

Associated neutralino-neutralino-photon production at NLC

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We study the potential of an e^+e^- linear collider to search for neutralino-neutralino-photon production. Our analysis shows that this signal is not viable under realistic expectations for electron beam polarization due to large Standard Model backgrounds. Such a search would be possible only if beam polarizations of near 100% could be achieved.

As part of the Snowmass effort to investigate the physics potential of next linear colliders, we have studied the possibility of extending the parameter space reach of e^+e^- colliders by searching for production of $\tilde{\chi}_1^0\tilde{\chi}_1^0\gamma$ events.

The photon plays a role of the trigger for pair production of massive invisible particles such as neutralinos in e^+e^- collisions. The Feynman diagrams for the $e^+e^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0\gamma$ *gamma* process are shown in Figure 1. The main irreducible background for this reaction is the Standard Model (SM) process of neutrino pair plus photon production— $e^+e^- \rightarrow \nu\nu\gamma$. The background Feynman diagrams are shown in Figure 2. One can expect strong background dependence on the polarization of the electrons in the initial state since W -boson exchange with pure left(right) coupling to the electron(positron) occurs. Those diagrams could be “switched off” in the ideal case of the 100% right polarized electron beam. If we imagine this idealized situation, then the main SM background will come from the off-shell Z-boson (on shell Z-boson contributions can be eliminated by using cut on the photon energy).

To illustrate this situation qualitatively we have chosen the center of mass energy of e^+e^- equal to 500 GeV as well as the following set of the supersymmetric parameters:

- 1) gaugino masses $M_1=M_2=200$ GeV,
- 2) selectron masses: $m_{\tilde{e}_{1,2}}=500$ GeV,
- 3) $\tan\beta = 3$ and $\mu = 300$ GeV,

for which $m_{\tilde{\chi}^0} = 157$ GeV. We first apply a cut on the photon transverse momentum $p_T^\gamma > 10$ GeV to avoid soft and collinear divergences of the cross section for this tree-level process. Our calculations has been done using the CompHEP software package [1].

For this choice of parameters, in case of unpolarized electron-positron beams the signal is 0.14 fb while the background is 2300 fb i.e. about 4 orders of magnitude bigger than the signal. In case of 100% left-polarized electron (100% right-polarized positron) beam signal and background cross section increase by about a factor 3 and become 0.36 and 7300 fb respectively. As expected, the situation for S/B ratio drastically changes in case of opposite electron (positron)polarization. For a 100% right-polarized electron beam the signal drops only by factor 2 compared to 100% left-polarized case and becomes equal to 18 fb while background is reduced by factor more than 20 down to 342 fb.

Further improvement of the signal to background ratio could be done by elimination of the on-shell Z-boson contribution for the background. To do this one can study the transverse momentum and energy distribution of the photon and apply corresponding kinematical cuts. In Figure 3, 4 we present photon transverse momentum and energy respectively. The first natural cut following from the p_T^γ distribution is $p_T^\gamma < 150$ GeV. The E^γ distribution of the background has the bump around 240 GeV which is connected with the Z-boson resonance in $\nu\nu$ mass distribution. We apply $E^\gamma < 150$ GeV cut to eliminate Z-boson on-shell contribution. Suggested p_T^γ and E^γ cuts reduce background further by factor more than 30. It becomes now 10 fb. The signal remains unchanged. The signal to background ratio is still $(0.18 \text{ fb}/10 \text{ fb}) \sim 1/50$.

Finally we have applied detector acceptance cut for the photon $|\cos\theta_\gamma| < 0.95$ which reduces the signal only by 14% (down to 0.16 fb) while background drops by 33% down to 7.7 fb because

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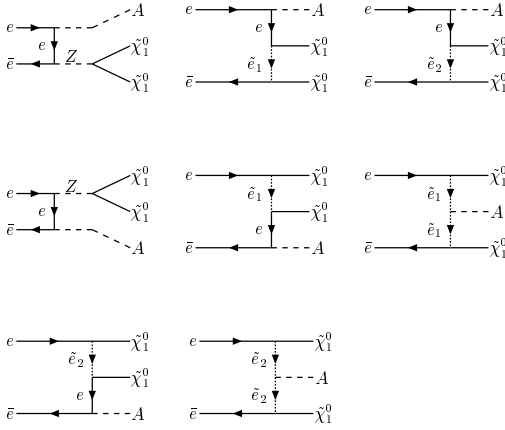


Figure 1: Feynman diagrams for $e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \gamma$ process

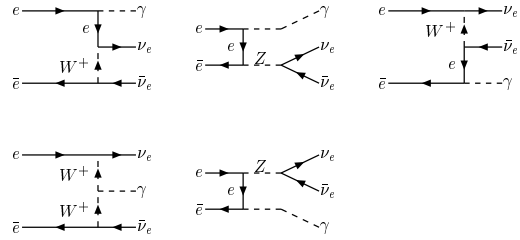


Figure 2: Feynman diagrams for $e^+e^- \rightarrow \nu \nu \gamma$ SM background process

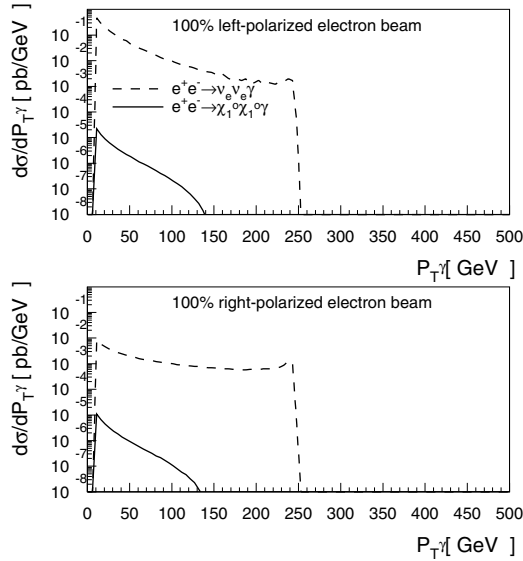


Figure 3: Photon transverse momentum distribution of $e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \gamma$ signal process (solid line) and its $e^+e^- \rightarrow \nu \nu \gamma$ background process (dashed line). Upper plot presents distributions for 100% left-polarized electron while bottom plot is for 100% right-polarized electron case.

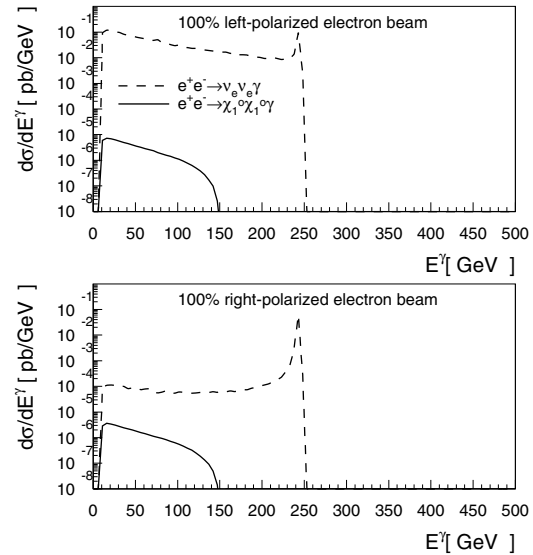


Figure 4: Photon energy distribution of $e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \gamma$ signal process (solid line) and its $e^+e^- \rightarrow \nu \nu \gamma$ background process (dashed line). Upper plot presents distributions for 100% left-polarized electron while bottom plot is for 100% right-polarized electron case.

background photon tends to be little bit more forward-backward than that from signal.

There is no any further cuts were found to significantly reduce the background. Therefore one could check the possible signal enhancement factors: signal dependence on selectron mass (Fig. 5) and neutralino mass together with neutralino mixing matrix elements.

In Figure 6 we present contour plots of the signal cross section and the neutralino mass (150 GeV) and chargino mass (250 GeV) in the (μ, M_1) plane for which $m_{\tilde{e}_{1,2}}$ was fixed to 250 GeV. For this figure we use also $M_2 = 2M_1$ and $\tan \beta = 3$.

One can see from Figure 6 that signal cross section could be as big as 5 fb for $M_1 \leq 150$ GeV and

$m_{\tilde{\chi}_1^0} \sim 150$ GeV. This happens when the neutralino is almost a pure gaugino. Thus, the process looks viable for pure right polarized beams.

Using a more realistic electron right handed polarization of 95%, the background level after all cuts is at the 150 fb level, far beyond the best signal levels. Therefore the process under study is not likely to be useful for extending the SUSY parameter space reach of an e^+e^- linear collider unless an almost pure level of beam polarization can be achieved.

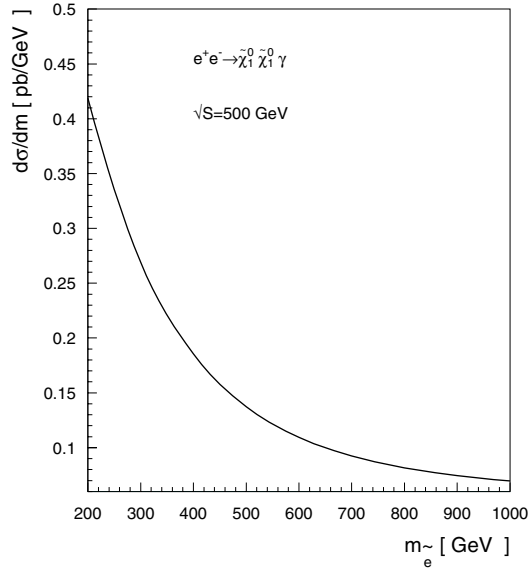


Figure 5: Cross section of $e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \gamma$ as the function of the selectron mass for non-polarized electron beam. SUSY parameters were taken as follows: $\mu = 300$ GeV, $M_1 = M_2 = 200$ GeV, $\tan \beta = 3$.

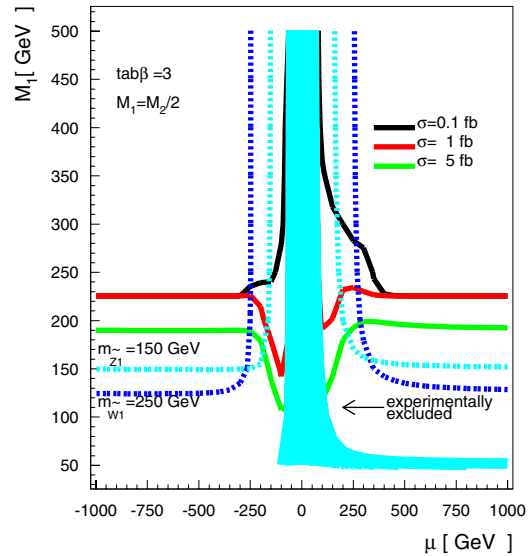


Figure 6: Contour plot of the signal cross section and neutralino mass iso-levels in (μ, M_1) plane for $m_{\tilde{e}_{1,2}} = 500$ GeV.

Acknowledgments

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References

- [1] Pukhov, A. and others, *CompHEP: A package for evaluation of Feynman diagrams and integration over multi-particle phase space. User's manual for version 33*, 1999, hep-ph/9908288.