renormalizable model, but such virtual effects are suppressed by a factor of $(g^2/16\pi^2) \simeq 2.7$ 10^{-3}. Moreover, further suppression is expected from the decoupling properties of heavy particles in most renormalizable models. For instance, SM one-loop TGC predictions are known [3, 4] and give, at $\sqrt{s} = 190$ GeV [2] ($\sqrt{s} = 500$ GeV): $\Delta\kappa_\gamma \simeq 4.1$–$5.7 \times 10^{-3}$ (5.5–(−5.4) $\times$ 10^{-4}), for $M_{Higgs} = 0.065$–1 TeV and $m_{top} = 175$ GeV (with $\Delta\kappa_Z$ of the same order and even smaller contributions to $\lambda_{\gamma,Z}$). The smallness of those SM contributions at 500 GeV is due to their fast decreasing at high energies, $q^2 >> M^2_{W,Z}, m^2_{top}$, in accordance with the good unitarity behaviour, while even for a heavy Higgs its effects in $\Delta\kappa_{\gamma,Z}$ are screened, giving non-decoupling but small (constant) contributions for $M_{Higgs} \to \infty$.

A more interesting situation is thus expected if, for example, some particles in the loops have a stronger non-decoupling behavior (e.g due to Yukawa type couplings) and/or are close to their production threshold. The latter is likely to be the case in the Minimal Supersymmetric Standard Model (MSSM) [5] since, as is well known, the resolution of the hierarchy problem requires the spectrum of supersymmetric partners to appear at O(1 TeV) or below. A study of MSSM one-loop contributions to TGC [6, 7] can therefore provide a complementary information on a range of MSSM parameter values which may not be available from direct particle production.

[1]On leave from U.R.A. 768 du C.N.R.S., F34095 Montpellier France.

2 Extracting TGC from Loops

In momentum space the vertex issued from the C-, P-conserving part of the general TGC effective Lagrangian [8] reads ($V \equiv \lambda, Z$)

$$\Gamma^V_{\mu\alpha\beta} = i g_{VWW}\{f_V[2g_{\alpha\beta}\Delta_\mu + 4(g_{\alpha\mu}Q_\beta - g_{\beta\mu}Q_\alpha)] \tag{1}$$
$$+2\Delta\kappa'_V(g_{\alpha\mu}Q_\beta - g_{\beta\mu}Q_\alpha) + 4\frac{\Delta Q_V}{M_W^2}\Delta_\mu(Q_\alpha Q_\beta - g_{\alpha\beta}\frac{Q^2}{2})\},$$

where $2Q_\mu$, $(\Delta - Q)_\alpha$, and $-(\Delta + Q)_\beta$ designate the four-momenta and Lorentz indices of the *incoming* γ (or Z), W^+, and W^-, respectively, and the (q^2-dependent) coefficients in (1) are related to the more conventional TGC parameters [8, 2] as
$\Delta\kappa'_V \equiv \kappa_V - 1 + \lambda_V \ = \Delta\kappa_V + \lambda_V$; $\Delta Q_V \equiv -2\lambda_V$.

Naively, TGC are obtained by summing all MSSM contributions to the appropriate parts in eq. (1) from vertex loops with entering γ (or Z) and outgoing W^+, W^-. But, as is well known, the vertex graphs with virtual gauge bosons need to be combined with parts of box graphs for the full process, $e^+e^- \to W^+W^-$, to form a gauge-invariant contribution. This is most conveniently done by the pinch technique [4], i.e 'pinching' in an appropriate manner the irrelevant propagator lines from boxes, which preserves all the well-behaved features and properties expected from radiative corrections (Ward identities, good unitarity behaviour, infra-red finiteness, etc). The resulting combinations define purely s-dependent –and in that sense universal– TGC since, by definition, t and u-dependent box contributions are left over in this procedure. In what follows we have evaluated the complete set of s-dependent TGC, using the pinch technique for the relevant graphs. The sfermions, gauginos, and Higgses contribute separately to vertex graphs at the one-loop level, and we illustrate in fig. 1 those three contributions to $\Delta\kappa_\gamma$ for a representative choice of MSSM parameters [2] (contributions to $\Delta\kappa_Z$ are of the same order [7]). As a general remark, we note that the total contributions from the three sectors are comfortably of the order of the expected accuracy, but most particles give their maximal contributions when their masses are slightly above their direct production thresholds, showing a decoupling behavior for larger masses, as expected. An exception occurs for the sfermions, whose largest (and indeed dominant) contributions are obtained for a large mass splitting among up and down components (a situation where one does not expect any decoupling behavior, and in fact $\Delta\kappa_V$ tend to a constant in that case).

Now it is not clear whether the remnant (u,s)- and (t,s)-dependent boxes –which also form a gauge-invariant set by themselves– do not contribute a substantial part of

[2] For illustration we choose values which give somewhat maximal effects.

the full radiative corrections to TGC, especially at such high energies. Even if the above concept of a gauge-invariant, universal quantity defined from the pinch technique could be theoretically useful, one practical problem (as far as TGC measurements are concerned) is that there are no planned experimental procedure to distinguish among "universal" and "remnant" TGCs: clearly *anything* contributing at the loop-level to the coefficients in eq.(1) will be extracted from the data (provided, of course, that it gives large enough contribution to be detected). We thus illustrate as well in fig. 2 some partial (but gauge-invariant) box contributions, with internal sleptons and gauginos. Although partial, this indicates what relative amount of universal versus "remnant box" contributions may be expected at those energies.

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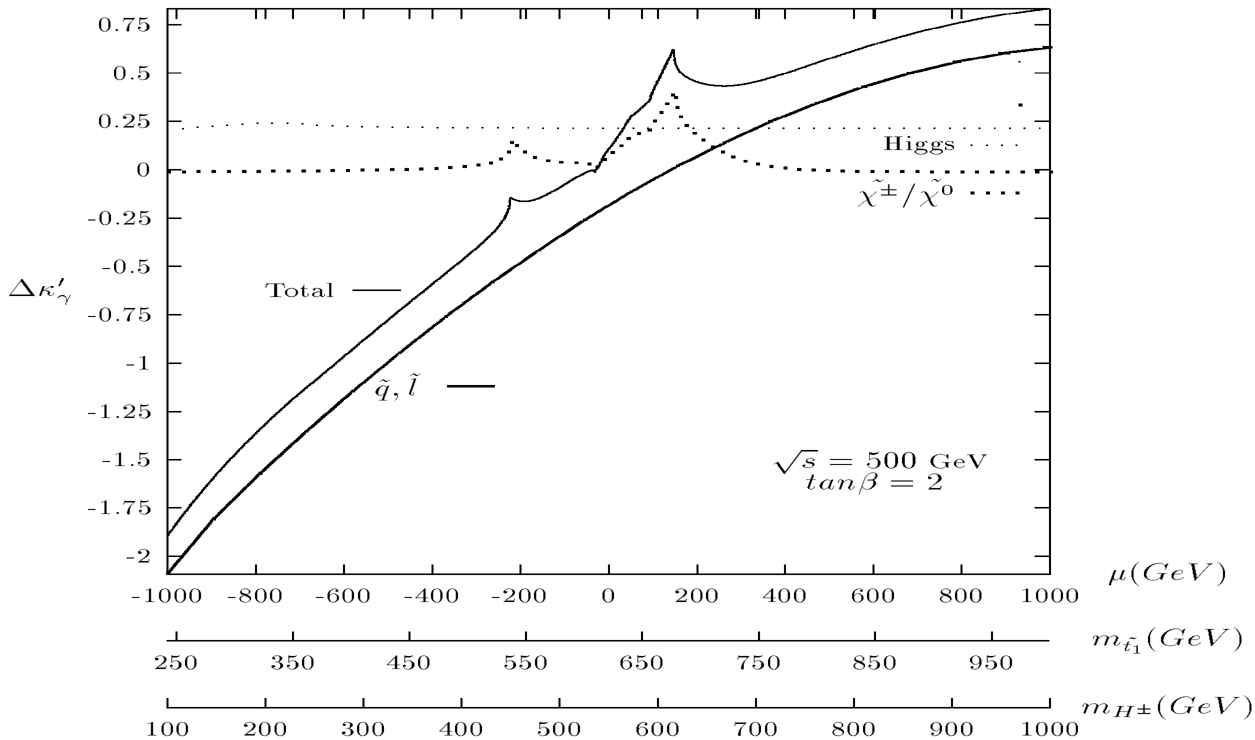

Figure 1: s-dependent $\Delta\kappa'_\gamma$ contributions (in units of $g^2/16\pi^2$) from Higgses, sfermions and gauginos. Other parameters fixed to $m_{\tilde{t}_1} = m_{\tilde{t}_2} = m_{\tilde{U}_1} = m_{\tilde{U}_2} = m_{\tilde{l}_1} = m_{\tilde{l}_2}$; $m_{\tilde{t}_1} + m_{\tilde{\nu}_L} = 1.245$ TeV and $m_{\tilde{t}_1} + m_{\tilde{D}_{1,2}} = 1.47$ TeV; M =190 GeV, M' =70 GeV.

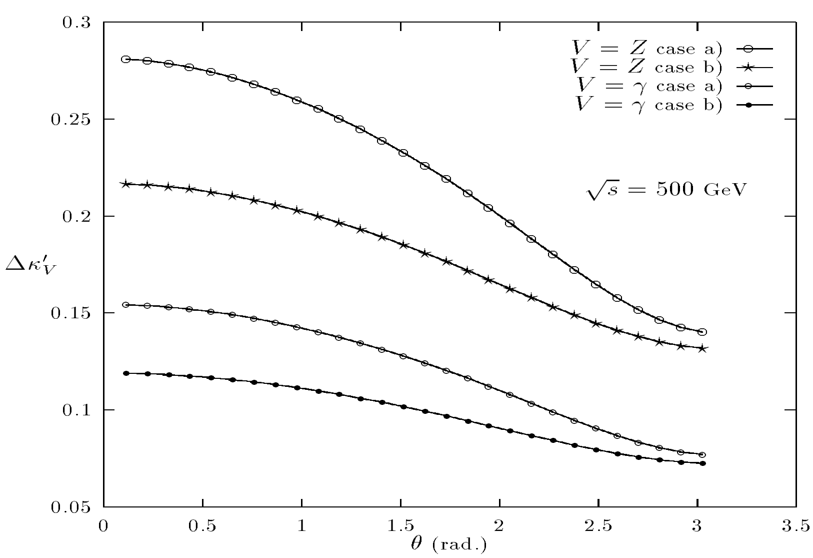

Figure 2: t-dependent non-pinch box contributions (in units of $g^2/16\pi^2$) with one chargino (resp. neutralino), two sneutrinos (resp. selectrons) and one selectron (resp. sneutrino) versus the W^- production angle θ. $m_{\tilde{e}_1} = m_{\tilde{\nu}_L} = 260$ GeV, zero left-right mixing angle; case a) $M = \mu$ =150 GeV, M' =100 GeV, $\tan\beta = 15$; case b) $M = M' = \mu =$ 250 GeV, $\tan\beta = 2$.