SELECTRON MASS EFFECTS IN NEUTRALINO PRODUCTION*

S. Hesselbach and H. Fraas

Institut für Theoretische Physik, Universität Würzburg
Am Hubland, D-97074 Würzburg, Germany

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We study the possibility to measure the masses of the selectrons in neutralino production at an e^+e^- linear collider with polarized beams. The cross sections and polarization asymmetries of neutralinos with gaugino character strongly depend on the masses of the exchanged selectrons. If the usual GUT relations of the selectron masses in the MSSM are relaxed large effects are possible especially in the polarization asymmetries. These can be used to determine the masses of both selectrons.

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1. Introduction

The search for supersymmetric particles and the determination of their masses is one of the main goals of a future e^+e^- linear collider. Especially the use of polarized beams plays an important role for the measurement of the parameters of the underlying supersymmetric model.

In our contribution we study the effects of the selectron masses on the cross sections, polarization asymmetries and decay angular distributions of neutralino production in e^+e^- annihilation. We focus on the production of light neutralinos $e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_2^0$ in the Minimal Supersymmetric Standard Model (MSSM) [1] with GUT relation for the gaugino mass parameters $M_1/M_2 = 5/3\tan^2\theta_W$. We assume that the masses of the left selectron $m_{\tilde{e}_{\mathrm{L}}}$ and of the right selectron $m_{\tilde{e}_{\mathrm{R}}}$ are both independent parameters of the model. The motivation for this is that in models with new U(1) factors in the gauge group also additional D-terms appear in the mass terms of the selectrons [2]. These D-terms are of the order of the masses $m_{Z'} = \mathcal{O}(1\ \mathrm{TeV})$

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of the corresponding new gauge bosons which results in larger differences between $m_{\tilde{e}_\mathrm{L}}$ and $m_{\tilde{e}_\mathrm{R}}$ and even $m_{\tilde{e}_\mathrm{R}} > m_{\tilde{e}_\mathrm{L}}$ is possible. The character of the light neutralinos in these extended supersymmetric models which can be motivated by superstring theory [3] is in most cases very similar to the MSSM [4, 5]. Therefore in the following the selectron mass effects in neutralino production will be discussed in the MSSM.

2. Production of neutralinos

In e^+e^- annihilation the higgsino components of the neutralinos are produced only via s channel exchange of Z bosons whereas the gaugino components are produced only via t and u channel exchange of selectrons [6]. So we choose a scenario

$$M_2 = 200 \text{ GeV}, \quad \mu = 350 \text{ GeV}, \quad \tan\beta = 3 \tag{1}$$

of the neutralino parameters where $\tilde{\chi}^0_1$ ($m_{\tilde{\chi}^0_1} = 93$ GeV) and $\tilde{\chi}^0_2$ ($m_{\tilde{\chi}^0_2} = 175$ GeV) have both a large gaugino component (96.5 % and 87.9 % respectively) to analyze the selectron mass effects. Then the contribution of the Z exchange can be neglected and for longitudinally polarized beams the total cross section [6, 7] consists of two terms describing the exchange of left and right selectrons, respectively $\sigma \approx \sigma_{\tilde{e}} = \sigma_{\tilde{e}_\mathrm{L}} + \sigma_{\tilde{e_\mathrm{R}}}$. The structure of $\sigma_{\tilde{e}_\mathrm{L/R}}$ is

$$\sigma_{\tilde{e}_\mathrm{L/R}} = (f^\mathrm{L/R}_{e1} f^\mathrm{L/R}_{e2})^2 \left[(1 - P_- P_+) \mp (P_- - P_+)\right] f(s, m_{\tilde{e}_\mathrm{L/R}}) \tag{2}$$

with the $\tilde{\chi}^0_i \tilde{e}_\mathrm{L/R} e_\mathrm{L/R}$ coupling $f^\mathrm{L/R}_{ei}$ [6] and the polarization $P_{-/+}$ of the electron and positron beam, respectively. Thus the selectron mass effects in the cross section σ and in the polarization asymmetry for electron beam polarization of 90 %

$$A_\mathrm{LR} = \frac{\sigma(P_- = -0.9) - \sigma(P_- = +0.9)}{\sigma(P_- = -0.9) + \sigma(P_- = +0.9)} \tag{3}$$

depend on the ratio

$$r_f = (f^\mathrm{R}_{e1} f^\mathrm{R}_{e2})^2 / (f^\mathrm{L}_{e1} f^\mathrm{L}_{e2})^2 \,. \tag{4}$$

In scenario (1) with $r_f = 0.19$ the exchange of $\tilde{e}_\mathrm{L}$ dominates.

Figs. 1(a), (b) show A_LR and σ for different values of $m_{\tilde{e}_\mathrm{L}}$ and a fixed value of $m_{\tilde{e}_\mathrm{R}}$. Because of the dominating $\tilde{e}_\mathrm{L}$ exchange σ drops significantly with increasing $m_{\tilde{e}_\mathrm{L}}$. Especially near threshold also A_LR strongly depends on $m_{\tilde{e}_\mathrm{L}}$. For $m_{\tilde{e}_\mathrm{L}} = m_{\tilde{e}_\mathrm{R}}$ it is approximately independent of energy $A_\mathrm{LR} \approx 0.9(1 - r_f)/(1 + r_f) \approx +60$ %. For $m_{\tilde{e}_\mathrm{L}} \gg m_{\tilde{e}_\mathrm{R}}$ it tends to the value -90 % at threshold, whereas for increasing energy it runs asymptotically to the

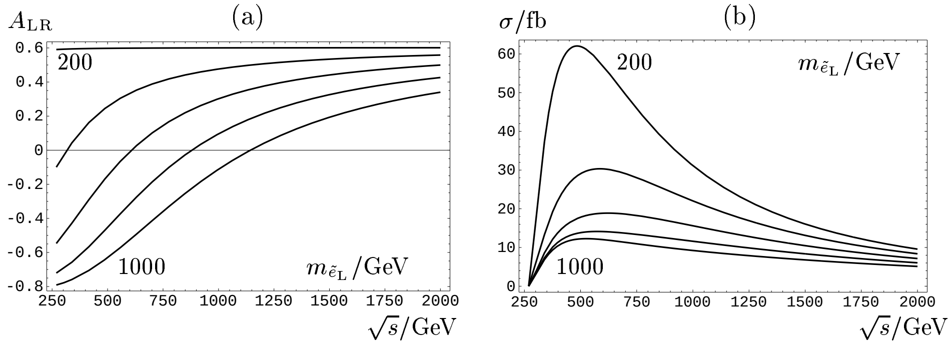

Fig. 1. (a) Polarization asymmetries $A_{\rm LR}$ and (b) cross sections σ of the process $e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2$ for $m_{\tilde{e}_{\rm R}} = 200$ GeV, $m_{\tilde{e}_{\rm L}} = 200$, 400, 600, 800 and 1000 GeV and $P_+ = 0$.

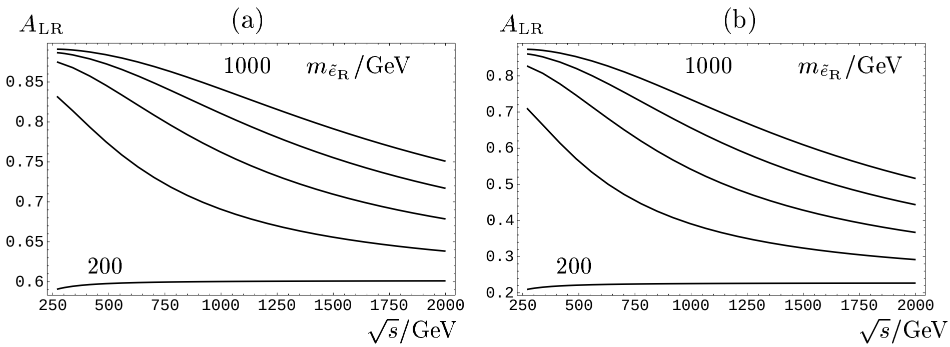

Fig. 2. Polarization asymmetries $A_{\rm LR}$ of the process $e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2$ for $m_{\tilde{e}_{\rm L}} = 200$ GeV, $m_{\tilde{e}_{\rm R}} = 200$, 400, 600, 800 and 1000 GeV and (a) $P_+ = 0$, (b) $P_+ = -50\,\%$.

value for equal masses. So $A_{\rm LR}$ has different sign near threshold depending on $m_{\tilde{e}_{\rm L}}$. In Fig. 2(a) $A_{\rm LR}$ is depicted for fixed $m_{\tilde{e}_{\rm L}}$ and different $m_{\tilde{e}_{\rm R}}$. For $m_{\tilde{e}_{\rm R}} \gg m_{\tilde{e}_{\rm L}}$ it tends to the value +90 % at threshold. Since the dominating contribution comes from $\tilde{e}_{\rm L}$ exchange the dependence on $m_{\tilde{e}_{\rm R}}$ is weaker than that on $m_{\tilde{e}_{\rm L}}$ in Fig. 1(a). For fixed $m_{\tilde{e}_{\rm L}}$ and increasing $m_{\tilde{e}_{\rm R}}$ also σ drops less than in Fig. 1(b) (*e.g.* $\sigma = 52$ fb for $m_{\tilde{e}_{\rm L}} = 200$ GeV, $m_{\tilde{e}_{\rm R}} = 1000$ GeV and $\sqrt{s} = 500$ GeV). The dependence on $m_{\tilde{e}_{\rm R}}$ can be enlarged if additionally the positron beam is polarized (Fig. 2(b)).

Fig. 3 shows the contours of $A_{\rm LR}$ and σ in the $m_{\tilde{e}_{\rm L}}$-$m_{\tilde{e}_{\rm R}}$ parameter space. These two observables form a network which in principle allows to determine the two selectron masses, if the parameters of the neutralino sector are known. In Fig. 4 the contours of r_f are plotted in the M_2-μ parameter space. Above the lines $r_f = 20$ the higgsino character of the neutralinos dominates, so the selectron mass effects are not visible. In the lower left corner (large negative μ) r_f is very small. Then only the left selectrons contribute to the cross section and therefore $A_{\rm LR} \approx +90$ % independently of $m_{\tilde{e}_{\rm R}}$. But in large regions of the parameter space not too far below the lines $r_f = 0.05$ both selectrons contribute and the selectron mass effects in the neutralino production are measurable.

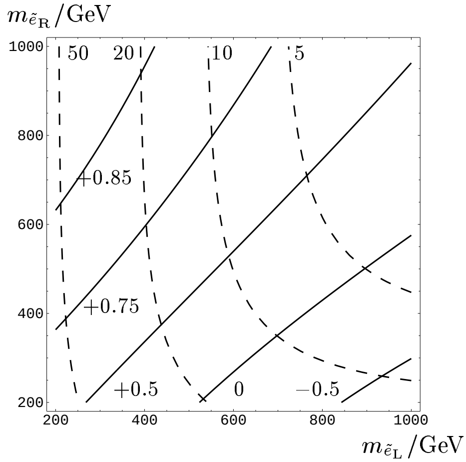

Fig. 3. Contours of the polarization asymmetry $A_{\rm LR}$ for $P_+ = 0$ (solid) and of the cross section (in fb) for $P_+ = P_- = 0$ (dashed) of the process $e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2$ for $\sqrt{s} = 500$ GeV.

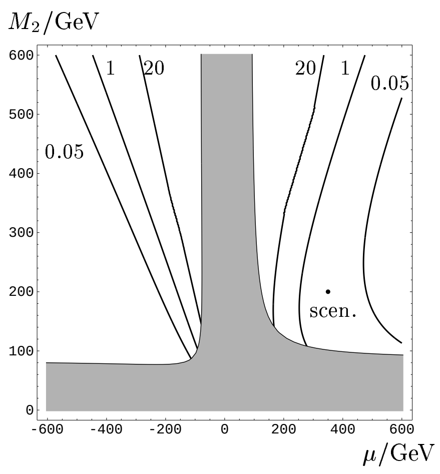

Fig. 4. Contours of the ratio r_f (4) for $\tan\beta = 3$. Also shown are the experimentally excluded parameter space (shaded) and the scenario (1).

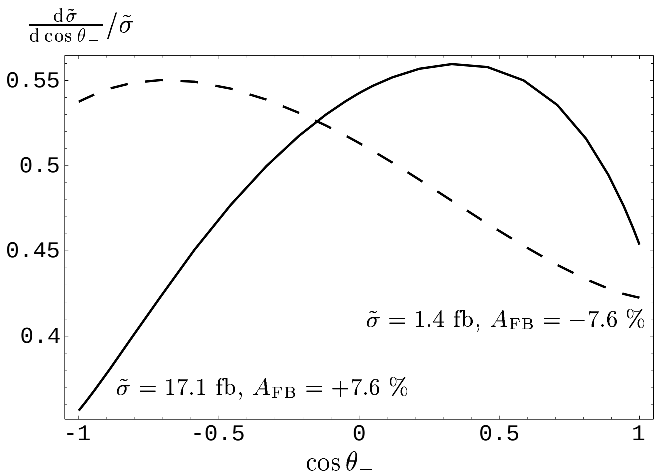

Fig. 5. Decay angular distributions of the decay leptons $\frac{d\tilde{\sigma}}{d\cos\theta_-}/\tilde{\sigma}$ for $P_- = -90$ %, $P_+ = 0$, $\sqrt{s} = 500$ GeV, $m_{\tilde{e}_R} = 200$ GeV and $m_{\tilde{e}_L} = 200$ GeV (solid) or $m_{\tilde{e}_L} = 400$ GeV (dashed).

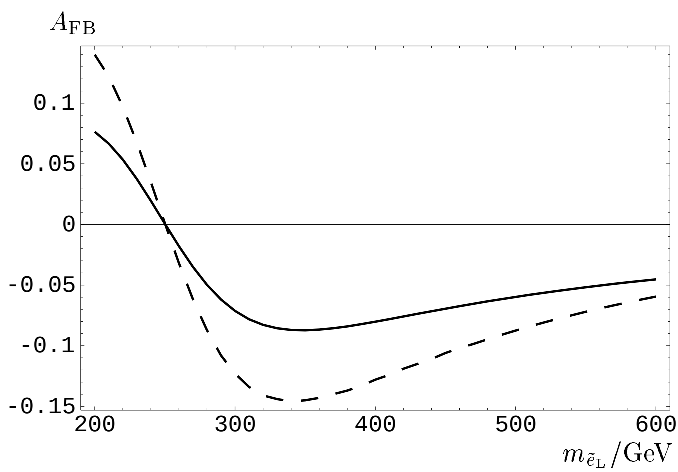

Fig. 6. Forward-backward asymmetries $A_{\rm FB}$ of the decay leptons for $P_- = -90$ %, $P_+ = 0$, $m_{\tilde{e}_R} = 200$ GeV and $\sqrt{s} = 500$ GeV (solid) or $\sqrt{s} = 300$ GeV (dashed).

In Fig. 5 the decay angular distributions $\frac{d\tilde{\sigma}}{d\cos\theta_-}$ for the leptonic decay of the $\tilde{\chi}^0_2$ are shown for two values of $m_{\tilde{e}_L}$. They are computed with full spin correlations between production and decay [8, 9] and are normalized on the total cross section $\tilde{\sigma}$ of the combined process $e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2 \to \tilde{\chi}^0_1\tilde{\chi}^0_1 e^+e^-$, where θ_- is the angle between the ingoing e^- and the outgoing e^-. The angular distributions also show a strong dependence on the selectron masses for the chosen beam polarization. The forward-backward asymmetries A_{FB} [8] change sign with increasing $m_{\tilde{e}_{\mathrm{L}}}$ (Fig. 6). The dependence of A_{FB} on $m_{\tilde{e}_{\mathrm{L}}}$ is larger for $\sqrt{s}$ closer to threshold.

3. Conclusions and outlook

The cross section, polarization asymmetry and forward-backward asymmetry of neutralino production strongly depend on the selectron masses for suitable beam polarization especially near threshold. A simultaneous measurement of σ and A_{LR} allows in principle the determination of the selectron masses. This also provides a possibility to discriminate between the MSSM and extended models. Thus beam polarization is an important feature of a future linear collider to determine the parameters of the underlying model.

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