CONSTRAINING THE SELECTRON MASS IN THE PROCESS $e^- + \gamma \longrightarrow \tilde{\chi}_1^0 + \tilde{e}^-_{\mathrm{L/R}} \longrightarrow e^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$ *

Claus Blöchinger and Hans Fraas

Institut für Theoretische Physik, Universität Würzburg
Am Hubland, D-97074 Würzburg, Germany
e-mail:bloechi@physik.uni-wuerzburg.de
e-mail:fraas@physik.uni-wuerzburg.de

(Received October 25, 1999)

With the process $e^-\gamma \to \tilde{\chi}_1^0 \tilde{e}^-_{\mathrm{L/R}} \to e^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$ it is possible to constrain selectron masses above the kinematical limit of the pair production process in e^+e^- colliders. We investigate these mass ranges and discuss the possibility to test the renormalization group equations for the selectron masses.

PACS numbers: 11.30.Pb, 13.88.+e, 14.80.Ly

1. Introduction

The electron-photon collision mode of an e^+e^- linear collider [1] provides us with the possibility to produce single selectrons in association with the lightest supersymmetric particle (LSP), which is assumed to be the lightest neutralino $\tilde{\chi}_1^0$. Thus selectrons can be produced with masses beyond the kinematical range for pair production at an e^+e^- linear collider. Also the production mechanism (electron exchange in the s-channel and selectron exchange in the t-channel) for associated selectron-neutralino production is simpler than that for selectron pair production in e^+e^- collisions. Assuming a common scalar mass m_0 at the unification point the masses of the selectrons are related to the MSSM parameters $\tan\beta$ and M_2, the SU(2) gaugino mass parameter, by renormalization group equations [2]. In the MSSM quite generally the right selectron $\tilde{e}_{\mathrm{R}}$ is lighter than the left selectron $\tilde{e}_{\mathrm{L}}$. In extended SUSY models, however, $\tilde{e}_{\mathrm{R}}$ could be heavier than $\tilde{e}_{\mathrm{L}}$ [3]. We study in this paper the process $e^-\gamma \longrightarrow \tilde{\chi}_1^0 \tilde{e}_{\mathrm{L/R}} \longrightarrow e^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$ with polarized beams.

* Presented by C. Blöchinger at the XXIII International School of Theoretical Physics "Recent Developments in Theory of Fundamental Interactions", Ustroń, Poland, September 15–22, 1999.

Since the cross section and the forward-backward asymmetry of the decay electron depend sensitively on the selectron masses this process is suitable for testing the renormalization group relation between $m_{\tilde{e}_{\rm R}}$ and $m_{\tilde{e}_{\rm L}}$.

2. Cross section and forward–backward asymmetry

The associated production of selectrons and the LSP proceeds via e^- exchange in the s-channel and $\tilde{e}_{\rm L/R}$ exchange in the t-channel. In the narrow width approximation the total cross section $\sigma_{e\gamma}^{\rm L/R}$ for the combined process of $\tilde{e}^-_{\rm L/R}\tilde{\chi}^0_1$ production and the subsequent decay $\tilde{e}^-_{\rm L/R} \longrightarrow e^-\tilde{\chi}^0_1$ factorizes into the production cross section σ_P and the leptonic branching ratio:

$$\sigma_{e\gamma}^{\rm L/R} = \sigma_P\left(s_{e\gamma}\right)\cdot {\rm BR}\left(\tilde{e}^-_{\rm L/R} \longrightarrow e^-\tilde{\chi}^0_1\right) . \tag{1}$$

The measured cross section $\sigma_{ee}^{\rm L/R}$ in the e^+e^- cms is obtained by folding $\sigma_{e\gamma}^{\rm L/R}$ with the energy spectrum $P(y)$ of the Compton backscattered laser beam taking into account the mean helicity of the photon beam [4]:

$$\sigma_{ee}^{\rm L/R} = \int dyP\left(y\right)d\hat{\sigma}_{e\gamma}^{\rm L/R}\left(s_{e\gamma}=ys_{ee}\right) , \tag{2}$$

$$\hat{\sigma}_{e\gamma}^{\rm L/R} = \sigma_{e\gamma}^{\rm L/R}\left(1+\lambda\left(y\right)A_c\right) . \tag{3}$$

A_c is the circular photon asymmetry and $y = E_\gamma/E_e$ is the ratio of the photon energy and the energy of the converted electron beam. The energy spectrum $P\left(y\right)$ and the mean helicity $\lambda\left(y\right)$ of the high energy photon beam sensitively depend on the polarizations $\lambda_{\rm L}$ of the laser beam and λ_k of the converted electron beam. Beyond the cross section $\sigma_{ee} = \sigma_{ee}^L + \sigma_{ee}^R$, we study the forward-backward asymmetry of the decay electrons:

$$A_{\rm FB} = \frac{\sigma_{ee}^{\rm F} - \sigma_{ee}^{\rm B}}{\sigma_{ee}^{\rm F} + \sigma_{ee}^{\rm B}} . \tag{4}$$

The forward direction is defined by the electron beam.

Apart from the kinematics the selectron masses enter the cross sections and the forward-backward asymmetries explicitly via the selectron propagator in the t-channel. Assuming a common scalar mass m_0 at the unification point the masses of the selectrons are related to the MSSM parameters $\tan\beta$ and the gaugino mass parameter M_2 by renormalization group equations [2]:

$$m^2_{\tilde{e}_{\rm R}} = m_e^2 + m_0^2 + 0.23M_2^2 - m_Z^2\cos 2\beta\sin^2\theta_W , \tag{5}$$

$$m^2_{\tilde{e}_{\rm L}} = m_e^2 + m_0^2 + 0.79M_2^2 + m_Z^2\cos 2\beta\left(-0.5+\sin^2\theta_W\right) . \tag{6}$$

In the MSSM quite generally the right selectron $\tilde{e}_{\rm R}$ is lighter than the left selectron $\tilde{e}_{\rm L}$. In extended SUSY models these relations are changed as a consequence of additional D-terms in the scalar potential and the right selectron may be heavier than the left selectron.

In Chapter 3 we study the dependence of the cross section σ_{ee} and the forward-backward asymmetry $A_{\rm FB}$ on $m_{\tilde{e}_{\rm R}}$ and $m_{\tilde{e}_{\rm L}}$. We shall see that this process is useful for testing the GUT-relations Eqs. (5), (6).

3. Numerical results

We present numerical results for the MSSM parameters $M_2 = 152$ GeV, $M_1 = 78.7$ GeV, $\mu = 316$ GeV and $\tan\beta = 3$ for the cms-energy $\sqrt{s_{ee}} = 500$ GeV. The LSP is gaugino-like with $m_{\tilde{\chi}^0_1} = 71.9$ GeV. For $m_{\tilde{e}_{\rm R}} = 127$ GeV and $m_{\tilde{e}_{\rm L}} = 171$ GeV this corresponds to one ECFA/DESY reference scenario for the linear collider [5]. Fig. 1 shows the total cross section σ_{ee} and the forward-backward asymmetry $A_{\rm FB}$ for $\lambda_k = +1$ and $\lambda_{\rm L} = -1$. This choice of λ_k and $\lambda_{\rm L}$ leads to a strongly marked high energetic peak in the energy spectrum $P(y)$ [4] and therefore to maximal cross sections. For the electron beam in the $e\gamma$ collision we choose in Fig. 1(a), (b) the polarization $P_e = 0.9$. Then due to $\sigma_{ee}^{\rm L/R} \propto (1 \mp P_e)$ the cross section for $\tilde{e}_{\rm R}$ is enhanced whereas that for $\tilde{e}_{\rm L}$ is strongly suppressed so that σ_{ee} is nearly independent of $m_{\tilde{e}_{\rm L}}$. The cross section for this polarization configuration (Fig. 1(a)) allows to constrain $m_{\tilde{e}_{\rm R}}$ up to 344 GeV. In a region around 200 GeV the dependence of σ_{ee} on $m_{\tilde{e}_{\rm R}}$ is rather weak. In this case $A_{\rm FB}$ (Fig. 1(b)) gives additional informations on the mass $m_{\tilde{e}_{\rm R}}$. For $m_{\tilde{e}_{\rm R}} > 344$ GeV the production of right selectrons becomes impossible and due to the suppression by the polarization factor $(1 - P_e)$ the cross section is rather small: $\sigma_{ee} = \sigma_{ee}^L \sim 2.5$ fb for $m_{\tilde{e}_{\rm L}} = 100$ GeV. Then $A_{\rm FB}$ only depends on $\sigma_{ee}^{\rm L}$ and is independent of $m_{\tilde{e}_{\rm R}}$ (see Fig. 1(b)).

For Figs. 1(c) and 1(d) we choose $P_e = -0.9$. Now the production and decay of left selectrons is no longer neglectible. Fig. 1(c) gives the cross sections for three different masses $m_{\tilde{e}_{\rm R}} = 100$ GeV, 127 GeV, 200 GeV. In all three cases it should be possible to constrain $m_{\tilde{e}_{\rm L}}$ up to 170 GeV. For masses larger than 170 GeV the dependence of σ_{ee} on $m_{\tilde{e}_{\rm L}}$ is too weak so that one obtains only a lower limit on $m_{\tilde{e}_{\rm L}}$. For large values of $m_{\tilde{e}_{\rm R}}$ the measurement of the asymmetry $A_{\rm FB}$ (Fig. 1(d)) could be helpful to extend this mass range to somewhat higher values.

If the renormalization group relations Eqs. (5), (6) are satisfied then $m_{\tilde{e}_{\rm L}}$ is larger than $m_{\tilde{e}_{\rm R}}$, $m^2_{\tilde{e}_{\rm L}} - m^2_{\tilde{e}_{\rm R}} \sim 0.56 M_2^2$. This relation can be tested with the total cross sections in figures 1a and 1c up to $m_{\tilde{e}_{\rm L}} = 170$ GeV, complementary to the measurements at an e^+e^--collider. Fig. 1d shows that for higher masses of $\tilde{e}_{\rm R}$ the asymmetry could allow a test of the renormalization group relations, Eqs. (5),(6).

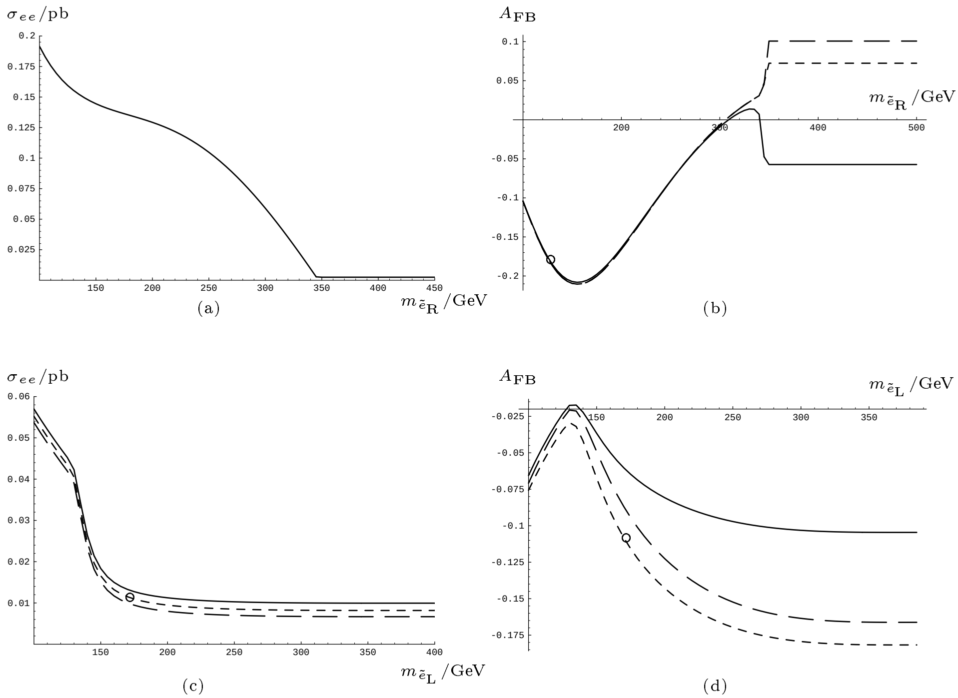

Fig. 1. Cross sections and forward-backward asymmetries for $\sqrt{s}_{ee} = 500$ GeV, $\lambda_k = +1$, $\lambda_L = -1$ (the values of the ECFA/DESY reference scenario are marked by small circles); (a) dependence of the total cross section σ_{ee} on $m_{\tilde{e}_R}$ for $P_e = 0.9$ and $m_{\tilde{e}_L} = 100$ GeV (nearly independetnt of $m_{\tilde{e}_L}$); (b) dependence of the asymmetry A_{FB} on $m_{\tilde{e}_R}$ for $P_e = 0.9$ ($m_{\tilde{e}_L} = 100$ GeV ——–, $m_{\tilde{e}_L} = 171$ GeV - - - -, $m_{\tilde{e}_L} = 200$ GeV — — —); (c) dependence of the total cross section σ_{ee} on $m_{\tilde{e}_L}$ for $P_e = -0.9$ ($m_{\tilde{e}_R} = 100$ GeV ——–, $m_{\tilde{e}_R} = 127$ GeV - - - -, $m_{\tilde{e}_R} = 200$ GeV — — —); (d) dependence of the asymmetry A_{FB} on $m_{\tilde{e}_L}$ for $P_e = -0.9$ ($m_{\tilde{e}_R} = 100$ GeV ——–, $m_{\tilde{e}_R} = 127$ GeV $- - - -$, $m_{\tilde{e}_R} = 200$ GeV — — —)

4. Conclusion

With a suitable choice of beam polarizations it is possible to constrain $m_{\tilde{e}_R}$ up to 344 GeV and $m_{\tilde{e}_L}$ up to 170 GeV in the process $e^-\gamma \to \tilde{\chi}_1^0 \tilde{e}_{L/R} \to e^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$ from a measurement of the total cross sections. The forward-backward asymmetry A_{FB} gives additional information on these masses. Especially one could measure masses $m_{\tilde{e}_L} > 170$ GeV if $m_{\tilde{e}_R}$ is high enough. The cross sections and the forward-backward asymmetries allow to test the equations for the selectron masses complementary to an e^+e^--collider.

We are grateful to Gudrid Moortgat-Pick and Stefan Hesselbach for valuable discussions. Claus Blöchinger thanks the organizers of the XXIII. School of Theoretical Physics for the friendly atmosphere during the conference. This work was supported by the Deutsche Forschungsgemeinschaft under contract no. FR 1064/4-1, the Bundesministerium für Bildung und Forschung (BMBF) under contract number 05 HT9WWA 9 and the Stiftung für deutsch-polnisch Zusammenarbeit, Warszawa.

REFERENCES

[1] I. Ginzburg, G. Kotkin, V. Serbo, V. Telnov, *Nucl. Instrum. Methods* **205**,47 (1983); V. Telnov, Proceedings of the First Arctic Workshop on Future Physics and Accelerators, Saariselka, 1994, eds. M. Chaichian, K. Huitu, R. Orava.

[2] L.J. Hall, J. Polchinski, *Phys. Lett.* **152B**, 335 (1985).

[3] M. Drees, *Nucl. Phys.* **B298**, 333 (1988); H.-C. Cheng, L.J. Hall, *Phys. Rev.* **D51**, 5289 (1995); C. Kolda, S.P. Martin, *Phys. Rev.* **D53**, 3871 (1996); E. Keith, E. Ma, B. Mukhopadhyaya, *Phys. Rev.* **D55**, 3111 (1997); H. Baer, M. A. Diaz, J. Ferrandis, X. Tata, hep-ph/9907211; S. Hesselbach, Ph.D. thesis, University of Würzburg, 1999.

[4] I.F. Ginzburg, G.L. Kotkin, S.L. Panfil, V.G. Serbo, V.I. Telnov, *Nucl. Instrum. Methods Phys. Res.* **A219**, 5 (1984); D.L. Borden, D.A. Bauer, D.O. Caldwell, *Phys. Rev.* **D48**, 4018 (1993); D.L. Borden, D.A. Bauer, D.O. Caldwell, SLAC-PUB-5715, 1992, UCSB-HEP-92-01, 1992; F. Cuypers, G.J. van Oldenborgh, R. Rückl, *Nucl. Phys.* **B383**, 45 (1992); F. Cuypers, G. J. van Oldenborgh, R. Rückl, in e^+e^- Collisions at 500 GeV: The Physics Potential, Part B, Proceedings of the Workshop, Munich, Annecy, Hamburg, Germany, 1993, edited by P. M. Zerwas, DESY Report No. 93-123C, Hamburg,1993, p. 475.

[5] S. Ambrosanio, G.A. Blair, P. Zerwas, ECFA-DESY LC-Workshop, 1998, http://www.desy.de/conferences/ecfa-desy-lc98.html.