SEARCH FOR SLEPTONS AND SQUARKS AT THE Z PEAK IN e^+e^- COLLIDER

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ABSTRACT

We investigate single scalar lepton and scalar quark production processes $e^-e^+ \to Z^\circ \to \tilde{l}^\mp \tilde{\gamma} l^\pm, \tilde{q}\tilde{\gamma}\bar{q}$ and $\tilde{q}\tilde{g}\bar{q}$ at the Z° peak. We find that a detectable number of these scalars should be produced at the SLC and LEP-I colliders even if their masses substantially exceed the beam energy $E=m_Z/2 \simeq 45$GeV.

Selectrons $\tilde{e}$(the supersymmetric partners of electron) could be pair-produced in e^-e^+ annihilation if the beam energy were to exceed their mass. As pointed out by several authors[1,2,3] the selectrons with masses larger than the beam energy could be produced singly in the process

$$e^-e^+ \to \tilde{e}^\mp \tilde{\gamma} e^\pm \qquad (1)$$

where $\tilde{\gamma}$ is the photino which is assumed to be almost massless. In this article assuming light photino and gluino($\tilde{g}$) we point out that a detectable number of sleptons($\tilde{l}^\mp$) and squarks($\tilde{q}$) should be singly produced via processes such as

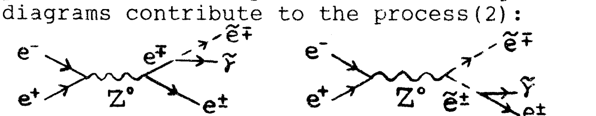
$$e^-e^+ \to Z^\circ \to \tilde{e}^\mp \tilde{\gamma} e^\pm , \qquad (2)$$

$$e^-e^+ \to Z^\circ \to \tilde{q}\ \tilde{\gamma}\ \bar{q} \qquad (3)$$

and $$e^-e^+ \to Z^\circ \to \tilde{q}\ \tilde{g}\ \bar{q}\ , \qquad (4)$$

in the run at the Z° peak at the SLC and LEP-I colliders even if their masses substantially exceed the beam energy $E=m_Z/2 \simeq 45$GeV[4].

Several diagrams can contribute to the process(1) [2]. As the Z° formation dominates the total e^-e^+ cross section at the Z° peak ($E=m_Z/2$), the contribution(2) dominates the process(1) at the peak. The following two diagrams contribute to the process(2):



The total cross section for the process (1) at the Z° peak in this approximation is then given by

$\sigma_{TOT}(e^-e^+ \to \tilde{e}^\mp \tilde{\gamma} e^\pm) = 1.26\times10^{-37} (1.68\times10^{-38})$ cm^2 for $m_{\tilde{e}}=50$GeV(60GeV)$\gg m_{\tilde{\gamma}}$. With the design luminosities of SLC and LEP-I ($L=10^{31}$ and 10^{32}cm^{-2}sec^{-1}, respectively) one has the expected number of events for the single $\tilde{e}$ production at the Z° peak in a 3-month run as follows:
9.8(1.3)events for $m_{\tilde{e}}=50(60)$GeV$\gg m_{\tilde{\gamma}}$ at SLC,
98 (13) events for $m_{\tilde{e}}=50(60)$GeV$\gg m_{\tilde{\gamma}}$ at LEP-I.
The same holds for the single $\tilde{\mu}$ and $\tilde{\tau}$ production. Hence it should be possible to detect the charged sleptons($\tilde{e}, \tilde{\mu}$ and $\tilde{\tau}$) in the run at $\sqrt{s}=m_Z$ at SLC and LEP-I if their masses are less than 50GeV and 60GeV, respectively.

Our approach can also be applied to the single $\tilde{e}$ production in $\bar{p}p$ collision(via the Z° production and its subsequent decay into $\tilde{e}\tilde{\gamma}e$, i.e., $\bar{p}p \to Z X \to \tilde{e}^\mp \tilde{\gamma} e^\pm X$) at the SPS-collider and the TEVATRON collider. Unfortunately we find that with the expected parameters of the colliders $\tilde{e}$ masses only up to $\sim m_Z/2 \simeq 45$ GeV can be reached in such experiment due to insufficient luminosity.

As for the single squark production processes(3) and (4), calculating the diagrams similar to those depicted above one obtains the expected number of events for the single $\tilde{q}$ production at the Z° peak in a 3-month run as follows:

SLC	LEP-I	
44(5.8)	440(58)	$\tilde{q}\tilde{\gamma}q$ for $m_{\tilde{q}}=50(60)$GeV and $m_{\tilde{\gamma}} \ll m_{\tilde{q}}$
630(77)	6300(770)	$\tilde{q}\tilde{g}q$ for $m_{\tilde{q}}=60(70)$GeV and $m_{\tilde{g}} \ll m_{\tilde{q}}$
1520(69)	15200(690)	$\tilde{q}\tilde{g}q$ for $m_{\tilde{q}}=50(60)$GeV and $m_{\tilde{g}}=20$GeV.

Hence in case $m_{\tilde{g}} \ll m_{\tilde{q}}$ it should be possible to detect squarks together with gluinos in a typical run at $\sqrt{s}=m_Z$ at SLC(LEP-I) if $m_{\tilde{q}} \lesssim 60$ GeV(70GeV); In the case $m_{\tilde{g}}=20$GeV these numbers are reduced to $m_{\tilde{q}} \lesssim 50$GeV(60GeV). Likewise in case $m_{\tilde{\gamma}} \ll m_{\tilde{q}}$ it should be possible to detect the $\tilde{q}$ production associated with the $\tilde{\gamma}$ in the same run as above at SLC(LEP-I) if $m_{\tilde{q}} \lesssim 50$ GeV(60GeV). We find that considerably higher (by about 8 GeV) slepton and squark masses can be reached by increasing (luminosity)x (running time) by a factor 5.

The signal and backgrounds for the $\tilde{e}^\mp \tilde{\gamma} e^\pm$ event are as follows (As for the $\tilde{q}\tilde{\gamma}q$ and $\tilde{q}\tilde{g}q$ events, see ref.[4].):
(i)Signal; The produced $\tilde{e}^\mp$ decays immediately into $e^\mp$ and $\tilde{\gamma}$ and the final state becomes $e^-e^+\tilde{\gamma}\tilde{\gamma}$. The $\tilde{\gamma}$ behaves like a neutrino and escapes detection. Hence the signal for this event is an acoplanar e^-e^+ pair with large missing p_T and missing energy.
(ii)Backgrounds; The $\tau^-\tau^+$ pair background($\tau^\mp \to e^\mp \nu\bar{\nu}$) should not be serious, since the e^- and e^+ from $\tau^\mp$ decay are almost back to back and hence coplanar. Backgrounds from pair production of L^-L^+(heavy lepton), $W^\pm W^\mp_{virtual}$, $\tilde{w}^+\tilde{w}^-$ (wino), H^+H^-(higgs) and $\tilde{H}^+\tilde{H}^-$(higgsino) where each particle decays into "$e^\mp$+ missing neutrals(ν and $\tilde{\gamma}$)" could be discriminated from the single slepton production events($\tilde{l}^\mp \tilde{\gamma} l^\pm$) on the basis that they lead also to acoplanar $e^\mp \mu^\pm$ events with $N(e^+\mu^-)+N(e^-\mu^+)=2N(e^-e^+)$ in remarkable contrast to the $\tilde{l}^\mp \tilde{\gamma} l^\pm$ events. Moreover $\sigma_{TOT}(e^-e^+ \to W^\pm "W^\mp" \to e^\pm e^\mp \nu\bar{\nu})$ is negligibly small at the Z° peak. Backgrounds from two-photon events, $e^-e^+\gamma$, $\tau^-\tau^+\gamma$ events and so on[3] should not be serious, since such events will tend to have p_T balance and/or coplanarity.

It is to be noted that in actual experiment one introduces various cuts, such as mssing p_T and acoplanarity angle cuts, to eliminate these background events and that such cuts reduce the number of signal events typically by about 50 %.

We conclude that a detectable number of sleptons and squarks should be singly produced at the Z° peak at the SLC and LEP-I even if their masses substantially exceed the beam energy.

References

[1]M.K.Gaillard et al.,Phys.Lett.116B,279(1982);[2]M.Kuroda et al.,Phys.Lett.127B,467(1983);[3]L.Gladney et al.,Phys.Rev.Lett.51,2253(1983) and E.Fernandez et al.,Phys.Rev.Lett,52,22(1984);[4]K.Hidaka,H.Komatsu and P.Ratcliffe,under submission for publication.