Radiative corrections to $e^+e^- \to H^+H^-$

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Abstract

We discuss the one-loop electroweak corrections to the pair production of charged Higgs bosons $e^+e^- \to H^+H^-$ in the Minimal Supersymmetric Standard Model.

In contrast to hadronic machines, a high energy e^+e^- collider in the TeV range will be a rather unique place to discover and study charged higgses in a clean environment. These would be produced either in pairs [1], our main concern here, or in associate (rare) production with $W^\pm$. It was first found in [2] that loop corrections from matter fermions and their susy partners (mainly the $(t,b),(\tilde{b},\tilde{t})$ sector), are likely to change the tree-level result at $\sqrt{s} = 500$ GeV [1, 3], by asmuch as 10% dip in the cross-section.The effect could even lie between -25% and 25% and perhaps grow out of perturbative control, though in a reasonable range of the model-parameters. Such a sensitivity to loop effects appears to be related to the fact that at tree-level the γ and Z mediated process is exclusively controlled by $U_B(1) \times U_{W_3}(1)$ gauge invariance and thus knows nothing about the non-standard extension whatsoever.

The aim of the present study is to improve on the previous one by including: **a)** the complete Higgs sector contributions (self-energies, vertices and boxes), **b)** the infrared part, including initial and final soft photon radiation as well as $\gamma\gamma$ and γZ boxes, **c)** The complete set of charginos/neutralinos/$\tilde{e}/\tilde{\nu}$ box diagrams, and thus to identify the various origins of large effects, whether in the MSSM or in a type II two-Higgs-doublet model (THDM-II).

It turns out that besides the sensitivity to the heavy quark-squark sector there are, on one hand large effects from the soft photon radiation and on the other, possibly important effects in the purely Higgs sector. The latter case occurs when deviations from the tree-level supersymmetric $H^+H^- - H^0(h^0)$ couplings are allowed bringing in increasingly large effects for increasing values of $\tan\beta$ at a given $\sqrt{s}$. To quantify such effects we thus allow for a general deviation from the supersymmetric relations among the bare parameters of the Higgs potential as follows :

$$\begin{aligned}
&\lambda_1 = \lambda_2 + \delta_{12} \quad , \quad \lambda_3 = \frac{1}{8}(g^2 + g'^2) - \lambda_1 + \delta_{31} \\
&\lambda_4 = 2\lambda_1 - \frac{1}{2}g'^2 + \delta_{41} \quad , \quad \lambda_5 = -\frac{1}{2}(g^2 + g'^2) + 2\lambda_1 + \delta_{51} \qquad (1) \\
&\lambda_6 = -\frac{1}{2}(g^2 + g'^2) + 2\lambda_1 + \delta_{61}
\end{aligned}$$

The $\lambda_i's$ are as defined in [4] and the (softly broken) susy case corresponds to $\delta_i = 0$. Eq.(1) translates in a definite way into deviations from the MSSM tree-level relations among the higgs masses, $\tan 2\alpha$ and $\tan\beta$, as well as the couplings of the higgs sector, leading to 6 free parameters. However, one can find conditions relating the $\delta's$ in such a way to *preserve* these relations *even in a non-susy case.* These conditions which we dub "quasi-susy", are certainly not generic but constitute a good ground to test minimal deviations from the MSSM in a simple way, since one then has just one extra free parameter (ex. λ_3) besides $\tan\beta$ and $M_{H^\pm}$ in the higgs sector. In quasi-susy the only deviations from the MSSM tree-level triple Higgs couplings that contribute to one-loop order in our case are in $H^+ - H^- - (H^0, h^0)$. For large $\tan\beta$ these couplings behave as:

$$(H^+H^-(H^0,h^0))_{susy} - igM_W(cos(\beta-\alpha)\Delta_{(1,2)} + (1 \mp cos(2\alpha))cos(\alpha)\mathbf{tan}(\beta)\Delta_3 \qquad (2)$$

the $\Delta's$ being functions of the $\delta's$ of eq.(1), and vanish in the MSSM.

Fig.1 illustrates how the Higgs sector contributions can counterbalance those of the heavy quarks found in [2] for large tan(β), but only near threshold. Far from threshold most of the effects become again negative, except for WW boxes. Furthermore the "neutral" model-independent contributions, including soft bremsstrahlung, obtained by adding one photon (or Z) line to the tree diagrams depend loosely on $M_{H^\pm}$ or $\sqrt{s}$ and contribute at the level of -17% for $\Delta E_\gamma \sim 0.1 E_{beam}$. In Fig.2 we show (excluding those "neutral" contributions) the integrated cross-section for two values of $M_{H^\pm}$ and tan(β). In THDM-II the total loop effect increases (negatively) with increasing tan(β), the farther one goes from production threshold. In the MSSM ($\lambda_3 = \lambda_{3_{susy}}$) the leading effects come exclusively from the heavy quark-squark sector and the conclusions of [2] remain unaltered in this case. [For instance the 150 boxes involving $\chi^\pm/\chi^0/\tilde{e}/\tilde{\nu}$ largely cancel among each other leading at most to $1-3\%$ effect for a wide range of sparticle masses.]

References

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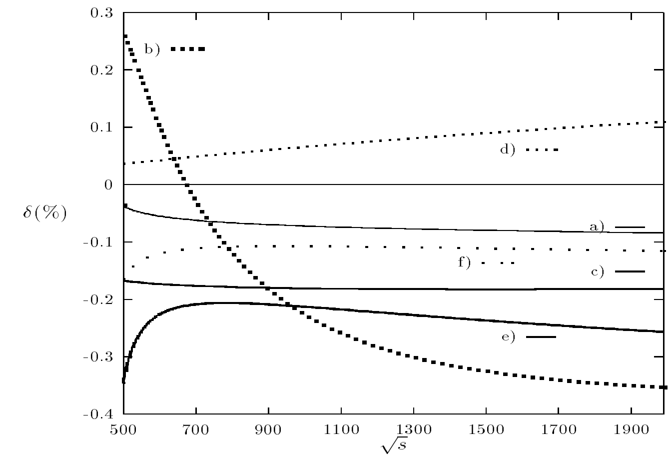

Fig.1: Contributions in % to the integrated cross section in quasi-susy, i $\lambda_3 = -0.61, M_{H^\pm} =$ 220i GeV; a) Higgs sector, $\tan\beta = 2$; b) Higgs sector, $\tan\beta = 30$; c) virtual Z, γ and soft bremsstrahlung; d) virtual W boxes; e) matter fermion sector, $m_{top} = 180 GeV, \tan\beta = 30$; f) same as e) but with $\tan\beta = 2$.

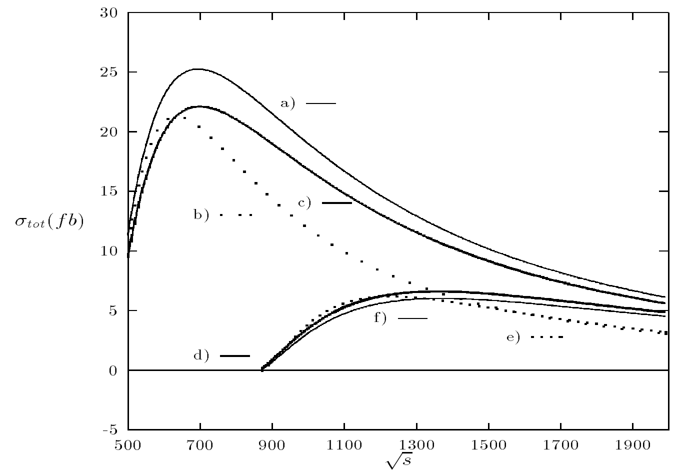

Fig.2: a) Tree-level, $M_{H^\pm} = 220 GeV$; b) quasi-susy, $\lambda_3 = -0.61$ (MSSM value -0.71), $\tan\beta =$ 30; c) quasi-susy, $\lambda_3 = -0.61, \tan\beta = 2$; d) Tree-level, $M_{H^\pm} = 430 GeV$; e) quasi-susy, $\lambda_3 = -2.6$ (MSSM value -2.84), $\tan\beta = 30$; f) same as e) but with $\tan\beta = 2$; $m_{top} = 180 GeV$.