Constraining the Selectron Mass in the Process
$$e^- + \gamma \rightarrow \tilde{\chi}^0_1 + \tilde{e}^-_{L/R} \rightarrow e^- \tilde{\chi}^0_1 \tilde{\chi}^0_1$$

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With the process $e^- \gamma \rightarrow \tilde{\chi}^0_1 \tilde{e}^-_{L/R} \rightarrow e^- \tilde{\chi}^0_1 \tilde{\chi}^0_1$ 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.

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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 $\tilde{\chi}^0_1$. 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 $\tilde{e}_R$ is lighter than the left selectron $\tilde{e}_L$. In extended SUSY models, however, $\tilde{e}_R$ could be heavier than $\tilde{e}_L$. 

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We study in this paper the process $e^- \gamma \rightarrow \tilde{\chi}_1^0 e_L/R \rightarrow e^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$ with polarized beams. 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 $m_{\tilde{e}_R}$ and $m_{\tilde{e}_L}$.

2. Cross Section and Forward-Backward Asymmetry

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

$$\sigma_{e\gamma}^{L/R} = \sigma_P(s_{e\gamma}) \cdot BR(\tilde{e}_{L/R}^- \rightarrow e^- \tilde{\chi}_1^0) \quad (1)$$

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

$$\sigma_{ee}^{L/R} = \int dy P(y) d\sigma_{e\gamma}^{L/R} (s_{e\gamma} = y s_{ee}) \quad (2)$$

$$d\sigma_{e\gamma}^{L/R} = \sigma_{e\gamma}^{L/R} (1 + \lambda(y) A_c) \quad (3)$$

$A_c$ 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 $P(y)$ and the mean helicity $\lambda(y)$ of the high energy photon beam sensitively depend on the polarizations $\lambda_L$ of the laser beam and $\lambda_k$ 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:

$$A_{FB} = \frac{\sigma_{ee}^F - \sigma_{ee}^B}{\sigma_{ee}^F + \sigma_{ee}^B} \quad (4)$$

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]:

$$m_{\tilde{e}_R}^2 = m_e^2 + m_0^2 + 0.23 M_2^2 - M_2^2 \cos 2\beta \sin^2 \theta_W \quad (5)$$
\[ m_{\tilde{e}_L}^2 = m_\nu^2 + m_0^2 + 0.79 M_2^2 + m_Z^2 \cos 2\beta \left(-0.5 + \sin^2 \theta_W \right) \]  

(6)

In the MSSM quite generally the right selectron \( \tilde{e}_R \) is lighter than the left selectron \( \tilde{e}_L \). 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 \( \sigma_{ee} \) and the forward-backward asymmetry \( A_{FB} \) on \( m_{\tilde{e}_R} \) and \( m_{\tilde{e}_L} \). We shall see that this process is useful for testing the GUT-relations equs. (5), (6).

3. Numerical Results

We present numerical results for the MSSM parameters \( M_2 = 152 \text{ GeV}, M_1 = 78.7 \text{ GeV}, \mu = 316 \text{ GeV} \) and \( \tan \beta = 3 \) for the cms-energy \( \sqrt{s_{ee}} = 500 \text{ GeV} \). The LSP is gaugino-like with \( m_{\tilde{\chi}_0^1} = 71.9 \text{ GeV} \). For \( m_{\tilde{e}_R} = 127 \text{ GeV} \) and \( m_{\tilde{e}_L} = 171 \text{ GeV} \) this corresponds to one ECFA/DESY reference scenario for the linear collider [5]. Fig. 1 shows the total cross section \( \sigma_{ee} \) and the forward-backward asymmetry \( A_{FB} \) for \( \lambda_k = +1 \) and \( \lambda_L = -1 \). This choice of \( \lambda_k \) and \( \lambda_L \) 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. 1a,b the polarization \( P_\gamma = 0.9 \). Then due to \( \sigma_{ee}^{L/R} \propto (1 \mp P_\gamma) \) the cross section for \( \tilde{e}_R \) is enhanced whereas that for \( \tilde{e}_L \) is strongly suppressed so that \( \sigma_{ee} \) is nearly independent of \( m_{\tilde{e}_L} \). The cross section for this polarization configuration (fig. 1a) allows to constrain \( m_{\tilde{e}_R} \) up to 344 GeV. In a region around 200 GeV the dependence of \( \sigma_{ee} \) on \( m_{\tilde{e}_R} \) is rather weak. In this case \( A_{FB} \) (fig. 1b) gives additional informations on the mass \( m_{\tilde{e}_R} \). For \( m_{\tilde{e}_R} > 344 \text{ GeV} \) the production of right selectrons becomes impossible and due to the suppression by the polarization factor \((1 - P_\gamma)\) the cross section is rather small: \( \sigma_{ee} \approx 2.5 \text{ fb} \) for \( m_{\tilde{e}_L} = 100 \text{ GeV} \). Then \( A_{FB} \) only depends on \( \sigma_{ee}^L \) and is independent of \( m_{\tilde{e}_R} \) (see fig. 1b).

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

If the renormalization group relations equs. (5), (6) are satisfied then \( m_{\tilde{e}_L} \) is larger than \( m_{\tilde{e}_R}, m_{\tilde{e}_L}^2 - m_{\tilde{e}_R}^2 \sim 0.56 M_2^2 \). This relation can be tested with the total cross sections in figure 1a and 1c up to \( m_{\tilde{e}_L} = 170 \text{ GeV} \), com-
Fig. 1. Cross sections and forward-backward asymmetries for $\sqrt{s_{ee}} = 500$ GeV, $\lambda_\ell = +1, \lambda_L = -1$ (the values of the ECFA/DESY reference scenario are marked by small circles): (a) dependence of the total cross section $\sigma_{ee}$ on $m_{\tilde{e}_R}$ for $P_e = 0.9$ and $m_{\tilde{e}_L} = 100$ GeV (nearly independent 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 $\sigma_{ee}$ 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 $e^-\gamma \rightarrow \chi^0_1\chi^0_{1L/R} \rightarrow e^-\chi^0_1\chi^0_1$ 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.

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