Associated Slepton-Neutralino/Chargino Production at LEP⊗LHC

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Abstract

We examine for representative gaugino-higgsino mixing scenarios slepton-neutralino
and slepton-chargino production in deep inelastic ep-scattering at $\sqrt{s} = 1.8$ TeV. We
find sneutrino-chargino production to be the dominant process with cross sections more
than one order of magnitude bigger than those for slepton-squark production. Also
for associated production of sneutrinos and zino-like neutralinos the cross sections are
at least comparable to those for $\tilde{l}q$-production, whereas selectron-neutralino/chargino
production is with cross sections significantly smaller than those for selectron-squark
production less favorable. Typical signatures include events with up to four charged
leptons, hadronic jets and, in some cases, gauge bosons.

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1 Introduction

Supersymmetry is considered to be one of the most attractive extensions for physics beyond the Standard Model. Searching for supersymmetric particles will therefore play an important role also in the experimental program of the future $ep$-collider LEP⊗LHC. It especially provides a very good possibility to search for the scalar partners of electrons and neutrinos: Since in the simplest phenomenological model which implements the idea of supersymmetry, the Minimal Supersymmetric Standard Model (MSSM), $R$-parity is conserved a selectron or a sneutrino is always produced with a second SUSY-particle, which can be either a squark or a neutralino or chargino respectively. If the sum of the masses of the slepton and squark is smaller than 600 GeV, then $ep \rightarrow \tilde{e}qX$ and $ep \rightarrow \tilde{\nu}qX$ are the most promising processes to search for SUSY-particles at LEP⊗LHC [1]. If, however, squarks are heavy but sleptons are relatively light, than these processes are suppressed or even inaccessible and the associated production of a slepton and a neutralino $\tilde{\chi}^0_i (i = 1, \ldots, 4)$ or a slepton and a chargino $\tilde{\chi}^\pm_i (i = 1, 2)$, which lead to new interesting signatures, become the most important processes at $ep$-colliders [2].

At the parton level the possible production channels are (a) $eq \rightarrow \tilde{e}\tilde{\chi}^0_i q$, (b) $eq \rightarrow \tilde{e}\tilde{\chi}^+_i q'$, (c) $eq \rightarrow \tilde{e}\tilde{\chi}^-_i q'$, (d) $eq \rightarrow \tilde{\nu}\tilde{\chi}^0_i q'$, (e) $eq \rightarrow \tilde{\nu}\tilde{\chi}^-_i q$. Expecting that the production of the lightest supersymmetric particle (LSP) $\tilde{\chi}^0_1$ in processes (a) and (d) is particularly favorable, only the associated production of the LSP has been analyzed in detail in the deep inelastic region assuming, further, that the LSP is photino-like [3]. The couplings of the neutralinos and charginos, however, sensitively depend on their nature which is determined by the way gauginos and higgsinos are mixed. Therefore the question which of the four neutralinos or two charginos will be produced with the highest rate sensitively depends on the mixing scenario. Further the chargino production in the process (e) can proceed via photon and $Z^0$ exchange, which can lead to detectable cross sections also for associate chargino production.

We therefore investigate all five production channels and show for LEP⊗LHC energy ($\sqrt{s} = 1.8$ TeV) the total cross sections for three representative gaugino-higgsino mixing scenarios and for different ratios of slepton and squark masses. Our choice of scalar
masses is partly motivated by renormalization group relations coupling the sfermion masses and the gaugino mass parameter of the MSSM. It turns out that the cross sections especially for $ep \rightarrow \tilde{\nu} \tilde{\chi}^{-} X$ may attain values between one or two orders of magnitude bigger than those for slepton-squark production.

Further, the associated production of squarks and neutralinos/charginos could be of interest, especially in case of the same mass for all sfermions. Because squark production, however, leads in many scenarios to signatures with many hadronic jets, associated squark-neutralino/chargino production is less favorable and not subject of this paper.

In order to see if these reactions might be suitable for providing us with a SUSY signal at LEP$\otimes$LHC we include some remarks on the competing Standard Model (SM) backgrounds and a brief discussion of the decay patterns of the particles produced and the ensuing signatures for the five reaction channels. Angular distributions and energy spectra would be appropriate observables to extract SUSY events from SM backgrounds. We therefore give in the appendix a complete list of the amplitudes squared which also enables us to extend our investigations to polarized electron beams.

## 2 The Minimal Supersymmetric Standard Model (MSSM)

We briefly describe those parts of the MSSM, which will be used for our calculations in section 3. We will use the notation of [4]. From this we get for the neutralino mass term

$${\mathcal L}^m_{\chi^0} = -\frac{1}{2} m_Z (\psi^0_i)^T Y_{ij} \psi^0_j + h.c..$$

(1)

With the spinors $\psi^0_i$ of the photino, the zino and the neutral higgsinos,

$$\psi^0_i = (-i\lambda_\gamma, -i\lambda_Z, \psi^1_{H_1} \cos \beta - \psi^2_{H_2} \sin \beta, \psi^1_{H_1} \sin \beta + \psi^2_{H_2} \cos \beta), \quad i = 1, \ldots, 4,$$

(2)

and the mass matrix $Y_{ij}$

$$Y = \begin{pmatrix}
M(\sin^2 \theta_W + \frac{M'}{M} \cos^2 \theta_W) & M(1 - \frac{M'}{M}) \sin \theta_W \cos \theta_W & 0 & 0 \\
M(1 - \frac{M'}{M}) \sin \theta_W \cos \theta_W & M(\cos^2 \theta_W + \frac{M'}{M} \sin^2 \theta_W) & m_Z & 0 \\
0 & m_Z & \mu \sin 2\beta & -\mu \cos 2\beta \\
0 & 0 & -\mu \cos 2\beta & -\mu \sin 2\beta
\end{pmatrix}$$

(3)
We may diagonalize this matrix with the real symmetric matrix $N_{ij}$, where the columns of this matrix are given by the neutralino mass eigenstates $\chi_0^i$ in the basis of eq. (2) [E]:

$$\chi_0^i = N_{ij} \psi_j^0,$$

with $\eta_i$ a sign factor, which arise because the eigenvalues from $Y_{ij}$ may be negative.

$$\chi_0^i = \frac{1}{N_i} \left( \begin{array}{c} \frac{m}{m_Z} (1 - \frac{M'}{M}) \sin \theta_W \cos \theta_W \left( m_i^2 - \mu^2 \right) \\ \frac{1}{m_Z} \left( m_i - M \left( \sin^2 \theta_W + \frac{M'}{M} \cos^2 \theta_W \right) \right) \left( m_i^2 - \mu^2 \right) \\ \left( m_i - M \left( \sin^2 \theta_W + \frac{M'}{M} \cos^2 \theta_W \right) \right) \left( m_i + \mu \sin 2 \beta \right) \\ \left( m_i - M \left( \sin^2 \theta_W + \frac{M'}{M} \cos^2 \theta_W \right) \right) \left( -\mu \cos 2 \beta \right) \end{array} \right),$$

with

$$N_i = \left( \begin{array}{c} \left( \frac{m_i^2 - \mu^2}{m_Z^2} \right) \left( \sin^2 \theta_W (m_i - M)^2 + \cos^2 \theta_W (m_i - M')^2 + (m_i - M)^2 (m_i - M')^2 \right) \\ \left( m_i - M \left( \sin^2 \theta_W + \frac{M'}{M} \cos^2 \theta_W \right) \right)^2 \left( \mu \sin^2 \beta \right)^2 \right)^{1/2}.$$

The chargino mass sector is described by

$$\mathcal{L}_{\chi^\pm} = -\frac{1}{2} \left( \begin{array}{c} \psi^+ \psi^- \\ \psi^+ \psi^- \end{array} \right) \left( \begin{array}{cc} 0 & X^T \\ X & 0 \end{array} \right) \left( \begin{array}{c} \psi^+ \\ \psi^- \end{array} \right) + h.c.,$$

with the mass matrix

$$X = \left( \begin{array}{cc} M & m_W \sqrt{2} \sin \beta \\ m_W \sqrt{2} \cos \beta & \mu \end{array} \right)$$

and the two-component spinors $\psi^\pm_j$ of the winos and charged higgsinos

$$\psi^+_j = (-i \lambda^+, \psi^1_{H_2}), \quad \psi^-_j = (-i \lambda^-, \psi^2_{H_1}), \quad j = 1, 2.$$

We may diagonalize $X$ by unitary $2 \times 2$-matrices $U$ and $V$

$$U_{im}^* V_{jn} X_{mn} = \eta_i m_i \delta_{ij},$$

with the mass eigenstates

$$\chi^+_i = V_{ij} \psi^+_j, \quad \chi^-_i = U_{ij} \psi^-_j.$$
Notice that like in the neutralino case we get also positive or negative mass eigenvalues with \[5\]
\[\eta_{1,2}m_{1,2} = \frac{1}{2} \sqrt{(M - \mu)^2 + 2m_W^2(1 + \sin 2\beta)} = \sqrt{(M + \mu)^2 + 2m_W^2(1 - \sin 2\beta)}. \quad (11)\]
The matrix elements \(U_{ij}\) and \(V_{ij}\) are
\[U_{12} = \frac{\theta_1}{\sqrt{2}} \sqrt{1 + \frac{M^2 - \mu^2 - 2m_W^2 \cos 2\beta}{W}}, \quad (12)\]
\[U_{22} = -U_{11} = \frac{\theta_2}{\sqrt{2}} \sqrt{1 - \frac{M^2 - \mu^2 - 2m_W^2 \cos 2\beta}{W}}, \quad (13)\]
\[V_{12} = -V_{12} = \frac{\theta_3}{\sqrt{2}} \sqrt{1 + \frac{M^2 - \mu^2 + 2m_W^2 \cos 2\beta}{W}}, \quad (14)\]
\[V_{22} = -V_{11} = \frac{\theta_4}{\sqrt{2}} \sqrt{1 - \frac{M^2 - \mu^2 + 2m_W^2 \cos 2\beta}{W}}, \quad (15)\]
with \(W = \sqrt{(M^2 + \mu^2 + 2m_W^2)^2 - 4(M\mu - m_W^2 \sin 2\beta)^2}\).
The sign factors \(\theta_i, i = 1, \ldots, 4\) are given in table 1.

For further details of this mixings see e.g. \[5\].

The couplings in the Feynman graphs follow from the lagrangian of the MSSM. The sfermion-fermion-neutralino couplings we get from
\[\mathcal{L}_{f\tilde{f}\chi^0} = \sum_{ij} \frac{1}{i} \left( (\eta_{f_{iL}}^0)_{ij} \tilde{f}_{iR} \tilde{\chi}_j^0 + (\eta_{f_{iR}}^0)_{ij} \tilde{f}_i \tilde{\chi}_j^0 \right) + h.c., \quad (16)\]
with \(f_{iR,L} = P_{R,L} f_i, \ P_{R,L} = \frac{1}{2}(1 \pm \gamma_5)\) and
\[\begin{align*}
(\eta_{f_{iL}}^0)_{ij} &= -ig\sqrt{2} \left( \frac{1}{\cos \theta_W} \left( T_{3f_i} - e_{f_i} \sin^2 \theta_W \right) N_{j2} + e_{f_i} \sin \theta_W N_{j1} \right) \\
(\eta_{f_{iR}}^0)_{ij} &= -ig\sqrt{2} e_{f_i} \sin \theta_W \left( \tan \theta_W N_{j2} - N_{j1}^* \right) \quad j = 1, \ldots, 4.
\end{align*} \quad (17)\]
With \(g = e/\sin \theta_W, \ e > 0\) and \(e_{f_i}, T_{3f}\) the charge and the third component of the weak isospin of the fermion \(f\). The fermion-sfermion-chargino couplings we get from
\[\mathcal{L}_{f\tilde{f}\tilde{\chi}^\pm} = -g \sum_i \left( \bar{u}_L U_{i1} \tilde{\chi}_i \tilde{d}_L + \bar{d}_L V_{i1} \tilde{\chi}_i \tilde{u}_L \right) + h.c. \quad (18)\]
where we also introduce the couplings \((\eta_f)_i\),
\[\begin{align*}
(\eta_{f_{iR}}^0)_{ij} &= 0 \\
(\eta_{u_{iL}}^0)_{ij} &= -igU_{i1} \\
(\eta_{d_{iL}}^0)_{ij} &= -igV_{i1}^* \quad i = 1, 2.
\end{align*} \quad (19)\]
where the \( u (d) \) are the uptype (downtype) fermions.

The couplings of a gauge boson with two neutralinos or charginos we get from

\[
\mathcal{L}_{W-\tilde{\chi}^0} = -i W^\mu \tilde{\chi}^0 \gamma^\mu (O^L_{ij} P_L + O^R_{ij} P_R) \tilde{\chi}^+_j \\
\mathcal{L}_{Z\tilde{\chi}^+\tilde{\chi}^-} = -i Z\mu \tilde{\chi}^+ \gamma^\mu (O^L_{ij} P_L + O^R_{ij} P_R) \tilde{\chi}^-_j, \\
\mathcal{L}_{Z\tilde{\chi}^0\tilde{\chi}^0} = -\frac{i}{2} Z\mu \tilde{\chi}^0 \gamma^\mu (O^L_{ij} P_L + O^R_{ij} P_R) \tilde{\chi}^0_j, \\
\mathcal{L}_{\gamma\tilde{\chi}^+\tilde{\chi}^-} = -\epsilon A_\mu \tilde{\chi}^+ \gamma^\mu \tilde{\chi}^-_j.
\]

with

\[
O^L_{ij} = \frac{i g}{\sqrt{2}} (\sin \theta_V N_{i4} - \cos \theta_V N_{i3}) V_{j2}^* + g (\sin \theta_W N_{i1} + \cos \theta_W N_{i2}) V_{j1}^*, \\
O^R_{ij} = \frac{i g}{\sqrt{2}} (\cos \theta_V N_{i4} + \sin \theta_V N_{i3}) U_{j2}^* + g (\sin \theta_W N_{i1}^* + \cos \theta_W N_{i2}^*) U_{j1}^*, \\
O^{iL}_{ij} = \frac{i g}{\cos \theta_W} \left( \delta_{ij} \sin^2 \theta_W - V_{i1} V_{j1}^* - \frac{1}{2} V_{i2} V_{j2}^* \right), \\
O^{iR}_{ij} = \frac{i g}{\cos \theta_W} \left( \delta_{ij} \sin^2 \theta_W - U_{i1}^* U_{j1} - \frac{1}{2} U_{i2}^* U_{j2} \right), \\
O^{iL}_{ij} = \frac{i g}{2 \cos \theta_W} \left( (N_{i3} N_{j3}^* - N_{i4} N_{j4}^*) \cos 2 \theta_V - (N_{i3} N_{j4}^* + N_{i4} N_{j3}^*) \sin 2 \theta_V \right), \\
O^{iR}_{ij} = O^{R*}_{ij}.
\]

Finally the sfermion-sfermion-gauge boson couplings we get from

\[
\mathcal{L}_{\tilde{f}\tilde{f}W} = \frac{-i g}{\sqrt{2}} \left( W^\mu_\mu (\tilde{u}_{L}^* \partial^\mu \tilde{d}_{L}) + (W^\mu_\mu (\tilde{d}_{L}^* \partial^\mu \tilde{u}_{L}) \right) - \frac{i g}{\cos \theta_W} Z_\mu \sum_i (T_{3i} - e_i \sin^2 \theta_W f_i^* \partial^\mu \tilde{f}_i^* - i e A_\mu \sum_i e_i \tilde{f}_i^* \partial^\mu \tilde{f}_i^*).
\]
models), it follows from [6] a relation connecting the sfermion with the gaugino/higgsino masses, which we will use in some of our scenarios

\[ m_{f_{L,R}}^2 = m_f^2 + m_0^2 + C(f)M^2 \pm m_Z^2 \cos 2\beta (T_{3f} - e_f \sin^2 \theta_W), \]  

with \( C(\tilde{q}_{R,L}) \approx 10, C(\tilde{l}_R) \approx 0.23 \) and \( C(\tilde{l}_L) \approx 0.79. \)

### 3 Analytical Results

We will now consider the analytical calculations for the processes \( ep \to \tilde{t}_{\chi_i}^{0,\pm} X. \) The Feynman graphs related to the basic subprocesses \( eq \to \tilde{t}_{\chi_i}^{0,\pm} q \) are shown in fig. 1. The corresponding amplitudes are:

\[
(M_{1})_{ab} = \bar{u}_{\tilde{t}_i}(p_{\tilde{t}_i}) (\eta_e)_{i} u_e(p_e) \bar{u}_{\tilde{q}_{out,b}}(p_{\tilde{q}_{out}}) \gamma_{\mu} u_{\bar{q}_{in,b}}(p_{\bar{q}_{in}}) (p_{\bar{q}_i} + p_e - p_{\tilde{t}_i})^\mu \\
\sum_X \left( (\Delta X)(p_{\bar{q}_{in}}, p_{\tilde{q}_{out}})(f_e)_{X}(f_{\bar{q}})_{X} \right) \frac{i}{(p_{\bar{q}_i} - p_{\tilde{t}_i})^2 - m_{\tilde{t}_i}^2}
\]

\[
(M_{2})_{ab} = \sum_j \bar{v}_{\tilde{e}_a}(p_e) (\eta_e)_{j} \frac{i}{(p_{\tilde{t}_i} - p_e)^2 - m_{\tilde{e}_j}^2} (\eta_q)_{j} u_{\bar{q}_{in,b}}(p_{\bar{q}_{in}}) \\
\frac{i}{(p_{\tilde{q}_{out}} + p_{\tilde{t}_i})^2 - m_{\tilde{q}}^2 + \frac{i}{q} m_{q} \Gamma_{\tilde{q}_{out,b}}(p_{\tilde{q}_{out}}) \left( \eta_q \right)_{i} \gamma\!\!\!\!m_{\tilde{t}_{\chi_i}}(p_{\tilde{t}_{\chi_i}})
\]

\[
(M_{3})_{ab} = \bar{u}_{\tilde{t}_i}(p_{\tilde{t}_i}) i \frac{\gamma_{\mu}}{(p_{\tilde{t}_i} + p_t)^2 - m_{\tilde{t}_i}^2} (\eta_e)_{i} \bar{u}_{\tilde{q}_{out,b}}(p_{\tilde{q}_{out}}) (\eta_q)_{i} u_{\bar{q}_{in,b}}(p_{\bar{q}_{in}}) \\
\sum_X \left( (\Delta X)(p_{\bar{q}_{in}}, p_{\tilde{q}_{out}})(f_e)_{X}(f_{\bar{q}})_{X} \right) 
\]

\[
(M_{4})_{ab} = -\sum_j \bar{u}_{\tilde{q}_{out,b}}(p_{\tilde{q}_{out}}) (\eta_q^*)_{j} \frac{i}{(p_{\tilde{t}_i} - p_t)^2 - m_{\tilde{t}_i}^2} (\eta_e)_{j} u_{\bar{e}_a}(p_e) \\
\frac{i}{(p_{\bar{q}_{in}} - p_{\tilde{t}_i})^2 - m_{\tilde{q}}^2} \bar{u}_{\tilde{t}_i}(p_{\tilde{t}_i}) (\eta_q)_{i} u_{\bar{q}_{in,b}}(p_{\bar{q}_{in}})
\]

\[
(M_{5})_{ab} = \sum_j \bar{u}_{\tilde{t}_i}(p_{\tilde{t}_i}) \gamma_{\mu} \sum_X \left( (\Delta X)(p_{\bar{q}_{in}}, p_{\tilde{q}_{out}})(f_q)_{X}(f_{\bar{q}})_{X} \right) \\
\frac{i}{(p_e - p_{\tilde{t}_i})^2 - m_{\tilde{t}_i}^2} (\eta_e)_{i} u_{\bar{e}_a}(p_e) \bar{u}_{\tilde{q}_{out,b}}(p_{\tilde{q}_{out}}) (\eta_q)_{i} u_{\bar{q}_{in,b}}(p_{\bar{q}_{in}}) \\
\gamma_{\mu} u_{\bar{q}_{in,b}}(p_{\bar{q}_{in}}) 
\]

The momenta of the incoming quark, outgoing quark, the electron, the slepton and the neutralino/chargino are denoted by \( p_{\bar{q}_{in}}, p_{\tilde{q}_{out}}, p_e, p_{\tilde{t}_i} \) and \( p_{\tilde{t}_{\chi_i}}. \) The index \( i \) denotes
the outgoing neutralino/chargino and the indices \( a = R, L \) and \( b = R, L \) denote the polarisation of the electron and the incoming quark, respectively. Further

\[
\Delta_X(p_{\text{out}} - p_{\text{in}}) = \frac{-i}{(p_{\text{out}} - p_{\text{in}})^2 - m_X^2}
\]

Where \( X = \gamma, Z^0, W \) denotes the gauge boson exchanged in the graphs 1, 3 and 5. Because \( X \) depends on the process, we show in table 2 this connection between exchanged gauge boson and process.

In eqs. (29)–(33) \((f_f)_X\) are the electro weak couplings of the fermion \( f \) and the gauge boson \( X \) with

\[
(f_f)_\gamma = -ie e_f,
(f_f)_Z = ie \tan \theta_W e_f,
(f_{f_L})_Z = -i \frac{e}{\sin \theta_W \cos \theta_W} \left( T_{3f} - \sin^2 \theta_W e_f \right),
(f_{f_L})_W = -i \frac{e}{\sqrt{2} \sin \theta_W}.
\]

The supersymmetric couplings from eqs. (17) and (19) are denoted by \((\eta_f)_i\) and these from eqs. (24)–(26) are denoted by \((O_{X}^{R,L})_{ij}\) with

\[
(O_X)_{ij} = (O_X^{R})_{ij} \frac{1 + \gamma_5}{2} + (O_X^{L})_{ij} \frac{1 - \gamma_5}{2}.
\]

For selectron and sneutrino production we have in the amplitudes \(\mathcal{M}_2, \mathcal{M}_4\) and \(\mathcal{M}_5\) to sum the contributions from the exchange of all four neutralinos and both charginos respectively. Since the squark exchanged in graph 2 may approach its mass shell in the accessible region of the phase space, the squark width \(\Gamma^\text{tot}_\tilde{q}\) enters in \(\mathcal{M}_2\).

Depending on the production channel and the polarisation of the sleptons and squarks certain amplitudes vanish. Thus for the process (b) and (d) one obtains contributions from left-handed \(u\)-quarks and right-handed \(d\)-quarks only, whereas only left-handed \(d\)-quarks and right-handed \(u\)-quarks are contributing to the process (c). To the process (e) all quarks contribute to the terms \(\mathcal{M}_{1,3,5}\) but only left-handed \(u\)-quarks (\(d\)-quarks) and right-handed \(\bar{u}\)-quarks (\(\bar{d}\)-quarks) are contributing to the amplitude \(\mathcal{M}_2 (\mathcal{M}_4)\). In process (a) all quarks contribute. Further for the processes (d) and (e) as well as for process (b)/(c) and the amplitude \(\mathcal{M}_3/\mathcal{M}_4\) we obtain contributions from left-handed
electrons only. Finally the amplitude $M_1$ in case of process (b) and $M_3$ in case of
process (c) vanish.

The amplitudes squared are completely listed in appendix A. In order to obtain the
total cross section, we average over the polarisations of the incoming particles, sum
over the polarisations of the outgoing particles, fold this with the appropriate quark
distributions, sum over all partons of the proton and integrate over the whole phase
space:

$$\sigma^{\text{tot}}(ep \to \tilde{l}\tilde{\chi}_i X) = \frac{1}{8(E_{\text{cm}}^e)^2(2\pi)^5} \sum_{a,b} \int \frac{d^3 p_{\tilde{l}}}{2E_{\tilde{l}}} \int \frac{d^3 p_{\tilde{\chi}_i}}{2E_{\tilde{\chi}_i}} \int \frac{d^3 p_{\text{out}}}{2E_{\text{out}}} \times q_k(x,Q^2) \left| \sum_n (M_{n})_{ab} \right|^2 \delta^4(p_e + p_{q_{in}} - p_{\tilde{l}} - p_{\tilde{\chi}_i} - p_{\text{out}}) \quad (35)$$

The specific parametrization of the momenta in the phase space is, as well as the limits
of the phase space integration, given in appendix B.

4 Numerical Results

To show the importance of gaugino-higgsino mixing we shall present numerical results
for the total production cross section at $\sqrt{s} = 1.8$ TeV, for three representative gaugino
higgsino mixing scenarios, shown in table 3. For the SUSY parameters we assumed
$M'/M = \frac{3}{5} \tan \theta_W$, $m_{\tilde{g}} = M \sin^2 \theta_W \alpha_s/\alpha_{\text{em}} \simeq 3M$ with $\sin^2 \theta_W = 0.228$ and $\alpha_s = 0.1,$
and $\tan \beta = v_2/v_1 = 2$ (notice that the numerical results are not very sensitive to the
value of $\tan \beta$). For the masses of the gauge bosons we used $m_Z = 91.2$ GeV and
$m_W = 80.1$ GeV.

The crucial difference lies in the nature of the neutralino states and the chargino
states. In scenario (A) the lightest neutralino $\tilde{\chi}_1^0$ is almost a photino, whereas in scenario
(C) it is nearly a higgsino and in scenario (B) it is a zino-photino-higgsino mixture.
Similarly the light (heavy) chargino is wino-like (higgsino-like) in scenario (A), higgsino-
like (wino-like) in scenario (C), whereas in scenario (B) both charginos are wino-higgsino
mixtures. The second lightest neutralino $\tilde{\chi}_2^0$ is almost a pure weak eigenstate in each of
the three scenarios: a zino in scenario (A), a photino in scenario (B) and a higgsino in
scenario (C) with only small admixtures from other weak eigenstates. Similarly $\tilde{\chi}_3^0$ is
almost a higgsino in scenarios (A) and (B) and a photino in (C). The heaviest neutralino $\tilde{\chi}_4^0$ finally is almost a pure higgsino in scenario (A), a zino in scenario (C) and a zino-higgsino mixture with a rather small photino component in scenario (B). We shall see that the question which of the neutralinos or charginos will be produced with the highest rate sensitively depends on the nature of the mass eigenstates. Thus it may happen that the cross section for the production of the heaviest neutralino $\tilde{\chi}_4^0$ is by one order of magnitude higher than that for the lightest one $\tilde{\chi}_1^0$.

For each of these mixing scenarios total production cross sections have been calculated for three different relations between slepton mass and squark mass: $m_{\tilde{q}} = m_{\tilde{l}}$ in scenarios (A1), (B1) and (C1) and $m_{\tilde{q}} = 4 \cdot m_{\tilde{l}}$ in scenarios (A2), (B2) and (C2). Three further scenarios (A'), (B') and (C') with $m_{\tilde{l}} = m_{\tilde{g}}$ and $m_{\tilde{q}} = 1.4 \cdot m_{\tilde{l}}$ are motivated by the renormalization group relation eq. (28) coupling the sfermion masses and the gaugino mass parameter $M$ of the MSSM. Allowing an error of at most 4% for the sfermion masses this choice (neglecting the mass difference between left and right-handed as well as between up and down-type sfermions) is for values of $M$ between 45 GeV and 450 GeV and $\tan \beta = 2$ compatible with the mass relation eq. (28). The value of $\mu$ in scenarios (A'), (B') and (C') is the same as in scenarios (A), (B) and (C), respectively, whereas $M$ is varied between 45 GeV and 450 GeV, which corresponds to values of the gluino mass between $m_{\tilde{g}} = 1.5 \cdot m_Z$ and $m_{\tilde{g}} = 15 \cdot m_Z$. Notice that from there in these scenarios both the mass and the mixing character of the neutralinos and charginos depend on the respective value of the sfermion mass.

In order to compute the cross sections for ep-scattering, eq. (35), we fold the amplitudes squared for the parton subprocesses with the quark distribution functions $q_k(x, \bar{Q}^2)$ of Glück, Reya and Vogt [7] and integrate over the whole phase space. In contrast to slepton-squark production the momentum transfer squared to the nucleon $\bar{Q}^2$ depends on the respective production mechanism: $\bar{Q}^2 = Q^2 = -(p_{q_{\text{out}}} - p_{q_{\text{in}}})^2$ for the graphs 1, 3 and 5, whereas for the graphs 2 and 4 one has $\bar{Q}^2 = Q^2 = -(p_{\tilde{l}} - p_e)^2$. We have, however, numerically checked that in the kinematic region investigated here $\bar{Q}^2 = \frac{1}{2} (sx - (m_{\tilde{\nu}} + m_{\tilde{\chi}}))^2$ is a satisfactory approximation leading to an error of at most 10% in the most unfavorable case of processes dominated by neutralino or chargino ex-
change. For processes dominated by gauge boson exchange the error is smaller.

For avoiding divergences arising from photon exchange and also in order to separate deep inelastic from elastic scattering and exclusive inelastic processes we impose a cut for the momentum transfer squared $Q^2$ to the quark with $Q^2_{cut} = 10 \text{(GeV)}^2$. It is true that this choice of $Q^2_{cut}$ involves some uncertainty for the values of the total cross sections. We have, however, numerically checked that processes dominated by the exchange of massive gauge bosons or neutralinos/charginos are rather insensitive to the actual value of $Q^2_{cut}$. For processes dominated by photon exchange the dependence on $Q^2_{cut}$ of the cross sections is approximately logarithmic (i.e. for $Q^2_{cut} = 10/5/2.5 \text{ GeV}$ we get for the production of $\tilde{\chi}_1^0$ and a selectron in scenario (A.2) and $m_{\tilde{e}} = 300 \text{ GeV}$ a cross section from $\sigma = 1.2/1.3/1.4 \cdot 10^{-4} \text{ pb}$).

For the squark width entering into $M_2$ we have taken into account all contributions from its two body decays. Three body decays are suppressed in case of our scenarios [4]. The integration was performed using the monte carlo program *vegan*.

### 4.1 The Process $ep \to \tilde{e} \tilde{\chi}_i^0 X$

From all production channels investigated in this paper only associated production of a selectron and a photino-like LSP $\tilde{\chi}_1^0 \simeq \tilde{\gamma}$ has been examined in detail in the literature [3].

In figs. 2–5 we show total cross sections $\sigma(ep \to \tilde{e} \tilde{\chi}_i^0 X)$, $i = 1, \ldots, 4$ for all four neutralino states as a function of the selectron mass. Since the cross sections are rather small, we give as examples the numerical results for scenarios (A1), (A2) and (C1), (C2) only most obviously revealing some interesting features. Especially we omit graphs for the scenarios based on the mass relations eq. (28). For scenario (A’) the cross sections are smaller than $10^{-2} \text{ pb}$ and for scenarios (B’) and (C’) smaller than $10^{-3} \text{ pb}$.

Apart from the region of small selectron mass in scenario (C1) and (B1) the cross sections are the largest for photino-like neutralinos, i.e. the LSP $\tilde{\chi}_1^0$ in scenarios (A1) and (A2), $\tilde{\chi}_2^0$ in scenarios (B1) and (B2) and the heavy neutralino $\tilde{\chi}_3^0$ in scenarios (C1) and (C2). In the case of a photino-like (or zino-like) neutralino the dominating contributions are from the Feynman graphs 1 and 3 with strong electron-selectron-photino couplings.
In scenarios (A1), (B1) and (C1) also graph 2 gives remarkable contributions. The steep ascent in these scenarios of the cross sections most strongly marked in scenario (C1) originates from the contribution of the Feynman graph 2 where for \(m_\tilde{q} \geq m_\tilde{\chi}_i\) the squark approaches its mass shell in the accessible region of phase space. Then neglecting contributions from all other graphs as well as interference contributions we have
\[
\sigma(ep \rightarrow \tilde{e}\tilde{\chi}_i^0 X) \simeq \sigma(ep \rightarrow \tilde{e}\tilde{q}X) \cdot BR(\tilde{q} \rightarrow \tilde{\chi}_i^0 q)
\]
as a reasonable estimation for \(m_\tilde{q} > m_\tilde{\chi}_i\).

It is remarkable that in scenario (C1) for \(m_\tilde{\epsilon} \geq 150\) GeV the cross section for the heavy photino-like neutralino \(\tilde{\chi}_3^0\) and for \(m_\tilde{\epsilon} \geq 300\) GeV even that for the heaviest neutralino with dominating zino component is by one order of magnitude higher than that for the lightest higgsino-like state \(\tilde{\chi}_1^0\) produced via the reaction mechanism of Feynman graph 5 mainly (pur higgsinos are only produced by graph 5, but only in case of scenarios with at least one higgsino-chargino mixing state, which couples at both vertices of the exchanged neutralino).

This demonstrates that the question which of the neutralino cross sections is the dominating one crucially depends on the mixing properties of the respective states, whereas their mass is of minor importance.

For comparison we also give in the figs. the cross sections for selectron-squark production. For \(m_\tilde{\epsilon} = m_\tilde{\epsilon}\) the biggest of the neutralino cross sections (\(\tilde{\chi}_1^0\) for \(m_\tilde{\epsilon} \simeq 200\) GeV in scenario (A1) and \(\tilde{\chi}_3^0\) for \(m_\tilde{\epsilon} \simeq 250\) GeV in scenario (C1)) is at best approximately 30\% of that for selectron-squark production. If, however, the squarks are considerably heavier than the selectrons (\(m_\tilde{q} = 4 \cdot m_\tilde{\epsilon}\)) than the selectron-squark cross section rapidly drops for increasing selectron mass, so that for \(m_\tilde{\epsilon} \geq 300\) GeV associated selectron-neutralino production is the dominating process.

### 4.2 The Process \(ep \rightarrow \tilde{e}\tilde{\chi}_i^+ X\)

For the same reasons as for neutralino production we compare in figs. 6, 7 the total cross sections for \(\tilde{e}\tilde{\chi}_i^+\)-production (and \(\tilde{e}\tilde{\chi}_i^-\)-production) in scenarios (A1), (A2) only with those for \(\tilde{e}\tilde{q}\)-production. And we also give no results for the scenarios (A'), (B') and (C'). In scenarios (A1) and (A2) the cross sections are the largest for wino-like light
charginos $\tilde{\chi}_1^\pm$. Similar as for production of a photino-like neutralino the dominating contributions are those from Feynman graph 3 and also from graph 2 if the squark approaches its mass shell, generating the steep ascent of the cross sections for $\tilde{\chi}_1^\pm$ in scenario (A1) with $m_\tilde{q} = m_\tilde{\ell}$. In contrast to neutralino production the amplitude $M_5$ gives significant contributions to the production of both gaugino-like and higgsino-like charginos. Being of minor importance for charginos with dominating wino component, it is the crucial production mechanism for higgsino-like charginos, i.e. $\tilde{\chi}_2^\pm$ in scenario (A1), (A2) and $\tilde{\chi}_1^\pm$ in scenarios (C1), (C2).

In scenarios (C1) and (C2) a consequence of the interplay between mass and mixing character is the type of the chargino with the largest cross section changes with increasing selectron mass (and squark mass). In scenario (C1) it is for $m_\tilde{q} = m_\tilde{\ell} < 250$ GeV the higgsino-like light chargino, whereas for $m_\tilde{q} = m_\tilde{\ell} > 250$ GeV it is the wino-like heavy chargino, which is produced with the highest rate. Vice versa in scenario (C2) with heavy squarks it is for $m_\tilde{\ell} < 200$ GeV the wino-like $\tilde{\chi}_2^+$ whereas for $m_\tilde{\ell} > 200$ GeV it is the higgsino-like $\tilde{\chi}_1^+$ which yields the highest cross section. This shows the changing importance of the contributions from graph 2 compared to the contributions of graphs 1, 3 and 5.

Similar as for the case of neutralino production in scenario (A1) and (C1) (for $m_\tilde{q} = m_\tilde{\ell}$) the cross sections for selectron-chargino production are at best 30\% of that for selectron-squark production. For $m_\tilde{q} = 4 \cdot m_\tilde{\ell}$, however, the cross section for $\tilde{\ell}\tilde{q}$-production is rapidly decreasing with increasing selectron mass so that for $m_\tilde{\ell} \geq 250$ GeV associate selectron-chargino production is the dominating process with cross sections approximately one order of magnitude higher than those for selectron-neutralino production.

### 4.3 The Process $ep \rightarrow \tilde{\ell}\tilde{\chi}_i^- X$

Production of charginos $\tilde{\chi}_i^+$ and anti-charginos $\tilde{\chi}_i^-$ differs in two substantial features. Firstly the dominating reaction mechanism for production of a wino-like chargino $\tilde{\chi}^-$ is via graph 1 instead of graph 3 for a wino-like chargino $\tilde{\chi}^+$. Secondly only $d$ valence quarks are contributing to $\tilde{\ell}\tilde{\chi}^-$-production instead of $u$ valence quarks for $\tilde{\ell}\tilde{\chi}^+$-production. Thus
considerably differences are to be expected for the respective cross sections in figs. 6, 7. In the case of higgsino-like charginos $M_5$ is the dominating amplitude for both $\tilde{\chi}^+$ and $\tilde{\chi}^-$-production. Again for $m_{\tilde{q}} = m_{\tilde{\ell}}$ one obtains considerably contributions from squark exchange in amplitude $M_2$ generating in scenario (C1) a rise of the cross section for $\tilde{\chi}_2^-$. For the wino-like $\tilde{\chi}^-_1$ in scenario (A1) this is suppressed by the surmounting contribution of the amplitude $M_1$.

Apart from the region $m_{\tilde{\ell}} \geq 250$ GeV in scenario (C1) the cross section for $\tilde{\ell}\tilde{\chi}^-_1$-production are larger than those for $\tilde{\ell}\tilde{\chi}^+_1$-production and particularly for large selectron and squark masses higher than those for $\tilde{\ell}\tilde{q}$-production.

4.4 The Process $e p \rightarrow \tilde{\nu}_{\chi^0_i} X$

For these production channels we compare in figs. 8–14 beside the cross sections for scenarios (A1), (B1), (C1) and (A2), (B2), (C2) also that for scenario (A’) (based on the mass relation eq. (28)) with the cross section for $\tilde{\nu}\tilde{q}$-production. Again we omit figs. for scenarios (B’) with cross sections below $10^{-3}$ pb and (C’) with cross sections below $10^{-2}$ pb.

Due to the large $W$-couplings in the Feynman graphs 1, 3 and 5 in all our scenarios the cross sections are the largest for neutralinos with a dominating zino component, i.e. $\tilde{\chi}^0_2$ in scenarios (A1) and (A2), $\tilde{\chi}^0_1$ and $\tilde{\chi}^0_4$ in scenarios (B1) and (B2) and $\tilde{\chi}^0_4$ in scenarios (C1) and (C2). It is noticeable that in scenarios (B1) and (C1), (C2) it is the heaviest neutralino which is produced with the highest rate. Especially in scenario (C2) for $m_{\tilde{\nu}} > 150$ GeV the cross section for the heaviest neutralino $\tilde{\chi}^0_4$ is one order of magnitude larger than those for the lighter neutralino states.

Since pure higgsinos would solely be produced via the mechanism of Feynman graph 5 the cross sections in scenarios (A) for the heavy higgsino-like states $\tilde{\chi}^0_3$ and $\tilde{\chi}^0_4$, respectively, are nearly equal for $m_{\tilde{q}} = m_{\tilde{\ell}}$ and $m_{\tilde{q}} = 4 \cdot m_{\tilde{\nu}}$. In scenarios (C) the same holds for the light higgsino-like state $\tilde{\chi}^0_1$, whereas the small zino component of the higgsino-like neutralino $\tilde{\chi}^0_2$ gives rise to the rather different cross sections for scenarios (C1) and (C2).

In scenario (A’) the mass relation eq. (28) couples the gaugino mass parameter $M$ and the sfermion masses and the neutralino masses as well as their couplings are varying
with increasing sneutrino masses. This is the reason for the numerous crossings of the cross sections in fig. 10 for scenario (A').

In all scenarios examined neutralinos with a large zino component are produced with remarkably large cross sections comparable to or even considerably larger than those for sneutrino-squark production and also larger than selectron-squark production. Thus associated sneutrino-neutralino production appears to provide an attractive channel in the search for supersymmetric events at LEP ⊗ LHC. The importance of this channel is, however, somewhat reduced by the complex decay patterns of the particles produced leading for a sizeable fraction of events to final states with many hadronic jets unfavorable for a clearly visible supersymmetric signal.

4.5 The Process $ep \rightarrow \tilde{\nu} \tilde{\chi}_i^- X$

Due to the dominance of the contributions from gauge boson exchange in graphs 1, 3 and 5 the numerical results are nearly identical for $m_{\tilde{q}} = m_{\tilde{\nu}}$ and $m_{\tilde{q}} = 4 \cdot m_{\tilde{\nu}}$. We therefore give the results for scenarios (A1), (B1) and (C1) and (A'), (B') and (C') only. In contrast to $\tilde{\nu}q$-production all partons are contributing to $\tilde{\nu}\tilde{\chi}_i^-$-production. This together with the strong Z-couplings in graphs 1, 3 and 5 and the photon couplings in graphs 3 and 5 leads for all scenarios to cross sections for sneutrino-chargino production being between one and two orders of magnitude larger than those for $\tilde{\nu}q(e\bar{q})$-production. The cross section is the highest for the light wino like chargino $\tilde{\chi}_1^-$ in scenario (A1) attaining values between 1pb and 10pb (for $m_{\tilde{\nu}} < 400$ GeV) but even for the heavy wino like chargino $\tilde{\chi}_2^-$ in (C1) it is considerably larger than that for $\tilde{\nu}q$-production and also larger than that for the light higgsino like state $\tilde{\chi}_1^-$, with substantial contributions from $M_5$ only. Fig. 17 demonstrates once more the crucial importance of gaugino higgsino mixing. Both charginos being mixtures with considerably different masses, the somewhat larger wino component of the heavier one suffices to raise its cross section to nearly the same magnitude of that for the lighter one.

In contrast to all other processes discussed in the proceeding sections, also for scenarios (A'), (B') and (C') the cross sections for $\tilde{\nu}\tilde{\chi}_i^-$-production are larger than $10^{-2}$ pb in a wide range of parameter space and considerably larger than those for $\tilde{\nu}q$-production.
Notice that in scenarios (A’), (B’) and (C’) the mass specified in figs. 16, 18 and 20 as well as the coupling character of both charginos are varying with increasing sneutrino mass: For the lower values of $m_{\tilde{\nu}}$ the light chargino is more wino like, whereas the heavy chargino is higgsino like. The situation changes with increasing sneutrino mass so that the light chargino becomes more and more higgsino like whereas the heavy one becomes more and more wino like. Simultaneously the mass of the heavy chargino is rapidly increasing whereas that of the light chargino asymptotically approaches the value $|\mu|$. This interplay between mass and mixing character produces the two crossings of the cross sections in figs. 16, 18 and 20.

5 Signatures

In order to work out suitable signatures for signals from associate slepton-neutralino/chargino production it is indispensable to include the decay of these particles as well as a discussion of the competing standard model background. Here we shall restrict ourselves to some remarks, postponing a more detailed discussion of signatures and background to a subsequent paper.

Light supersymmetric particles decay directly into the lightest neutralino (which is assumed to be the lightest supersymmetric particle LSP and stable) and fermions, whereas heavy sparticles decay over complex cascades ending at the LSP. These cascade decays of heavy sparticles have two important consequences. On the one hand they will lead to events with besides one or several leptons, jets and missing energy one or two $W$ or $Z$ bosons in the final state $[8]$. On the other hand they can significantly enhance the possible signals of the respective process $[9]$. The actual decay patterns and the dominant signatures will, however, sensitively depend on the supersymmetric parameters and the slepton mass. Thus in scenario (A1) and (A2) where the cross sections are the biggest for the processes $ep \rightarrow \tilde{\nu}\tilde{\chi}_0^0 X$ and $ep \rightarrow \tilde{\nu}\tilde{\chi}_1^- X$, and the main decay channels are $\tilde{\nu} \rightarrow \nu\tilde{\chi}_1^-, \nu\tilde{\chi}_2^0, \nu\tilde{\chi}_1^0$ and $\tilde{\chi}_1^- \rightarrow \tilde{\chi}_1^0e\bar{\nu}, \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0\bar{l}\bar{l}$, the dominant signatures are $ej \ E$, $2ej \ E$ and $3ej \ E$ ($j$ denotes an arbitrary number of jets) for $m_{\tilde{\nu}} = 100$ GeV. For $m_{\tilde{\nu}} = 500$ GeV, where the main production channels are the same but the charginos and neutralinos
decay with a higher probability into lighter charginos/neutralinos and two quarks, the
dominant signatures are $ej \not{E}$, $2ej \not{E}$. For scenarios (C1) and (C2) on the other hand
with $ep \rightarrow \tilde{\nu}_{\lambda} \tilde{\chi}_{1}^{0} X$ and $ep \rightarrow \tilde{\nu}_{\lambda} \tilde{\chi}_{2}^{0} X$ as the dominant processes the favored signatures are
$ej \not{E}$ and $Wj \not{E}$ for $m_{\tilde{\nu}} = 100$ GeV, arising by the decay of the sneutrino into a lepton
and a light neutralino/chargino and the decay of the heavy neutralino/chargino either
into a chargino/neutralino and a $W$-boson or into a sfermion-fermion pair. $eWj \not{E}$
and $e2Wj \not{E}$ are favored signatures for $m_{\tilde{l}} = 500$ GeV in these scenarios, because the
sneutrino also may decay into a heavy neutralino/chargino and a lepton. For scenarios
(B1) and (B2), finally, with dominant contributions from $\tilde{\nu}_{\lambda} \tilde{\chi}_{-1}^{0}$ and $\tilde{\nu}_{\lambda} \tilde{\chi}_{-2}^{0}$-production
the decays of the gaugino-higgsino mixtures $\tilde{\chi}_{1}^{-}$ and $\tilde{\chi}_{2}^{-}$ will lead to final states with
both one or several leptons and one or two gauge bosons as favored signatures.

The most important sources of background are single $W$ and $Z$ production $ep \rightarrow
\nu WX, \nu ZX$ and $ep \rightarrow eWX, eZX$ followed by the decays $W \rightarrow l\nu, Z \rightarrow \nu \nu$ and
$Z \rightarrow l^{+}l^{-}$ giving rise to events with one, two or three charged leptons [10]. On the
other hand the case of single top production $ep \rightarrow \nu t b X$ followed by the decay $\bar{t} \rightarrow \bar{b} W^{-}$
gives rise to the $Wj \not{E}$ configuration and the neutral current process $ep \rightarrow etlX$ is a
source of the background for $e2Wj \not{E}$ events [11]. Since, however, the cross section
for $tt$-production is rather small, one would expect that this is the least dangerous of
the competing standard model backgrounds. Detailed Monte Carlo studies taking into
account the background are needed to asses the observability of the SUSY signal from
associate slepton-neutralino/chargino production.

6 Conclusion

We have analyzed for three representative gaugino-higgsino mixing scenarios and for
different slepton-squark mass ratios associate slepton-neutralino and slepton-chargino
production at LEP$\otimes$LHC. From all five production channels sneutrino-chargino pro-
duction appears to be the most attractive one. The cross sections for wino-like light
charginos $\tilde{\chi}_{1}^{-}$ in scenarios (A) as well as $\tilde{\chi}_{2}^{-}$ in scenarios (C) are between one and two
orders of magnitude bigger than those for $\tilde{\nu}\tilde{q}$-production: about 0.1 pb for $m_{\tilde{\nu}} = 500$
GeV and between 1 pb and 10 pb for $m_{\tilde{\nu}} = 50$ GeV. Similar results are obtained for higgsino-gaugino mixtures and even for light higgsino-like charginos the cross sections are one order of magnitude bigger than those for $\tilde{\nu}q$-production. Also for associated production of a zino-like neutralino and a sneutrino the cross sections are bigger (scenarios (A)) or comparable to (scenarios (C)) those for $\tilde{\nu}q$-production.

For all other production channels, especially for selectron-chargino production, the situation depends on the squark-slepton mass ratio and the gaugino-higgsino mixing scenario. Thus for $m_{\tilde{q}} = m_{\tilde{t}}$ the dominating process is slepton-squark production whereas for $m_{\tilde{q}} = 4 \cdot m_{\tilde{t}}$ and $m_{\tilde{t}} > 100$ GeV in scenarios (A) ($m_{\tilde{t}} > 200$ GeV in scenarios (B) and (C)) the cross sections for selectron-squark production are bigger than those for $\tilde{e}\tilde{q}$-production. Similarly for $m_{\tilde{q}} = 4 \cdot m_{\tilde{t}}$ and $m_{\tilde{t}} > 220$ GeV also selectron-neutralino production is distinguished by cross sections larger than those for $\tilde{e}\tilde{q}$-production.

For scenarios (A')–(C') motivated by the mass relation eq. (28) only the sneutrino-chargino cross sections are bigger than $10^{-2}$ pb in a noticeable range of the parameter space.

The question, which of the neutralinos/charginos will be produced with the highest rate, depends much more sensitively on the mixing properties than on their masses. Generally the production of gaugino-like states is considerably favored so that for selectron-neutralino production in scenario (C4) it is even the heavy photino-like neutralino $\chi_3^0$ which yields the dominating cross section. We find the same situation for sneutrino-chargino production: in scenario (C1) the cross section for the wino-like heavy chargino $\tilde{\chi}_2^-$ is considerably higher than that for the higgsino-like light chargino $\tilde{\chi}_1^-$. 

The subsequent decays of the produced sparticles lead to interesting signatures with up to four charged leptons, hadronic jets and in case of scenarios (B) and (C) massive gauge bosons. A quantitative analysis of these signatures and the competing background will be postponed to a subsequent paper.

The size of the cross section for sneutrino-chargino production, comparable to or even bigger than that for competing standard model processes, let us however suggest, that this process should provide an attractive channel in the discovery of supersymmetric models at LEP⊗LHC.
Appendix A

We list in this appendix the complete expressions for the amplitudes squared for the production channels (a)–(e) convenient for future computation of differential cross sections, energy spectra etc. The notation is as in eqs. (29)-(33). For the interference terms we write \((M_{i,j})^2 := 2Re(M_iM_j^*)\).

Where the expressions are depending on the polarisations we will write on the left-hand side \(a = b\) \((a \neq b)\) for the same (opposite) polarisation of the incoming electron and quark. On the righthand side \(a,b\) occurs in some cases in the formulas with \(a,b = \pm 1\) for right-, lefthanded electrons and quarks, respectively, or as an index at the couplings \((O_a^b)_{ij}\). If the expression is valid for arbitrary polarisations we have suppressed \(a,b\).

The \(m_{\tilde{\chi}_i}\) are the eigenvalues of the neutralino/chargino mixing matrix, respectively, and not the physical masses and so may be negative.

The antisymmetric terms – contractions with \(\epsilon\)-tensors – give no contributions to the total cross section, because they vanish by the phase space integration.

As for the couplings defined in eqs. (29)-(33) we have indicated by a suffix the corresponding Feynman graph: \((\eta^1_1)_i\) is, for instance, the coupling \((\eta_1)_1\) in graph 1 and \((\eta^4_1)_i\) is the complex conjugated from \((\eta^*_1)_j\) in graph 4. Depending on the respective process one has in the amplitudes \(M_1, M_3\) and \(M_5\) to sum over different contributions from exchange of gauge bosons \(X\), given in table 2. This has for clearness been indicated by a suffix \((\sum_X^1\) in the expression for \(|M_1|^2\), e.g.). The factors \((\mathcal{P}^k_x)\) etc. refer to the propagator of the particle \(x\) exchanged in Feynman graph \(k\). To give an example:

\[
(P^2_{\tilde{\chi}})_j = \frac{1}{(p_i - p_e)^2 - m^2_{\tilde{\chi}_j}}.
\]

\[
|M_1|^2 = 4 \left| \sum_X^1 (f^1_1(x)(f^1_q)X(\eta^1_1)_i)(P^1_i)(P^1_{\tilde{\chi}}) \right|^2
\]

\[
\left[ 2(p_i \cdot p_{qout} + p_e \cdot p_{qout} - p_{qin} \cdot p_{\tilde{\chi}_i})(p_i \cdot p_{qin} + p_e \cdot p_{qin} - p_{qin} \cdot p_{\tilde{\chi}_i}) - (m_i^2 + 2p_e \cdot p_i - 2p_i \cdot p_{\tilde{\chi}_i} + m_{\tilde{\chi}_i}^2 - 2p_e \cdot p_{\tilde{\chi}_i})p_{qin} \cdot p_{qout} \right] p_e \cdot p_{\tilde{\chi}_i}
\]

\[
|M_2|_{a=b}^2 = 4 \sum_j m_{\tilde{\chi}_j}(\eta^2_1)_j(\eta^2_q)_j(\eta^2_1)_i)(P^2_{\tilde{\chi}})_j(P^2_q) \left| p_e \cdot p_{qin} p_{\tilde{\chi}_i} \cdot p_{qout} \right|^2
\]

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\[ |\mathcal{M}_2|_{a \neq b}^2 = 4 \left| \sum_j (\eta_e^j) (\eta_{\bar{\ell}}^j) (\mathcal{P}_X^j) (\mathcal{P}_q^j) \right|^2 \]
\[ p_{\text{out}} \cdot p_{\tilde{\chi}_i} \left(2p_e \cdot p_{\bar{\ell}} (p_{\text{out}} \cdot p_{\tilde{\chi}_i} - p_e \cdot p_{\tilde{\chi}_i}) - p_{\text{out}} \cdot p_{\tilde{\chi}_i} (m_i^2 - 2p_e \cdot p_{\bar{\ell}}) \right) \]

\[ |\mathcal{M}_3|_{a = b}^2 = 16 \left| \sum_X (f_e^3 X f_q^3 X (\eta_{\bar{\ell}}^e)^i) (\mathcal{P}_X^3) (\mathcal{P}_q^3) \right|^2 \]
\[ p_e \cdot p_{\tilde{\chi}_i} \left[2(m_{\tilde{\chi}_i}^2 + p_{\bar{\ell}} \cdot p_{\tilde{\chi}_i}) (p_{\text{out}} \cdot p_{\tilde{\chi}_i} + p_{\bar{\ell}} \cdot p_{\tilde{\chi}_i}) - p_{\text{out}} \cdot p_{\tilde{\chi}_i} (m_{\tilde{\chi}_i}^2 + 2p_{\bar{\ell}} \cdot p_{\tilde{\chi}_i} + m_i^2) \right] \]

\[ |\mathcal{M}_3|_{a \neq b}^2 = 16 \left| \sum_X (f_e^3 X f_q^3 X (\eta_{\bar{\ell}}^e)^i) (\mathcal{P}_X^3) (\mathcal{P}_q^3) \right|^2 \]
\[ p_{\text{out}} \cdot p_{\tilde{\chi}_i} \left[2(m_{\tilde{\chi}_i}^2 + p_{\bar{\ell}} \cdot p_{\tilde{\chi}_i}) (p_{\text{out}} \cdot p_{\tilde{\chi}_i} + p_{\bar{\ell}} \cdot p_{\tilde{\chi}_i}) - p_{\text{out}} \cdot p_{\tilde{\chi}_i} (m_{\tilde{\chi}_i}^2 + 2p_{\bar{\ell}} \cdot p_{\tilde{\chi}_i} + m_i^2) \right] \]

\[ |\mathcal{M}_4|_{a = b}^2 = 4 \left| \sum_j (\eta_e^j) (\eta_{\bar{\ell}}^j) (\mathcal{P}_X^j) (\mathcal{P}_q^j) \right|^2 \]
\[ p_{\text{out}} \cdot p_{\tilde{\chi}_i} \left(2p_e \cdot p_{\bar{\ell}} (p_{\text{out}} \cdot p_{\tilde{\chi}_i} - p_e \cdot p_{\tilde{\chi}_i}) - p_{\text{out}} \cdot p_{\tilde{\chi}_i} (m_i^2 - 2p_e \cdot p_{\bar{\ell}}) \right) \]

\[ |\mathcal{M}_4|_{a \neq b}^2 = 4 \left| \sum_j m_{\tilde{\chi}_i} (\eta_e^j) (\eta_{\bar{\ell}}^j) (\mathcal{P}_X^j) (\mathcal{P}_q^j) \right|^2 \]
\[ p_{\text{out}} \cdot p_{\tilde{\chi}_i} \cdot p_{\text{out}} \cdot p_{\tilde{\chi}_i} \cdot p_{\bar{\ell}} \cdot p_{\bar{\ell}} \]

\[ |\mathcal{M}_5|^2 = 4 \sum_{k,l} \sum_{X,X'}^5 \left| (f_q^5 X (\eta_{\bar{\ell}}^e)^k) (\mathcal{P}_X^5) (\mathcal{P}_q^5) (\mathcal{P}_X^5) (\mathcal{P}_q^5) \right|^2 \]
\[ -2(\mathcal{O}_X^{a})_{ik} (\mathcal{O}_X^{-a})_{il} [p_e \cdot p_{\bar{\ell}} (p_{\text{out}} \cdot p_{\tilde{\chi}_i} (p_e \cdot p_{\tilde{\chi}_i} - p_{\bar{\ell}} \cdot p_{\tilde{\chi}_i})) + 2p_{\text{out}} \cdot p_{\tilde{\chi}_i} (p_e \cdot p_{\tilde{\chi}_i} - p_{\bar{\ell}} \cdot p_{\tilde{\chi}_i})] - \]
\[ 2(m_{\tilde{\chi}_i}^2 - 2p_e \cdot p_{\bar{\ell}}) - (\mathcal{O}_X^{a})_{ik} (\mathcal{O}_X^{a})_{il} m_{\tilde{\chi}_i} m_{\tilde{\chi}_i} \]
\[ (2p_{\text{out}} \cdot p_{\tilde{\chi}_i} + 2p_{\text{out}} \cdot p_{\tilde{\chi}_i}) + 2p_{\text{out}} \cdot p_{\tilde{\chi}_i} (p_e \cdot p_{\tilde{\chi}_i} - p_{\bar{\ell}} \cdot p_{\tilde{\chi}_i}) + \]
\[ 2m_{\tilde{\chi}_i} [(\mathcal{O}_X^{a})_{ik} (\mathcal{O}_X^{-a})_{il} m_{\tilde{\chi}_i} + (\mathcal{O}_X^{a})_{ik} (\mathcal{O}_X^{a})_{il} m_{\tilde{\chi}_i}] p_e \cdot p_{\bar{\ell}} p_{\text{out}} \cdot p_{\tilde{\chi}_i} (p_e \cdot p_{\tilde{\chi}_i} - p_{\bar{\ell}} \cdot p_{\tilde{\chi}_i}) - \]
\[ 2ab \left\{ -2(\mathcal{O}_X^{a})_{ik} (\mathcal{O}_X^{-a})_{il} p_e \cdot p_{\bar{\ell}} [p_{\text{out}} \cdot p_{\tilde{\chi}_i} (p_e \cdot p_{\tilde{\chi}_i} - p_{\bar{\ell}} \cdot p_{\tilde{\chi}_i}) - \]
\[ p_{\text{out}} \cdot p_{\tilde{\chi}_i} (p_e \cdot p_{\tilde{\chi}_i} - p_{\bar{\ell}} \cdot p_{\tilde{\chi}_i})] + \]
\[ [(\mathcal{O}_X^{a})_{ik} (\mathcal{O}_X^{-a})_{il} m_{\tilde{\chi}_i} m_{\tilde{\chi}_i}] \right\} \]
(\mathcal{M}_{1,2})_{a=b}^2 = -4\text{Re} \sum_j \sum_{X}^1 \left( (\eta_{\mu}^2)_{j}(\eta_{\mu}^2)_{j}m_{\tilde{\chi}_j}\eta_{\mu}^2_{i}(\mathcal{P}_{\tilde{\chi}}^2)_{j}(\mathcal{P}_{\tilde{\chi}}^2)_{j}(\eta_{\mu}^1_{i}f_{e}^{i*})_{i}(f_{e}^{i*})_{i}X_{1}(\mathcal{P}_{\tilde{\chi}}^1)(\mathcal{P}_{\tilde{\chi}}^1)m_{\tilde{\chi}_j} \right) \\
\left( p_{i} \cdot p_{out} + p_{e} \cdot p_{out} - p_{\tilde{\chi}_i} \cdot p_{out} \right) p_{e} \cdot p_{qin} + \\
\left( p_{i} \cdot p_{qin} + p_{e} \cdot p_{qin} - p_{\tilde{\chi}_i} \cdot p_{qin} \right) p_{e} \cdot p_{out} - \\
\left( p_{e} \cdot p_{i} - p_{e} \cdot p_{\tilde{\chi}_i} \right) p_{qin} \cdot p_{qout} - \\
8\text{Im} \sum_j \sum_{X}^1 \left( (\eta_{\mu}^2)_{j}(\eta_{\mu}^2)_{j}m_{\tilde{\chi}_j}\eta_{\mu}^2_{i}(\mathcal{P}_{\tilde{\chi}}^2)_{j}(\mathcal{P}_{\tilde{\chi}}^2)_{j}(\eta_{\mu}^1_{i}f_{e}^{i*})_{i}(f_{e}^{i*})_{i}X_{1}(\mathcal{P}_{\tilde{\chi}}^1)(\mathcal{P}_{\tilde{\chi}}^1)m_{\tilde{\chi}_j} \right) \\
a \cdot e^{\mu\nu\sigma\tau} p_{\mu} p_{\nu} p_{\sigma} p_{\tau} p_{\tilde{\chi}_i} (p_{qout}) \tag{44}

(\mathcal{M}_{1,2})_{a\neq b}^2 = -8\text{Re} \sum_j \sum_{X}^1 \left( (\eta_{\mu}^2)_{j}(\eta_{\mu}^2)_{j}m_{\tilde{\chi}_j}\eta_{\mu}^2_{i}(\mathcal{P}_{\tilde{\chi}}^2)_{j}(\mathcal{P}_{\tilde{\chi}}^2)_{j}(\eta_{\mu}^1_{i}f_{e}^{i*})_{i}(f_{e}^{i*})_{i}X_{1}(\mathcal{P}_{\tilde{\chi}}^1)(\mathcal{P}_{\tilde{\chi}}^1) \right) \\
\left( m_{\tilde{\chi}_j}^2 - 2p_{e} \cdot p_{out} \right) p_{qin} \cdot p_{qout} p_{e} \cdot p_{\tilde{\chi}_i} + \\
p_{qout} \cdot p_{\tilde{\chi}_i} p_{e} \cdot p_{qin} - p_{e} \cdot p_{out} p_{qin} \cdot p_{qout} p_{\tilde{\chi}_i} - \\
2p_{qout} \cdot p_{\tilde{\chi}_i}(p_{qin} \cdot p_{\tilde{\chi}_i} p_{e} \cdot p_{out} + p_{e} \cdot p_{\tilde{\chi}_i} p_{qin} \cdot p_{qout} - p_{qout} p_{qin} p_{\tilde{\chi}_i} p_{qin}) + \\
2m_{\tilde{\chi}_j}^2 p_{e} \cdot p_{qout} p_{qin} \cdot p_{qout} - p_{e} \cdot p_{qin} + p_{\tilde{\chi}_i} \cdot p_{qin} - \\
4p_{qin} \cdot p_{\tilde{\chi}_i} p_{e} \cdot p_{\tilde{\chi}_i} p_{out} \cdot p_{\tilde{\chi}_i} + \\
2p_{e} \cdot p_{\tilde{\chi}_i}(p_{e} \cdot p_{qout} p_{\tilde{\chi}_i} p_{qin} + p_{qout} \cdot p_{\tilde{\chi}_i} p_{e} \cdot p_{qin} - p_{qout} p_{qin} p_{\tilde{\chi}_i} p_{qin}) + \\
8\text{Im} \sum_j \sum_{X}^1 \left( (\eta_{\mu}^2)_{j}(\eta_{\mu}^2)_{j}m_{\tilde{\chi}_j}\eta_{\mu}^2_{i}(\mathcal{P}_{\tilde{\chi}}^2)_{j}(\mathcal{P}_{\tilde{\chi}}^2)_{j}(\eta_{\mu}^1_{i}f_{e}^{i*})_{i}(f_{e}^{i*})_{i}X_{1}(\mathcal{P}_{\tilde{\chi}}^1)(\mathcal{P}_{\tilde{\chi}}^1) \right) \\
a(2p_{i} \cdot p_{e} - m_{\tilde{\chi}_j}^2) \cdot e^{\mu\nu\sigma\tau} p_{\mu} p_{\nu} p_{\sigma} p_{\tau} p_{\tilde{\chi}_i} (p_{qout}) \tag{45}

(\mathcal{M}_{1,3})^2 = 8\text{Re} \sum_{X} \sum_{X'}^3 \left( (f_{e}^{i*})_{X}(f_{e}^{i*})_{X}(\eta_{\mu}^1_{i})(\mathcal{P}_{\tilde{\chi}}^1)(\mathcal{P}_{\tilde{\chi}}^1)(f_{e}^{i*})_{X'}(f_{e}^{i*})_{X'}(\eta_{\mu}^3_{i})(\mathcal{P}_{\tilde{\chi}}^3)(\mathcal{P}_{\tilde{\chi}}^3) \right) \\
\left[ \left[ p_{e} \cdot p_{qin}(m_{\tilde{\chi}_j}^2 + p_{i} \cdot p_{\tilde{\chi}_i}) + p_{e} \cdot p_{\tilde{\chi}_i}(p_{qin} \cdot p_{\tilde{\chi}_i} + p_{i} \cdot p_{qin}) - \\
p_{e} \cdot p_{\tilde{\chi}_i} + p_{e} \cdot p_{\tilde{\chi}_i} \right] (p_{i} \cdot p_{qout} + p_{e} \cdot p_{qout} - p_{qout} \cdot p_{\tilde{\chi}_i}) + \\
(p_{i} \cdot p_{qin} + p_{e} \cdot p_{qin} - p_{qin} \cdot p_{\tilde{\chi}_i}) \left[ p_{e} \cdot p_{\tilde{\chi}_i} + p_{e} \cdot p_{\tilde{\chi}_i} \right] (p_{e} \cdot p_{\tilde{\chi}_i} + p_{e} \cdot p_{\tilde{\chi}_i}) - \\
p_{e} \cdot p_{\tilde{\chi}_i} + p_{e} \cdot p_{\tilde{\chi}_i} (p_{e} \cdot p_{qout} \cdot p_{\tilde{\chi}_i} + p_{i} \cdot p_{qout}) - (p_{e} \cdot p_{\tilde{\chi}_i} + p_{e} \cdot p_{i}) p_{qout} \cdot p_{\tilde{\chi}_i} - \\
p_{qin} \cdot p_{qout} \left( p_{e} \cdot p_{i} - p_{e} \cdot p_{\tilde{\chi}_i} \right) (m_{\tilde{\chi}_j}^2 + p_{i} \cdot p_{\tilde{\chi}_i}) + \\
p_{e} \cdot p_{\tilde{\chi}_i} (p_{e} \cdot p_{\tilde{\chi}_i} - m_{\tilde{\chi}_j}^2 + m_{\tilde{\chi}_i}^2 + p_{e} \cdot p_{\tilde{\chi}_i}) - \\
(p_{e} \cdot p_{\tilde{\chi}_i} + p_{e} \cdot p_{\tilde{\chi}_i}) (p_{i} \cdot p_{\tilde{\chi}_i} + p_{e} \cdot p_{\tilde{\chi}_i} - m_{\tilde{\chi}_j}^2) \right] + \\
ab p_{e} \cdot p_{\tilde{\chi}_i} p_{qin} \cdot p_{\tilde{\chi}_i} (p_{e} \cdot p_{\tilde{\chi}_i} - m_{\tilde{\chi}_j}^2 + m_{\tilde{\chi}_i}^2 + p_{e} \cdot p_{\tilde{\chi}_i}) - \\
p_{e} \cdot p_{qout} (p_{\tilde{\chi}_i} \cdot p_{qin} + p_{i} \cdot p_{qin}) (p_{i} \cdot p_{\tilde{\chi}_i} + p_{e} \cdot p_{\tilde{\chi}_i} - m_{\tilde{\chi}_j}^2) \right) + \\
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\begin{align*}
\mathcal{M}_{1.4}^{2} & = -8 \text{Re} \sum_{j} \sum_{X} \left\{ \left( \eta_{e}^{4} \right)^{j} \left( \eta_{q}^{4} \right)^{j} \left( \eta_{e}^{1} \right)^{i} \left( \eta_{q}^{1} \right)^{i} \left( f_{e}^{1} \right)^{x} \left( f_{q}^{1} \right)^{x} \left( \mathcal{P}_{e}^{1} \right) \right) \right\} \\
\mathcal{M}_{1.4}^{2} & = 4 \text{Re} \sum_{j} \sum_{X} \left\{ \left( \eta_{e}^{4} \right)^{j} \left( \eta_{q}^{4} \right)^{j} \left( \eta_{e}^{1} \right)^{i} \left( \eta_{q}^{1} \right)^{i} \left( f_{e}^{1} \right)^{x} \left( f_{q}^{1} \right)^{x} \left( \mathcal{P}_{e}^{1} \right) \right) \right\}
\end{align*}

\begin{align*}
\mathcal{M}_{1.5}^{2} & = 16 \text{Re} \sum_{j} \sum_{X} \sum_{X'} \left\{ \left( \eta_{e}^{5} \right)^{j} \left( f_{q}^{5} \right) \left( \mathcal{P}_{e}^{5} \right)^{j} \left( \mathcal{P}_{q}^{5} \right)^{i} \left( \eta_{e}^{1} \right)^{i} \left( f_{q}^{1} \right)^{x} \left( f_{q}^{1} \right)^{x} \left( \mathcal{P}_{e}^{1} \right) \right) \right\}
\end{align*}

\begin{align*}
\mathcal{M}_{2.3}^{2} & = -16 \text{Re} \sum_{j} \sum_{X} \left\{ \left( m_{\tilde{X}_{e}} \eta_{e}^{2} \right)^{j} \left( \eta_{q}^{2} \right)^{j} \left( \eta_{e}^{3} \right)^{i} \left( \eta_{q}^{3} \right)^{i} \left( f_{e}^{3} \right)^{x} \left( f_{q}^{3} \right)^{x} \left( \mathcal{P}_{e}^{3} \right) \right) \right\}
\end{align*}
\begin{align}
(\mathcal{M}_{2,3})^2_{a \neq b} &= -16Re \sum_j \sum_X^3 \left( (\eta_e^2)^j_k (\eta_q^2)^j_q \right) (p^2_X)_{j} (p^2_q)_{j} (f^3_{q})_{i} (f^3_{q})_{i} (p^3_X)(p^3_q) \\
&\quad \left[ (p_{\text{qin}} \cdot p_{\text{qout}} - p_{\text{qout}} \cdot p_{\text{qin}}) \right] \left[ p_{\text{qout}} \cdot p_{\text{qin}} (p_p \cdot p_{\text{qin}} - p_p \cdot p_{\text{qout}}) + \\
&\quad p_p \cdot p_{\text{qout}} (m_{\tilde{X}}^2 \cdot + p_i \cdot p_{\tilde{X}}) - (p_p \cdot p_{\text{qout}} + p_{\text{qin}} \cdot p_{\text{qout}}) p_p \cdot p_{\tilde{X}} \\
&\quad (p_{\text{qout}} \cdot p_{\tilde{X}} p_p \cdot p_{\text{qin}} + p_p \cdot p_{\text{qout}} p_{\text{qin}} \cdot p_{\tilde{X}} - p_{\text{qin}} \cdot p_{\text{qout}} p_p \cdot p_{\tilde{X}}) - \\
&\quad 2p_{\text{qout}} \cdot p_{\tilde{X}} p_p \cdot p_{\text{qin}} p_p \cdot p_{\text{qout}} - p_p \cdot p_{\text{qin}} p_p \cdot p_{\text{qout}} m_{\tilde{X}}^2 \right] \\
&\quad 16Im \sum_j \sum_X^3 \left( (\eta_e^2)^j_k (\eta_q^2)^j_q \right) (p^2_X)_{j} (p^2_q)_{j} (f^3_{q})_{i} (f^3_{q})_{i} (p^3_X)(p^3_q) \\
&\quad a(p_p \cdot p_i - p_i \cdot p_p) + e^{\mu \nu \sigma \tau} p_\mu \rho p_\nu \rho p_\sigma \rho p_\tau \tag{51}
\end{align}

\begin{align}
(\mathcal{M}_{2,4})^2_{a \neq b} &= 4Re \left( \sum_k m_{\tilde{X}}^2 (\eta_e^2)^k_k (\eta_q^2)^k_q \right) (p^2_X)_{k} (p^2_q)_{k} \left( \sum_l (\eta_e^4)^l_l (\eta_q^4)^l_l \right) (p^4_X)_l (p^4_q)_l \\
&\quad m_{\tilde{X}} \left[ p_p \cdot p_{\text{qin}} (p_p \cdot p_{\text{qin}} - p_i \cdot p_{\text{qout}}) \\
&\quad p_p \cdot p_{\text{qout}} (p_p \cdot p_{\text{qin}} - p_i \cdot p_{\text{qout}}) - p_{\text{qin}} \cdot p_{\text{qout}} p_p \cdot p_i \\
&\quad 4Im \left( \sum_k m_{\tilde{X}}^2 (\eta_e^2)^k_k (\eta_q^2)^k_q \right) (p^2_X)_{k} (p^2_q)_{k} \left( \sum_l (\eta_e^4)^l_l (\eta_q^4)^l_l \right) (p^4_X)_l (p^4_q)_l \\
&\quad a \cdot e^{\mu \nu \sigma \tau} p_\mu \rho p_\nu \rho p_\sigma \rho p_\tau \tag{52}
\end{align}

\begin{align}
(\mathcal{M}_{2,4})^2_{a \neq b} &= 4Re \left( \sum_k (\eta_e^2)^k_k (\eta_q^2)^k_q \right) (p^2_X)_{k} (p^2_q)_{k} \left( \sum_l m_{\tilde{X}}^2 (\eta_e^4)^l_l (\eta_q^4)^l_l \right) (p^4_X)_l (p^4_q)_l \\
&\quad m_{\tilde{X}} \left[ p_p \cdot p_{\text{qout}} (p_p \cdot p_{\text{qout}} - p_i \cdot p_{\text{qin}}) \\
&\quad p_p \cdot p_{\text{qin}} (p_p \cdot p_{\text{qin}} - p_i \cdot p_{\text{qout}}) - p_{\text{qin}} \cdot p_{\text{qout}} p_p \cdot p_i \\
&\quad 4Im \left( \sum_k (\eta_e^2)^k_k (\eta_q^2)^k_q \right) (p^2_X)_{k} (p^2_q)_{k} \left( \sum_l m_{\tilde{X}}^2 (\eta_e^4)^l_l (\eta_q^4)^l_l \right) (p^4_X)_l (p^4_q)_l \\
&\quad a \cdot e^{\mu \nu \sigma \tau} p_\mu \rho p_\nu \rho p_\sigma \rho p_\tau \tag{53}
\end{align}

\begin{align}
(\mathcal{M}_{2,5})^2_{a \neq b} &= -8Re \sum_{k,l} \sum_X^3 (\eta_e^5)^k_k (\eta_q^5)^k_q \right) (p^5_X)_{k} (p^5_q)_{k} (f^5_{q})_{i} (f^5_{q})_{i} (p^5_X)(p^5_q) \\
&\quad \left[ 2(\mathcal{O}_X^{a*})_{im} m_{\tilde{X}} p_p \cdot p_{\text{qin}} p_p \cdot p_{\text{qout}} - (\mathcal{O}_X^{a*})_{im} m_{\tilde{X}} p_p \cdot p_{\text{qout}} p_p \cdot p_{\text{qin}} \cdot p_i \\
&\quad p_i \cdot p_{\text{qout}} p_p \cdot p_{\text{qin}} - p_{\text{qin}} \cdot p_{\text{qout}} p_i \cdot p_p \right] \tag{54}
\end{align}

\begin{align}
(\mathcal{M}_{2,5})^2_{a \neq b} &= -8aRe \sum_{k,l} \sum_X^3 (\eta_e^5)^k_k (\eta_q^5)^k_q \right) (p^5_X)_{k} (p^5_q)_{k} (f^5_{q})_{i} (f^5_{q})_{i} (p^5_X)(p^5_q) \\
&\quad \left[ (\mathcal{O}_X^{a*})_{im} m_{\tilde{X}} p_{\text{qout}} \cdot p_{\text{qin}} p_p \cdot p_i - p_i \cdot p_{\text{qout}} p_p \cdot p_{\text{qin}} + p_p \cdot p_{\text{qout}} p_i \cdot p_{\text{qin}} \\
&\quad - 2(\mathcal{O}_X^{a*})_{im} p_{\text{qout}} \cdot p_{\tilde{X}} (m_{\tilde{X}}^2 p_p \cdot p_{\text{qin}} - 2p_i \cdot p_{\text{qin}} p_i \cdot p_p) \right] \\
&\quad a \cdot e^{\mu \nu \sigma \tau} p_\mu \rho p_\nu \rho p_\sigma \rho p_\tau \tag{55}
\end{align}
\[ 8Im \sum_{k,l} \sum_{X} 5 \left( \eta_{k}^{2} k(n_{k}^{2})_{k}(\eta_{q}^{2})_{i}(\mathcal{P}_{X}^{5})(\mathcal{P}_{q}^{5})(f_{q}^{5*}) X(n_{e}^{5*})_{i}(\mathcal{P}_{X}^{5})(\mathcal{P}_{q}^{5})_{l} \right. \]
\[ 2a(\mathcal{O}_{X}^{a})_{il} m_{\psi} m_{\chi l} \cdot e^{\mu
u\sigma\tau} p_{\rho}^{\mu} p_{\sigma}^{\nu} p_{qin}^{\rho} p_{out}^{\tau} \]

\[(\mathcal{M}_{3.4})^{2}_{a=b} = 16Re \sum_{j} \sum_{X} \left( (q_{j}^{4})(n_{q}^{2})_{j}(\mathcal{P}_{q}^{4})(\mathcal{P}_{X}^{4})(f_{q}^{4*}) X(f_{q}^{4*}) X(\mathcal{P}_{X}^{4})(\mathcal{P}_{q}^{4}) \right) \]
[\left[ p_{e} \cdot p_{qin} p_{out} \cdot \tilde{p}_{\psi} \cdot (2p_{e} \cdot p_{\psi} - p_{e} \cdot p_{qin}) - p_{e} \cdot p_{qin} p_{e} \cdot p_{\psi} p_{qin} \cdot p_{out} - \left[ p_{qin} \cdot p_{out} \cdot (p_{e} \cdot \tilde{p}_{\psi} - 2p_{e} \cdot p_{qin}) + p_{e} \cdot p_{qin} p_{out} \cdot \tilde{p}_{\psi} - p_{e} \cdot p_{qout} p_{qin} \cdot \tilde{p}_{\psi} \right] \right] \]

\[(\mathcal{M}_{3.4})^{2}_{a \neq b} = 16Re \sum_{j} \sum_{X} \left( (q_{j}^{4})(n_{q}^{2})_{j} m_{\chi j} (n_{q}^{4})_{i}(\mathcal{P}_{q}^{4})(\mathcal{P}_{X}^{4})(f_{q}^{4*}) X(f_{q}^{4*}) X(\mathcal{P}_{X}^{4})(\mathcal{P}_{q}^{4}) \right) \]

\[ m_{\chi j} (p_{e} \cdot p_{qout} \cdot \tilde{p}_{i} + p_{qin} + p_{\psi i}) \]

\[(\mathcal{M}_{3.5})^{2} = 8Re \sum_{k,l} \sum_{X} \sum_{X'} \left( (n_{k}^{5})_{j}(f_{q}^{5}) X(\mathcal{P}_{X}^{5})(\mathcal{P}_{q}^{5})(n_{e}^{5*})_{i}(f_{q}^{5*}) X(\mathcal{P}_{X}^{5})(\mathcal{P}_{q}^{5}) \right) \]
\[ [(\mathcal{O}^{a})_{ij} \left[ 4p_{e} \cdot p_{i} (p_{\psi i} \cdot p_{qout} \tilde{p}_{i} + p_{qin} + p_{\psi i} p_{qin} \tilde{p}_{i} \cdot p_{out}) + 2m_{\chi i}^{2} p_{e} \cdot p_{qout} + 2m_{\chi i}^{2} (p_{\psi i} \cdot p_{qout} \tilde{p}_{i} + p_{qin} + p_{\psi i} p_{qin} \tilde{p}_{i} \cdot p_{out}) + 2m_{\chi i} m_{\chi j} (p_{\psi i} + \tilde{p}_{i} + p_{qout}) \right] \]

\[ ab \left( (\mathcal{O}^{a})_{ij} \left[ 4p_{e} \cdot p_{i} (p_{\psi i} \cdot p_{qout} \tilde{p}_{i} + p_{qin} + p_{\psi i} p_{qin} \tilde{p}_{i} \cdot p_{out}) + 2m_{\chi i}^{2} (p_{\psi i} p_{qin} \tilde{p}_{i} \cdot p_{out} + p_{\psi i} p_{qin} \tilde{p}_{i} \cdot p_{out}) - \left( p_{\psi i} p_{qin} \tilde{p}_{i} + p_{\psi i} p_{qin} \tilde{p}_{i} \cdot p_{out} \right) \right] - 2 \left( (\mathcal{O}^{a})_{ij} \left[ p_{qout} \cdot \tilde{p}_{i} (p_{e} \cdot \tilde{p}_{i} + p_{e} p_{qin} \cdot \tilde{p}_{i} + p_{e} \cdot p_{qin} \tilde{p}_{i} \cdot p_{out}) + p_{e} \cdot p_{qout} \cdot \tilde{p}_{i} + p_{e} \cdot p_{qout} \tilde{p}_{i} \cdot p_{out} \right] - \left( p_{e} \cdot p_{qout} \tilde{p}_{i} + p_{e} \cdot p_{qout} \tilde{p}_{i} \cdot p_{out} \right) \right) \]

\[ \left( (\mathcal{O}^{a})_{ij} \left[ p_{qout} \cdot \tilde{p}_{i} \cdot p_{e} \cdot \tilde{p}_{i} + p_{e} \cdot p_{qout} \tilde{p}_{i} \cdot p_{out} + p_{e} \cdot p_{qout} \tilde{p}_{i} \cdot p_{out} \right] - \left( p_{e} \cdot p_{qout} \tilde{p}_{i} + p_{e} \cdot p_{qout} \tilde{p}_{i} \cdot p_{out} \right) \right) \]

\[(\mathcal{M}_{4.5})^{2}_{a=b} = 8Re \sum_{k,l} \sum_{X} \sum_{X'} \left( (n_{e}^{5})_{k}(n_{q}^{4})_{k}(\mathcal{P}_{X}^{4})(\mathcal{P}_{q}^{4})(f_{q}^{5*}) X(n_{e}^{5*})_{l}(\mathcal{P}_{X}^{5})(\mathcal{P}_{q}^{5})_{l} \right) \]
\[ \left[ (\mathcal{O}^{a})_{il} m_{\psi} m_{\chi l} (p_{e} \cdot p_{i} p_{qin} \cdot \tilde{p}_{i} \cdot p_{out} + p_{e} \cdot p_{qin} \tilde{p}_{i} \cdot p_{out} - p_{e} \cdot p_{qout} \tilde{p}_{i} \cdot p_{in}) + \right. \]

\[ \left. \left[ (\mathcal{O}^{a})_{il} (p_{e} \cdot p_{i} p_{qin} \cdot \tilde{p}_{i} \cdot p_{out} + p_{e} \cdot p_{qin} \tilde{p}_{i} \cdot p_{out}) \right) \right] \]
(\mathcal{O}_X^{a*})_{\alpha}(4p_e \cdot p_\alpha p_{q_{in}} \cdot p_\alpha p_{q_{out}} - 2m_{\tilde{l}}^2 p_e \cdot p_{out} p_{q_{in}} \cdot p_\alpha) \right] \right] 

(\mathcal{M}_{4,5})_{a \neq b} = 8Re \sum_{k,l} \sum_X^5 (\eta_4^k \eta_4^k \eta_4^k \eta_4^k) (P_4^k (P_4^k f^5_X)(f^5_X)(P_4^k (P_4^k l) \right] 

(\mathcal{O}_X^{a*})_{\alpha}(4m_{\tilde{l}}^2 m_\chi l p_{q_{in}} \cdot p_\alpha p_{q_{out}} + p_e \cdot p_{q_{in}} p_\alpha p_{q_{out}} + p_e \cdot p_{q_{out}} p_\alpha p_{q_{in}} + 2(\mathcal{O}_X^{a*})_{\alpha}(4m_{\tilde{l}}^2 m_\chi l p_{q_{in}} \cdot p_\alpha p_{q_{out}})

\textbf{Appendix B}

In this appendix we give the parametricalization of the momenta as well as the limits for the phase space integration. We parametrize the momenta of the particles in the electron quark center-of-mass system as follows:

\[ p_e = E_{cm}^{eq} \begin{pmatrix} 1 \\ \sin \theta \cos \varphi \\ \sin \theta \sin \varphi \\ \cos \varphi \end{pmatrix} \quad p_{q_{in}} = E_{cm}^{eq} \begin{pmatrix} 1 \\ -\sin \theta \cos \varphi \\ -\sin \theta \sin \varphi \\ -\cos \varphi \end{pmatrix} \]

\[ p_{q_{out}} = E_{q_{out}} \begin{pmatrix} 1 \\ 0 \\ 0 \\ 1 \end{pmatrix} \quad p_{\tilde{l}} = \begin{pmatrix} E_{\tilde{l}} \\ \sqrt{E_{\tilde{l}}^2 - m_{\tilde{l}}^2} \sin \theta \cos \phi \\ \sqrt{E_{\tilde{l}}^2 - m_{\tilde{l}}^2} \sin \theta \sin \phi \\ \sqrt{E_{\tilde{l}}^2 - m_{\tilde{l}}^2} \cos \theta \end{pmatrix} \]

\[ p_{\chi_3} = \begin{pmatrix} 2E_{cm}^{eq} - E_{q_{out}} - E_{\tilde{l}} \\ -\sqrt{E_{\tilde{l}}^2 - m_{\tilde{l}}^2} \sin \theta \cos \phi \\ -\sqrt{E_{\tilde{l}}^2 - m_{\tilde{l}}^2} \sin \theta \sin \phi \\ -\sqrt{E_{\tilde{l}}^2 - m_{\tilde{l}}^2} \cos \theta - E_{q_{out}} \end{pmatrix} \]

with the momentum of the outgoing quark in direction of the \( x_3 \)-axis, \( \theta \) the angle between the electron beam and the \( x_3 \)-axis, \( \varphi \) the angle between the \( x_1-x_3 \)-plane and the plane fixed by the \( x_3 \)-axis and the electron beam, \( \varphi \) the angle between the slepton momentum and the \( x_3 \)-axis and \( \phi \) the angle between the \( x_1-x_3 \)-plane and the plane defined by the momenta of the outgoing particles. From momentum conservation and the mass shell
condition for \( p_{\tilde{\chi}_i} \) we get
\[
\cos \theta = \frac{(2E_{\text{cm}}^q - E_{\text{out}} - E_i)^2 - E_{\text{out}}^2 - E_i^2 + m_i^2 - m_{\tilde{\chi}_i}^2}{2E_{\text{out}} \sqrt{E_i^2 - m_i^2}}, \tag{61}
\]
and transform eq. (61) into
\[
\sigma^{\text{tot}}(eP \rightarrow \tilde{l} \tilde{\chi}_i X) = \sum_k \int \frac{1}{256(E_{\text{cm}}^q)^2(2\pi)^5} \sum_{a,b} \int dE_{\text{out}} \int dE_i \int d(cos \vartheta) \int d\varphi \int d\phi \times
q_k(x, Q^2) \left| \sum_n (\mathcal{M}_n)_{ab} \right|^2,
\tag{62}
\]
with the integration limits
\[
0 \leq \varphi \leq 2\pi,
\]
\[
0 \leq \phi \leq 2\pi.
\]
The integration limits for \( E_i, E_{\text{out}}, \vartheta \) and \( x \) are fixed as follows. From \(|\cos \theta| \leq 1\) we obtain
\[
E_{\text{max,min}} = \frac{2E_{\text{cm}}^q - E_{\text{out}}}{2} - \frac{(2E_{\text{cm}}^q - E_{\text{out}})(m_{\tilde{\chi}_i}^2 - m_i^2)}{8E_{\text{cm}}^q(E_{\text{cm}}^q - E_{\text{out}})} \pm \frac{E_{\text{out}}}{2|E_{\text{cm}}^q - E_{\text{out}}|} \times
\left[ E_{\text{out}}^2 + \frac{E_{\text{out}}}{E_{\text{cm}}^q} \left( \frac{1}{2} (m_{\tilde{\chi}_i}^2 - m_i^2 - 4(E_{\text{cm}}^q)^2) + m_i^2 \right) -
\right.
\left.
m_i^2 + \frac{1}{(4E_{\text{cm}}^q)^2} (m_{\tilde{\chi}_i}^2 - m_i^2 - 4(E_{\text{cm}}^q)^2)^2 \right]^{1/2}.
\tag{63}
\]
From eq. (63) we get for the upper limit of \( E_{\text{out}} \)
\[
E_{\text{out}}^{\text{max}} = E_{\text{cm}}^q \left( 1 - \frac{(m_i + m_{\tilde{\chi}_i})^2}{(2E_{\text{cm}}^q)^2} \right).
\]
In order to avoid divergences in the terms containing photon exchange (and in order to avoid the main part of elastic scattering) we introduce a cut \( Q_{\text{cut}}^2 \) for
\[
Q^2 = -(p_l + p_{\tilde{\chi}_i} - p_e)^2 = -(p_{\text{in}} - p_{\text{out}})^2 = 2E_{\text{cm}}^q E_{\text{out}}(1 + \cos \vartheta).
\]
Then from the condition \( Q^2 \geq Q_{\text{cut}}^2 \) the limits for the \( \vartheta \) integration are specified by
\[
\frac{Q_{\text{cut}}^2}{2E_{\text{cm}}^q E_{\text{out}} \sqrt{x}} - 1 \leq \cos \vartheta \leq 1
\]
From \((\cos \vartheta)_{\text{min}} \leq 1\) the lower limit of \( E_{\text{out}} \) is obtained as
\[
E_{\text{out}}^{\text{min}} = \frac{Q_{\text{cut}}^2}{4E_{\text{cm}}^q \sqrt{x}}.
and finally from \( E_{q_{\text{out}}}^{\text{min}} \leq E_{q_{\text{out}}}^{\text{max}} \) the region of \( x \) integration is fixed as
\[
\frac{Q_{\text{cut}}^2 + (m_i + m_{\tilde{\chi}_i})^2}{4(E_{\text{cm}}^{\text{P}})^2} \leq x \leq 1.
\]

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References

[1] A. Bartl, W. Majerotto, B. Mösslacher, N. Oshimo and S. Stippel, from Proceedings of the Large Hadron Collider Workshop. (Aachen, Oct. 1990), Vol. II, ed. G. Jarlskog, D. Rein, p. 1033

[2] A. Bartl, M. Drees, W. Majerotto and B. Mösslacher, in Physics at HERA, Vol. 2, p.1118, (Hamburg, Oct. 1991), ed. W. Buchmueller and G. Ingelman

[3] G. Altarelli, G. Martinelli, B. Mele, R. Rückl, Nucl. Phys. B262 (1985) 204. T. Kon, K. Nakamura, T. Kobayashi, Z. Phys. C 45 (1990) 567. T. Kobayashi, T. Kon, K. Nakamura, Acta Physica Polonica B21 (1990) 315.

[4] H.E. Haber, G.L. Kane, Phys. Rep. 117 (1985) 75.

[5] A. Bartl, H. Fraas, W. Majerotto, N. Oshimo, Phys. Rev. D40 (1989) 1594. A. Bartl, H. Fraas, W. Majerotto, B. Mösslacher, Z. Phys. C 55 (1992) 257.

[6] L.J. Hall, J. Polchinski, Phys. Lett. 152B (1985) 325. A. Bartl, M. Dittmar, W. Majerotto, from Proceedings of the Workshop: $e^+e^-$-collisions at 500 GeV. (Munich, Annecy, Hamburg, Febr.–Sept. 1991), Part B, ed. P.M. Zerwas, p. 603.

[7] M. Glück, E. Reya, A. Vogt, Z. Phys. C 53 (1992) 127.

[8] H. Baer, A. Bartl, D. Karatas, W. Majerotto, X. Tata, Int. J. of Mod. Phys. A 4 (1989) 4111.

[9] F. Cuypers, Phys. At. Nucl. 56 (1993) 1460.

[10] U. Baur, B.A. Kniehl, J.A.M. Vermaseren, D. Zeppenfeld, from Proceedings of the Large Hadron Collider Workshop. (Aachen, Oct. 1990), Vol. II, ed. G. Jarlskog, D. Rein, p. 956

[11] A. Ali, F. Barreiro, J.F. de Trocóniz, G.A. Schuler, J.J. van der Bij, from Proceedings of the Large Hadron Collider Workshop. (Aachen, Oct. 1990), Vol. II, ed. G. Jarlskog, D. Rein, p. 917
Table Captions

Table 1: Signfactor $\theta_i$, with $\varepsilon_A = \text{sign}(M \sin \beta + \mu \cos \beta)$ and $\varepsilon_B = \text{sign}(M \cos \beta + \mu \sin \beta)$.

Table 2: Gauge boson contribution to Feynman graphs 1, 3 and 5 for the basic subprocesses.

Table 3: Neutralino and chargino states in three different mixing scenarios (A), (B) and (C). Shown are the masses as well as the coefficients $N_{ik}$ from eq. (5) and $V_{ij}$ from eq. (12) of the decomposition into the weak eigenstates.

Figure Captions

Fig. 1: Feynman diagrams for the basic subprocess $eq \rightarrow \tilde{l}_i^{0(\pm)}q$. The gauge bosons exchanged in graphs 1, 3, 5 are denoted by $X$ (see table 2).

Fig. 2: Cross sections in scenario (A1) for the processes $ep \rightarrow \tilde{e}\chi_0^iX$, with dashed line for $i=1$, dotted line for $i=2$, dash-dotted for $i=3$, dash-dot-dot for $i=4$ and solid line for $ep \rightarrow \tilde{e}qX$.

Fig. 3: The same as fig. 2 for scenario (A2).

Fig. 4: The same as fig. 2 for scenario (C1).

Fig. 5: The same as fig. 2 for scenario (C2).

Fig. 6: Cross sections in scenario (A1) for the processes $ep \rightarrow \tilde{e}\chi^\pm_iX$, with dashed line for the production of $\tilde{\chi}_1^-$, dotted line for $\tilde{\chi}_2^+$, dash-dotted for $\tilde{\chi}_1^+$, dash-dot-dot for $\tilde{\chi}_2^-$ and solid line for $ep \rightarrow \tilde{e}qX$.

Fig. 7: The same as fig. 6 for scenario (A2).

Fig. 8: Cross sections in scenario (A1) for the processes $ep \rightarrow \tilde{\nu}\chi_0^iX$, with dashed line for $i=1$, dotted line for $i=2$, dash-dotted for $i=3$, dash-dot-dot for $i=4$ and solid line for $ep \rightarrow \tilde{\nu}qX$.

Fig. 9: The same as fig. 8 for scenario (A2).

Fig. 10: The same as fig. 8 for scenario (A').

Fig. 11: The same as fig. 8 for scenario (B1).
Fig. 12: The same as fig. 8 for scenario (B2).
Fig. 13: The same as fig. 8 for scenario (C1).
Fig. 14: The same as fig. 8 for scenario (C2).
Fig. 15: Cross sections in scenario (A1) for the processes $ep \to \bar{\nu}\tilde{\chi}^{-i}X$, with dashed line for $i=1$, dotted line for $i=2$ and solid line for $ep \to \bar{\nu}\tilde{q}X$.
Fig. 16: The same as fig. 15 for scenario (A'), with the masses of the charginos $\tilde{\chi}^{-1}$ and $\tilde{\chi}^{-2}$ included.
Fig. 17: The same as fig. 15 for scenario (B1).
Fig. 18: The same as fig. 16 for scenario (B').
Fig. 19: The same as fig. 15 for scenario (C1).
Fig. 20: The same as fig. 16 for scenario (C').
|      | $\tan \beta > 1$ | $\tan \beta < 1$ |
|------|------------------|------------------|
| $\theta_1$ | 1 | $\varepsilon_B$ |
| $\theta_2$ | $\varepsilon_B$ | 1 |
| $\theta_3$ | $\varepsilon_A$ | 1 |
| $\theta_4$ | 1 | $\varepsilon_A$ |

Table 1
|     | (a) $eq \rightarrow \tilde{e}_i^0 q$ | (b) $eq \rightarrow \tilde{e}_i^+ q'$ | (c) $eq \rightarrow \tilde{e}_i^- q'$ | (d) $eq \rightarrow \tilde{\nu}_i^0 q'$ | (e) $eq \rightarrow \tilde{\nu}_i^- q$ |
|-----|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| $\mathcal{M}_1$ | $X = \gamma, Z$ | $-$ | $X = W$ | $X = W$ | $X = Z$ |
| $\mathcal{M}_3$ | $X = \gamma, Z$ | $X = W$ | $-$ | $X = W$ | $X = \gamma, Z$ |
| $\mathcal{M}_5$ | $X = Z$ | $X = W$ | $X = W$ | $X = W$ | $X = \gamma, Z$ |

Table 2
|      | A            | B            | C            |
|------|--------------|--------------|--------------|
| tan β | 2            | 2            | 2            |
| μ    | -219 GeV     | 119 GeV      | -44 GeV      |
| M    | 73 GeV       | 169 GeV      | 219 GeV      |
| $\tilde{\chi}^0_1$ | $m = 40 \text{ GeV}, \eta = +1$ | $m = 40 \text{ GeV}, \eta = +1$ | $m = 40 \text{ GeV}, \eta = +1$ |
|      | (-0.95,+0.30,+0.08,+0.08) | (-0.35,+0.63,-0.62,-0.33) | (-0.06,+0.13,-0.18,+0.97) |
| $\tilde{\chi}^0_2$ | $m = 88 \text{ GeV}, \eta = +1$ | $m = 106 \text{ GeV}, \eta = +1$ | $m = 74 \text{ GeV}, \eta = -1$ |
|      | (-0.32,-0.89,-0.18,-0.27) | (-0.91,-0.06,+0.39,+0.14) | (+0.07,-0.33,+0.92,+0.22) |
| $\tilde{\chi}^0_3$ | $m = 225 \text{ GeV}, \eta = +1$ | $m = 122 \text{ GeV}, \eta = -1$ | $m = 118 \text{ GeV}, \eta = +1$ |
|      | (+0.02,+0.20,+0.35,-0.92) | (+0.02,-0.12,+0.35,-0.93) | (+0.92,-0.32,-0.20,+0.06) |
| $\tilde{\chi}^0_4$ | $m = 244 \text{ GeV}, \eta = -1$ | $m = 230 \text{ GeV}, \eta = +1$ | $m = 243 \text{ GeV}, \eta = +1$ |
|      | (+0.01,-0.27,+0.92,+0.29) | (+0.22,+0.77,+0.59,+0.13) | (+0.37,+0.88,+0.29,-0.04) |
| $\tilde{\chi}^+_1$ | $m = 87 \text{ GeV}, \eta = +1$ | $m = 66 \text{ GeV}, \eta = -1$ | $m = 61 \text{ GeV}, \eta = +1$ |
|      | (+0.99,+0.10) | (+0.65,-0.76) | (+0.39,-0.92) |
| $\tilde{\chi}^+_2$ | $m = 241 \text{ GeV}, \eta = +1$ | $m = 225 \text{ GeV}, \eta = +1$ | $m = 242 \text{ GeV}, \eta = +1$ |
|      | (-0.10,+0.99) | (+0.76,+0.65) | (+0.92,+0.39) |

Table 3
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