Sfermion production at a Linear Collider at one-loop

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We present the complete one-loop corrections to the sfermion pair production process $e^+e^- \rightarrow \tilde{f}_i \tilde{f}_j$ ($f = t, b, \tau, \nu, u, d, s, c$) in the Minimal Supersymmetric Standard Model. Our results also include the previously calculated SUSY-QCD corrections. We present some details of the renormalization scheme used. It is found that the weak corrections are of the same magnitude as the SUSY-QCD corrections at higher energies ($\sqrt{s} \sim 1 \text{ TeV}$). At these energies an important part of the weak corrections stems from the box contribution. We also include cross-sections for polarized beams and left-right asymmetry.

1 Introduction

Supersymmetry (SUSY) requires the existence of two scalar particles (sfermions) $\tilde{f}_L, \tilde{f}_R$ corresponding to the two chirality states of each fermion $f$. The sfermions of the third generation play a special role as $\tilde{f}_L$ and $\tilde{f}_R$ may strongly mix (proportionally to the fermion mass), forming the two mass eigenstates $\tilde{f}_1$ and $\tilde{f}_2$ (with $f = t, b, \tau$). As a consequence one eigenstate ($\tilde{f}_1$) can have a much lower mass than the other one and the mixing angle becomes an important parameter.

Sfermion pair production in $e^+e^-$ collisions, $e^+e^- \rightarrow \tilde{f}_i \tilde{f}_j, (i, j = 1, 2)$, has been studied extensively phenomenologically.\(^1\) The strong interest in sfermion production is mainly due to the fact that it gives access to one of the fundamental SUSY breaking parameters $A_f$, the trilinear coupling parameter.

It is clear that in the case of squark production QCD and SUSY-QCD corrections play an important role.\(^2\) Yukawa corrections\(^2\) were shown to be non negligible either. Here we review the results of the calculation of the full one-loop corrections to sfermion pair production within the Minimal Supersymmetric Standard Model (MSSM) as given in Refs.\(^2\).\(^3\). A complementary calculation of a production process with selectrons, smuons and the corresponding sneutrinos in the final state was also performed in Ref.\(^4\).
2 Calculation

The one-loop (renormalized) cross-section $\sigma^{\text{ren}}$ is expressed as

$$\sigma^{\text{ren}}(e^+e^- \rightarrow \tilde{f}_i \tilde{f}_j) = \sigma^{\text{tree}} + \Delta \sigma^{\text{QCD}} + \Delta \sigma^{\text{EW}}, \quad (1)$$

The electro-weak part can be further split into separate contributions\(^a\)

$$\Delta \sigma^{\text{EW}} = \Delta \sigma^{\text{vertex}} + \Delta \sigma^{\text{prop}} + \Delta \sigma^{\text{box}}, \quad (2)$$

where the individual terms denote renormalized vertices, renormalized propagators and box contributions, respectively. We restrict the discussion to pure weak corrections which do not require any inclusion of bremsstrahlung and are thus $\Delta E$ independent. Moreover we can separate the weak part on the basis of Feynman diagrams in a gauge-invariant way.

All the plots presented here use a scenario based on the SPS1a parameter input.\(^5\) As we use the on-shell (OS) values as input, we transform the DR parameters of the SPS1a scenario to obtain the OS parameters using the relation

$$X^{\text{OS}} = X^{\text{DR}}(Q) - \delta X^{\text{OS}}(Q). \quad (3)$$

3 Conclusion

Electroweak corrections are shown not to be negligible. In particular at high energy the contribution from box diagrams is important (see Fig.1). In case of sneutrino production where there is no QCD contribution and the Yukawa corrections are not so large (due to $m_{\nu} = 0$), the box contribution is the leading one-loop correction. The production of squarks of the 1st and 2nd generation is similar because the Yukawa couplings are zero (we neglect the masses of all quarks of the 1st and 2nd generation) and so the box diagrams are the largest weak correction.

Some additional information about higher order corrections can be extracted from polarized cross-sections and forward-backward asymmetries (see Fig.2). Here the forward-backward asymmetry $A_{FB}$ comes only from one loop corrections as there is no asymmetry at the tree-level.

A further goal is to include also the full QED corrections and thus complete the full $O(\alpha)$ calculation.

\(a\)These contributions are not necessarily gauge invariant. The whole calculation and the separation of the contributions were carried out in 't Hooft-Feynman gauge.
Figure 1: Stop production with the off-diagonal channel relative corrections shown.

Figure 2: Left: Forward-backward asymmetry in sbottom production Right: Polarized cross sections for stop production ($e^-$ beam polarized).

References

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