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NEUTRALINO PRODUCTION IN POLARIZED e^+e^--COLLISIONS

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1. Introduction

The search for supersymmetric (SUSY) partners of the ordinary particles is an important task of the future high-energy colliders /1,2/. As it has been pointed out recently /3-6/ polarized initial beams may be quite useful in the attempts to discover supersymmetry.

Here, we discuss the production of two neutralinos in arbitrarily polarized e^+e^- collisions in the framework of minimal SUSY extended standard model /7/. The cross section of this process has been calculated earlier in refs. /8-11/ for unpolarised and in ref. /4/ for polarised initial beams.

In the present paper the general case of neutralino mixing is considered. CP-invariance of the Lagrangian is assumed and the explicit dependence of the cross section on the CP-parities of the produced Majorana particles is obtained.

Three characteristic cases of neutralino mixing according to the type (higgsino, gaugino or some superposition of gaugino and higgsino components) of one of the produced neutralinos are considered separately: It is shown that the cross section and the spin asymmetries exhibit specific behaviour for each of them, determined by the general property of SUSY that the gauge couplings are common for the SUSY and the ordinary particles.

Finally, one of the neutralinos is assumed to be the lightest SUSY particle (LSP), and the possibilities to determine its type are discussed.

2. Cross Section of the Polarized e^+e^- Annihilation into Neutralinos

Let us consider the process

$$e^+ + e^- \longrightarrow \chi_1 + \chi_2 \tag{1}$$

where neutralinos χ_1 and χ_2 are two of the four massive Majorana states that are in general some mixtures of the superpartners $\tilde{\gamma}$, $\tilde{Z}$, $\tilde{H}_1^0$ and $\tilde{H}_2^0$ of the neutral gauge and Higgs bosons. We assume that one of the neutralinos is the LSP and the other is a short-lived particle having a decay mode into the LSP and a lepton or quark-antiquark pair. Thus, process (1) should be identified by an observation of the $\ell^+\ell^-$ pair (or the two hadronic jets) in one hemisphere and a large amount of missing momentum.

Neutralinos χ_i are related to the weak interaction eigenstates $\Psi_i^0 = (\tilde{B}^0\, \tilde{W}^3\, \tilde{H}_1^0\, \tilde{H}_2^0)$ through the unitary mixing matrix $\mathcal{N}$ /7/

$$\chi_{iL} = \mathcal{N}_{ij}\, \Psi^0_{jL} \tag{2}$$

where the subscript L denotes the left-handed components of the fields. The neutralino mixing matrix $\mathcal{N}$ is governed by the gauge and SUSY breaking mechanism. In our phenomenological analysis $\mathcal{N}_{ij}$ are considered free parameters.

The relevant terms of the CP-invariant interaction Lagrangian in the minimal SUSY model, which generate process (1), may be written in the form

$$\mathcal{L} = \mathcal{L}_\chi + \mathcal{L}_{\tilde{e}}, \tag{3}$$

$$\mathcal{L}_\chi = -\frac{ig}{\cos\theta_W}\left[\bar{e}\gamma_\alpha(c_V + c_A\gamma_5)e - \bar{\chi}_1\gamma_\alpha(G_V + G_A\gamma_5)\chi_2\right] Z_\alpha, \tag{4}$$

$$\mathcal{L}_{\tilde{e}} = \frac{ig}{2}\sum_{i=1,2}\left\{\eta_i\, \mathcal{U}_{iL}\, \tilde{e}_L\, \bar{e}\, \frac{1-\gamma_5}{2}\chi_i - \mathcal{U}_{iR}\, \tilde{e}_R\, \bar{e}\, \frac{1+\gamma_5}{2}\chi_i\right\} + h.c. \tag{5}$$

Here $\mathcal{L}_\chi$ denotes the interaction of the fermionic fields $e^\pm$ and $\chi_{1,2}$ with the gauge field Z_α and $\mathcal{L}_{\tilde{e}}$ describes the interaction of the neutralino with the electron and selectron $(\tilde{e}_L, \tilde{e}_R)$ fields. The couplings c_V and c_A are given by the standard model

$$c_V = \frac{1}{4} - \sin^2\theta_W, \qquad c_A = \frac{1}{4}, \tag{6}$$

where θ_W is the weak mixing angle. The $\chi_i - Z_\alpha$ couplings G_V, G_A and the $\chi_i - e - \tilde{e}_L(\tilde{e}_R)$ couplings $\mathcal{U}_{iL}(\mathcal{U}_{iR})$ are expressed through the elements of the neutralino mixing matrix:

$$G_V = O_{12}\,(1-\eta_1\eta_2)\,,\quad G_A = O_{12}\,(1+\eta_1\eta_2) \tag{7}$$

where

$$O_{12} = -\frac{1}{2} N_{13} N_{23} + \frac{1}{2} N_{14} N_{24}$$

and

$$\begin{aligned} u_{iL} &= N_{i2} + N_{i1}\,\mathrm{tg}\,\theta_W \\ u_{iR} &= 2N_{i1}\,\mathrm{tg}\,\theta_W\,, \quad i = 1,2 \end{aligned} \tag{8}$$

The sign factors η_i ($\eta_i = \pm 1$) in the Majorana condition for χ_i

$$C\,\bar{\chi}_i^{\,T}(x) = \eta_i\,\chi_i(x) \tag{9}$$

are related to the CP-parities η^i_{CP} of χ_i /12/: $i\eta_i = \eta^i_{CP}$ (C is the charge conjugate matrix). Such a choice of η_i ensures non-negative neutralino masses. Further on, we shall refer to η_i as to measurable quantities - the CP-parities of χ_i.

Neutralino pair production in e^+e^- collisions takes place via the s-channel Z-exchange and the t-channel $\tilde{e}_L$- and $\tilde{e}_R$-exchange. The corresponding Feynman diagrams in the leading order of the perturbation theory are shown in figs. (1) and (2a, 2b). The kinematical variables used in our calculations are defined on these diagrams.

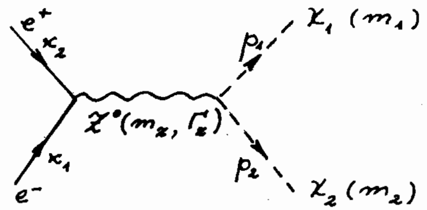

Fig. 1

The Z-exchange diagram

Let us note that the relative sign between the diagrams in fig. (1), fig. (2a) and fig. (2b) is determined by the anticommutation of the fermionic fields e, χ_1 and χ_2.

The chiral properties of the Lagrangian (3) lead to the following general expression /13/ for the cross section of process (1) with polarized e^+ and e^-.

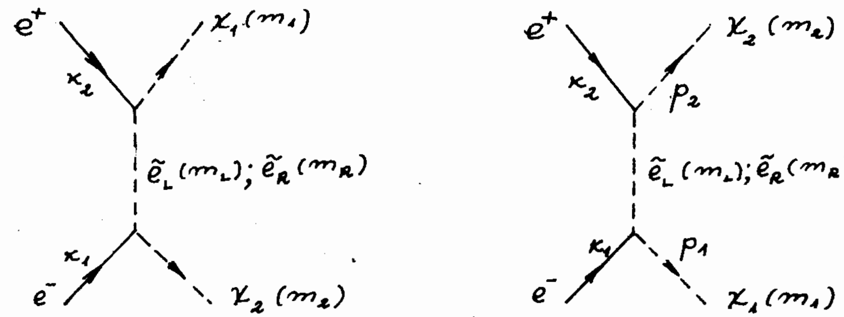

Fig. 2a

Fig. 2b

The $\tilde{e}_L$-, $\tilde{e}_R$-exchange diagrams

$$\left(\frac{d\sigma}{d\Omega}\right)_{\lambda_1\xi_{1\perp},\lambda_2\xi_{2\perp}} = \alpha_0\Big\{(1-\lambda_1\lambda_2)\,X_1(\theta) + (\lambda_2-\lambda_1)\,X_2(\theta) + \xi_{1\perp}\xi_{2\perp}\big(X_3(\theta)\cos 2\varphi + X_4(\theta)\sin 2\varphi\big)\Big\}. \tag{10}$$

Here

$$\alpha_0 = \frac{4\alpha^2|\vec{p}|^2}{s\sqrt{s}}\cdot\frac{1}{\sin^4\theta_W\,\cos^4\theta_W}\,, \tag{11}$$

$$s = -(\kappa_1+\kappa_2)^2,\quad |\vec{p}| = \frac{\left(s^2+m_1^4+m_2^4-2s\,m_1^2-2s\,m_2^2-2m_1^2m_2^2\right)^{1/2}}{2\sqrt{s}},$$

θ and φ are the polar angles of χ_1 in the c.m. frame where the z axis points to the direction of the electron beam; λ_1, λ_2 and $\xi_{1\perp}$, $\xi_{2\perp}$ are the longitudinal and transverse polarizations of e^- and e^+. We consider natural transverse polarization, generated in storage rings, which is parallel to the magnetic field for e^+ and antiparallel to it for e^-. The y axis is antiparallel to the magnetic field.

There will be three types of contributions to the differential cross-section, eq.(10): due to Z-exchange, to $\tilde{e}_L$- and $\tilde{e}_R$-exchange and to the interference between them. We denote the corresponding terms by $X_i^Z(\theta)$, $X_i^{\tilde{e}}(\theta)$ and $X_i^I(\theta)$ ($i = 1,2,3,4$):

$$X_i(\theta) = X_i^{Z}(\theta) + X_i^{\tilde e}(\theta) + X_i^{I}(\theta). \tag{12}$$

From Z-exchange diagram we have

$$X_1^{Z}(\theta) = (c_V^2 + c_A^2)\, X(\theta), \tag{13}$$

$$X_2^{Z}(\theta) = 2 c_V c_A\, X(\theta), \tag{14}$$

$$X_3^{Z}(\theta) = 2 O_{12}^2\, s\, |\vec p|^2 \sin^2\theta\, \frac{c_V^2 - c_A^2}{|D_Z(s)|^2}, \tag{15}$$

$$X_4^{Z}(\theta) = 0, \tag{16}$$

where

$$X(\theta) = \frac{4 O_{12}^2}{|D_Z(s)|^2}\left(A + B - \eta_1 \eta_2 m_1 m_2 \frac{s}{2}\right).$$

From the diagrams with the left and right selectron exchange we obtain

$$X_1^{\tilde e}(\theta) = X_L^{\tilde e}(\theta) + X_R^{\tilde e}(\theta), \tag{17}$$

$$X_2^{\tilde e}(\theta) = X_L^{\tilde e}(\theta) - X_R^{\tilde e}(\theta), \tag{18}$$

$$X_3^{\tilde e}(\theta) = \frac{1}{8}\left(\frac{\cos^2\theta_W}{4}\right)^2 \frac{s}{2} |\vec p|^2 \sin^2\theta\, U_{1L} U_{2L} U_{1R} U_{2R} \times \left(\frac{1}{D_L(p_1) D_R(p_2)} + \frac{1}{D_L(p_2) D_R(p_1)}\right), \tag{19}$$

$$X_4^{\tilde e}(\theta) = 0, \tag{20}$$

where

$$X_L^{\tilde e}(\theta) = \frac{1}{8}\left(\frac{\cos^2\theta_W}{4}\right)^2 U_{1L}^2 U_{2L}^2 \times \left(\frac{A}{D_L^2(p_1)} + \frac{B}{D_L^2(p_2)} - \frac{\eta_1 \eta_2 m_1 m_2\, s/2}{D_L(p_1)\, D_L(p_2)}\right).$$

Finally, from the interference between Z-exchange and selectron exchange we have

$$X_1^{I}(\theta) = (c_A + c_V)\, X_L(\theta) + (c_A - c_V)\, X_R(\theta), \tag{21}$$

$$X_2^{I}(\theta) = (c_A + c_V)\, X_L(\theta) - (c_A - c_V)\, X_R(\theta), \tag{22}$$

$$X_3^{I}(\theta) = -Re\left(\frac{1}{D_Z(s)}\right)\left\{(c_A - c_V)\, Y_L(\theta) + (c_A + c_V)\, Y_R(\theta)\right\} \tag{23}$$

$$X_4^{I}(\theta) = Im\left(\frac{1}{D_Z(s)}\right)\left\{(c_A - c_V)\, Y_L(\theta) - (c_A + c_V)\, Y_R(\theta)\right\} \tag{24}$$

where

$$X_L(\theta) = \frac{\cos^2\theta_W}{4}\, \frac{1}{2}\, Re\left(\frac{1}{D_Z(s)}\right) O_{12} \cdot U_{1L} \cdot U_{2L} \times \left\{\frac{2A}{D_L(p_1)} + \frac{2B}{D_L(p_2)} - \eta_1 \eta_2 m_1 m_2 \frac{s}{2}\left(\frac{1}{D_L(p_1)} + \frac{1}{D_L(p_2)}\right)\right\}$$

$$Y_L(\theta) = \frac{\cos^2\theta_W}{4}\, \frac{s}{4}\, |\vec p|^2 \sin^2\theta \cdot O_{12} \cdot U_{1L} \cdot U_{2L} \times \left\{\frac{1}{D_L(p_1)} + \frac{1}{D_L(p_2)}\right\}.$$

The quantities $X_R^{\tilde e}(\theta)$, $X_R(\theta)$ and $Y_R(\theta)$ are obtained from $X_L^{\tilde e}(\theta)$, $X_L(\theta)$ and $Y_L(\theta)$ by replacing U_{iL} and $D_L(p_i)$ by U_{iR} and $D_R(p_i)$. The other notation is as follows:

$$D_Z(s) = -s + m_Z^2 - i m_Z \Gamma_Z, \tag{25}$$

$$A = (x_1 p_1)(x_2 p_2), \quad B = (x_1 p_2)(x_2 p_1), \tag{26}$$

$$D_L(p_i) = (x_2 - p_i)^2 + m_L^2, \quad D_R(p_i) = (x_2 - p_i)^2 + m_R^2. \tag{27}$$

3. Different schemes of neutralino mixing

Now we shall compare the following three characteristic schemes of neutralino mixing: when one of the produced particles, say χ_1, is

i) of higgsino type:

$$\chi_{1L} = N_{13} \tilde H_{1L}^0 + N_{14} \tilde H_{2L}^0, \quad N_{11} = N_{12} = 0 \tag{28}$$

ii) of gaugino type:

$$\chi_{1L} = N_{11}\,\tilde{B}^0_L + N_{12}\,\tilde{W}^3_L\,, \quad N_{13} = N_{14} = 0. \tag{29}$$

iii) some general mixture of comparable amounts of higgsino and gaugino components.

Let us emphasize that no assumptions have been made for the other produced particle, i.e., χ_2 is considered an arbitrary mixture of all four weak eigenstates Ψ^0_i.

We shall show that measurements of the cross section and the longitudinal or transverse asymmetries of process (1) may distinguish between the above three cases. We shall also show that the asymmetries in case ii) strongly depend upon the fact whether $\tilde{e}_L$ and $\tilde{e}_R$ are degenerate in mass or not.

According to the fundamental assumption of supersymmetry, the ordinary particles and their SUSY partners have identical couplings known from the standard model. So Z^0 couples to $\tilde{H}^0_1$ and $\tilde{H}^0_2$ and does not couple to $\tilde{B}^0$ and $\tilde{W}^3$, while $\tilde{e}_L$ and $\tilde{e}_R$ couple only to $\tilde{B}^0$ and $\tilde{W}^3$, their couplings to $\tilde{H}^0_1$ and $\tilde{H}^0_2$ being negligible at the considered high energies. It is clear that the production of a pure higgsino (composed only of $\tilde{H}^0_1$, $\tilde{H}^0_2$) together with a pure gaugino (composed of $\tilde{B}^0$ and $\tilde{W}^3$) in process (1) is impossible. The behaviour of the cross section and the spin asymmetries is governed only by the Z-exchange diagram (fig. 1) in case i) and by the $\tilde{e}_L$- and $\tilde{e}_R$-exchange diagrams (figs. 2a, 2b) in case ii). Both diagrams in fig.(1) and figs. (2a, 2b) contribute in case iii).

4. Unpolarized cross section and longitudinal asymmetry

The integral unpolarized cross section $\sigma_0(s)$

$$\sigma_0(s) = \int X_1(\theta)\, d\cos\theta \tag{30}$$

reveals a resonance peak at $\sqrt{s} \simeq m_Z$ in cases i) and iii) due to the contribution of Z-exchange to the amplitude of process (1). The cross section $\sigma_0(s)$ is of an order of 10^{-30}–10^{-36} cm^{-2} in the LEP range of energies (if $m_1 \simeq 1$ GeV, $m_2 \simeq 30$ GeV) and reaches 10^{-31} cm^{-2} at the Z-peak. For case ii) a flat decreasing behaviour of $\sigma_0(s)$ is expected. Thus, measurements of $\sigma_0(s)$ would separate only case ii) from cases i) and iii). The cross section $\sigma_0(s)$ gives no information about the selectron mass spectrum.

Let us consider now the longitudinal asymmetry $A_{\parallel}(\theta)$:

$$A_{\parallel}(\theta) = \frac{1}{\lambda}\,\frac{d\sigma_{\lambda,0} - d\sigma_{-\lambda,0}}{d\sigma_{\lambda,0} + d\sigma_{-\lambda,0}} = -\frac{1}{\lambda}\,\frac{d\sigma_{0,\lambda} - d\sigma_{0,-\lambda}}{d\sigma_{0,\lambda} + d\sigma_{0,-\lambda}}\,, \tag{31}$$

where $d\sigma_{\lambda,0}$ ($d\sigma_{0,\lambda}$) denotes the differential cross section of process (1) when the electrons (positrons) have longitudinal polarization λ. From eqs. (10) and (31) we have

$$A_{\parallel}(\theta) = -\frac{X_2(\theta)}{X_1(\theta)}\,. \tag{32}$$

In case i) eqs. (32), (13) and (14) give

$$A_{\parallel}(\theta) = -\frac{2c_V c_A}{c_V^2 + c_A^2}\,. \tag{33}$$

Therefore, when one of the produced neutralinos is of the higgsino type, $A_{\parallel}(\theta)$ depends neither on the scattering angle θ nor on the energy $\sqrt{s}$; its value is uniquely determined by θ_W. At $\sin^2\theta_W = 0.22$, the asymmetry $A_{\parallel} \simeq 24\%$.

In case ii) the longitudinal asymmetry $A_{\parallel}(\theta)$ strongly depends on the relation between the left and right selectron masses. If $\tilde{e}_L$ and $\tilde{e}_R$ are degenerate in mass ($m_L \simeq m_R$), from eqs.(17), (18) and (32) we have

$$A_{\parallel}(\theta) = -\frac{U_{1L}^2\,U_{2L}^2 - U_{1R}^2\,U_{2R}^2}{U_{1L}^2\,U_{2L}^2 + U_{1R}^2\,U_{2R}^2}\,. \tag{34}$$

The asymmetry $A_{\parallel}(\theta)$ is again a constant with respect to the angle θ and energy $\sqrt{s}$. The value of $A_{\parallel}(\theta)$ is determined only by the gaugino components (N_{i1}, N_{i2}, i =1,2) of χ_1 and χ_2 and by the value of θ_W.

If the masses m_L and m_R are not equal, the longitudinal asymmetry is some function of θ and $\sqrt{s}$. If $m_L \gg m_R$ (or $m_R \gg m_L$), the $\tilde{e}_L$-exchange (or $\tilde{e}_R$-exchange) is suppressed, and $A_{\parallel}(\theta)$ is determined mainly by the other chiral diagram. The asymmetry $A_{\parallel}(\theta)$ is positive and reaches 100% in the limiting case $m_L \gg m_R$; for $m_R \gg m_L$, $A_{\parallel}(\theta)$ is negative and reaches - 100%.

The integral longitudinal asymmetry $A_{\parallel}(s)$:

$$A_{\parallel}(s) = -\frac{\int X_2(\theta)\, d\cos\theta}{\int X_1(\theta)\, d\cos\theta} \tag{35}$$

as a function of $\sqrt{s}$ is shown in fig. 3. Both for $m_L \gg m_R$ and $m_R \gg m_L$, $|A_{\parallel}(s)|$ is a decreasing function of $\sqrt{s}$ which equals 100% at the threshold $s = (m_1 + m_2)^2$ and tends to the

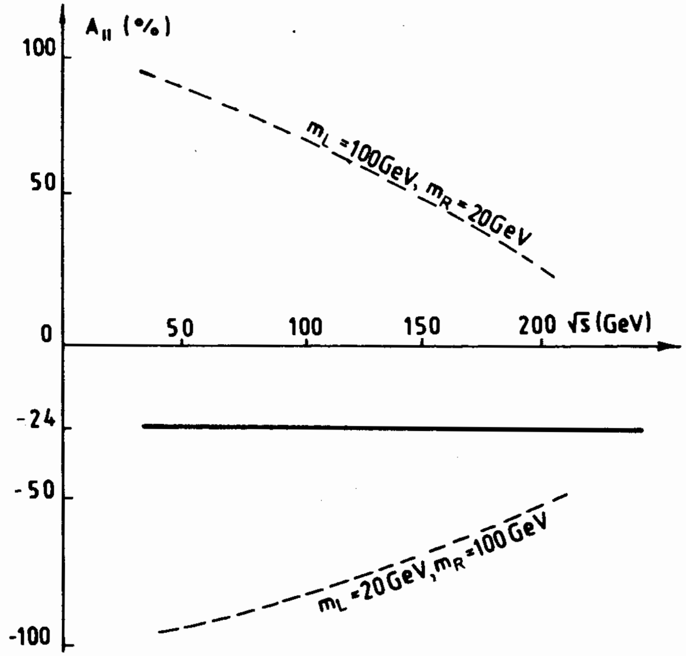

Fig. 3

The integral longitudinal asymmetry is the cases of higgsino (full line) and gaugino production (dotted line)

asymptotic value, eq.(34), at $s \gg m_L^2, m_R^2$.

In case iii), no definite predictions about the behaviour of $A_{\parallel}$ as a function of θ and $\sqrt{s}$ can be made.

The fulfilled analysis shows that the combined measurements of the unpolarized cross section $\sigma_0(s)$ and the longitudinal asymmetry $A_{\parallel}(s)$ in process (1) allows one to distinguish between the discussed three cases of neutralino mixing and to get information about the selectron mass spectrum. Here, we shall briefly summarize the results.

I) When $\sigma_0(s)$ has a peak at $\sqrt{s} \approx m_Z$, then:

if $A_{\parallel}(s) = const$, case i) is realized, i.e., one of the neutralinos is of the higgsino type; the other may be an arbitrary mixture, eq.(2);

if $A_{\parallel}(s) \neq const$, case iii) is realized, i.e., both neutralinos are general mixtures.

II) When no resonance peak at $\sqrt{s} \approx m_Z$ is observed in $\sigma_0(s)$, then:

if $A_{\parallel}(s) = const$, case ii) is realized and $m_L \approx m_R$; The value of $A_{\parallel}(s)$ could give information about the mixing matrix elements N_{i1}, N_{i2} ($i = 1,2$);

if $A_{\parallel}(s) \neq const$, $A_{\parallel}(s) > 0$, then case ii) is realized and $m_L \gg m_R$;

if $A_{\parallel}(s) \neq const$, $A_{\parallel}(s) < 0$, then case ii) is realized and $m_R \gg m_L$.

These results are schematically shown in Table 1.

Table 1. The type of the produced neutralinos according to the behaviour of $\sigma_0(s)$ and $A_{\parallel}(s)$. The notation is explained in the text: eqs. (28), (29).

$A_{\parallel}(s)$ \ $\sigma_0(s)$	= const	≠ const $A_{\parallel} > 0$	≠ const $A_{\parallel} < 0$
a peak at $\sqrt{s} = m_Z$	i)	iii)	iii)
no peak at $\sqrt{s} = m_Z$	ii) $m_L \approx m_R$	ii) $m_L^2 \gg m_R^2$	ii) $m_L^2 \ll m_R^2$

5. Transverse asymmetry

Let us now investigate the integral asymmetry $A_{\perp}(s)$ defined when both the initial e^+e^- beams are transversely polarized

$$A_{\perp}(s) = \frac{1}{\xi_{1L}\xi_{2L}} \left\{ \frac{\sigma_{\xi_{1L}\xi_{2L}} - \sigma_{0,0}}{\sigma_{0,0}} \right\}_{\varphi=0} = \int X_3(\theta)\, d\cos\theta \Big/ \int X_1(\theta)\, d\cos\theta . \tag{36}$$

Here $\sigma_{\xi_{1\perp},\xi_{2\perp}}$ is the total cross section of process (1) with transversely polarized e^+ and e^-. We shall show that information about the type of the produced neutralinos and the selectron mass spectrum can be obtained from $A_\perp(s)$ as well, if the corresponding measurements are made at $s \gg m_1^2, m_2^2$.

There is no compelling theoretical reason to expect both neutralinos to be light [14] (compared to the accessible energies). However, in our analysis we assume that the strong inequality $s \gg m_{1,2}^2$ holds and we obtain a number of interesting predictions about the behaviour of $A_\perp(s)$.

In case i), when χ_1 is of the higgsino type, eqs.(13), (15) and (36) imply

$$A_\perp(s) = \frac{1}{2}\,\frac{c_V^2 - c_A^2}{c_V^2 + c_A^2}\,. \tag{37}$$

Thus, similarly to $A_\parallel(s)$, the transverse asymmetry $A_\perp(s)$ is uniquely determined by the value of θ_W. For $\sin^2\theta_W = 0.22$, $A_\perp \approx -50\%$.

In the case ii) it is necessary to consider different possibilities for the $\tilde{e}_L$ and $\tilde{e}_R$ masses. If mass degeneracy takes place, $m_L \approx m_R = m$, and also $m_1^2, m_2^2 \ll m^2$, the following rather simple s-dependence of $A_\perp(s)$ is obtained

$$A_\perp(s) = -\frac{U_{1L}U_{2L}U_{1R}U_{2R}}{U_{1L}^2U_{2L}^2 + U_{1R}^2U_{2R}^2}\left\{1 + \frac{s}{s+2m^2} + O\left(\frac{m_1 m_2}{s}\ln\frac{m^2}{s+m^2}\right)\right\}. \tag{38}$$

From eq.(38) it immediately follows that if the selectron is much heavier than the energies considered: $m^2 \gg s$ (and so cannot be produced directly in e^+e^- collisions), $A_\perp(s)$ approaches a constant, $A_\perp = -\frac{U_{1L}U_{2L}U_{1R}U_{2R}}{U_{1L}^2U_{2L}^2 + U_{1R}^2U_{2R}^2}$ determined by the neutralino mixing matrix elements.

If the selectron mass m appears to be close to either (or both) of the neutralino masses, eqs.(17) and (19) lead to the following asymptotic $(s \gg m_1^2, m_2^2, m^2)$ behavior of $A_\perp$:

$$A_\perp(s) = \frac{-2U_{1L}U_{2L}U_{1R}U_{2R}}{U_{1L}^2U_{2L}^2 + U_{1R}^2U_{2R}^2}\left\{1 + O\left(\frac{\delta}{s}\ln\frac{\delta}{s}\right)\right\}. \tag{39}$$

Here δ is:

$$\delta = m^2 - m_1^2 \approx m^2 - m_2^2, \text{ if } m_1^2 \approx m_2^2 \approx m^2$$
$$\delta = m^2 - m_1^2, \text{ if } m_1^2 \ll m_2^2 \approx m^2$$
$$\delta = m^2 - m_2^2, \text{ if } m_1^2 \approx m^2 \ll m_2^2.$$

Thus, from eqs.(38), (39) it follows that if $m_L \approx m_R$, there is no reason to expect $A_\perp(s)$ to be small. If $U_{1L}U_{2L} = U_{1R}U_{2R}$, $A_\perp$ may reach 100%.

Let us consider now the case ii) when $m_L \neq m_R$ and assume $m_L \gg m_R$. Then, eqs.(17) and (19) imply

$$A_\perp(s) = -\frac{U_{1L}U_{2L}U_{1R}U_{2R}}{U_{1R}^2U_{2R}^2}\,O\left(\frac{m_R^2}{m_L^2}\right). \tag{40}$$

If $m_R \gg m_L$ we have analogously

$$A_\perp(s) = -\frac{U_{1L}U_{2L}U_{1R}U_{2R}}{U_{1L}^2U_{2L}^2}\,O\left(\frac{m_L^2}{m_R^2}\right). \tag{41}$$

Therefore, if the selectron masses are not degenerate, $A_\perp$ in case ii) will be small, independently of the fact whether one (or both) of the selectron masses is far beyond or is within the range of the considered energies.

No definite predictions about $A_\perp(s)$ can be made in case iii) when χ_1 and χ_2 are general superpositions of higgsino and gaugino components.

6. The type of LSP

The signature of process (1) implies that one of the produced neutralinos is the LSP. The existence of such a stable LSP is a common feature of SUSY models with R-parity conservation. As suggested by minimal supergravity models [15,16], the most plausible candidate for LSP is the lightest eigenstate of the neutral gaugino-higgsino sector.

Based on our previous analysis, we shall now show that measurements of $\sigma_0(s)$ and the spin asymmetries in process (1) would make it possible to distinguish between the LSP being higgsino-like, gaugino-like or some general mixture of higgsino and gaugino components. As the parameters associated with χ_1 and χ_2 enter symmetrically into the expressions for the cross section and the asymmetries, it is necessary to make some additional assumptions.

We suppose that the heavier particle, produced in process (1) cannot be a pure gaugino or a pure higgsino. This implies that the behaviour of $\sigma_\nu(s)$, $A_\parallel(s)$ and $A_\perp(s)$ is entirely governed by the type of the LSP. Therefore, the conclusions summarized in Table 1 concerning the nature of one of the produced neutralinos now refer uniquely to the LSP thus providing a test for the lightest SUSY particle. For example, observation of a resonance peak in $\sigma_\nu(s)$ at $\sqrt{s} \simeq m_Z$ and a constant behaviour of $A_\parallel(s)$ would correspond to LSP of the higgsino type, etc.

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Рождение нейтралино в столкновении поляризованных e^+e^-

В рамках минимальной суперсимметричной модели рассмотрена аннигиляция поляризованных e^+e^- в две нейтралино χ_1 и χ_2 в общем случае произвольного смешивания. Получена явная зависимость сечения от CP-четностей χ_i. Показано, что измерение сечения и поляризованных асимметрий позволяет отличить между следующими случаями смешивания: когда одно из нейтралино является типа хигсино, типа гейджино или содержит и хигсинные и гейджинные компоненты. Никаких ограничений на вид другого родившегося нейтралино не делается. Если предположить, что χ_1 самая легкая суперсимметричная частица, то можно определить ее вид.

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Neutralino Production in Polarized e^+e^--Collisions

Annihilation of arbitrarily polarized e^+e^- into two neutralinos χ_1 and χ_2 is considered in the framework of the minimal supersymmetric model. The cross section is calculated in the general case of neutralino mixing. The explicit dependence on the CP-parities of χ_i is obtained. It is shown that measurements of the unpolarized cross section and the spin asymmetries may distinguish between the following schemes of neutralino mixing: one of produced neutralinos is either of higgsino or gaugino type or is a general mixture of higgsino and gaugino components. No assumptions about the other produced neutralino are made. If χ_1 is assumed to be the lightest SUSY particle, information about its type can be obtained.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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