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SUPERSYMMETRY AT BAY?

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A B S T R A C T

If the squark mass $m_{\tilde{q}}$ is $O(40)$ GeV, as suggested by one interpretation of the CERN $p\bar{p}$ collider data, then one expects slepton masses $m_{\tilde{\ell}} \sim O(20 \text{ to } 30)$ GeV in a wide class of models. Sleptons with such masses would be produced copiously in $W \rightarrow \tilde{\chi}\tilde{\nu}$ and $Z^0 \rightarrow \tilde{\chi}^+\tilde{\chi}^-$ decays. We present rates and distributions for these processes, incorporating detector resolutions and experimental cuts. We show how the supersymmetric signals (especially for $Z^0 \rightarrow \tilde{\chi}^+\tilde{\chi}^-$) can easily be distinguished from the Standard Model backgrounds.

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There are many good reasons for Nature to be approximately supersymmetric¹⁾ - the naturalness of light elementary scalars, the hierarchy problem, unification of matter with forces, aesthetics, the only possible symmetry of the S-matrix not yet known to be exploited, etc. If Nature heeds these good pieces of advice, and associates a boson with every known fermion, as well as a fermion with every known boson, then where are they? We have grown accustomed to hearing of experimental lower bounds on sparticle masses, e.g., $m_{\tilde{e}}, m_{\tilde{\mu}} \gtrsim 0(20)$ GeV from e^+e^- annihilation²⁾, and a more indirect limit on $m_{\tilde{e}}$ which varies with the assumed value of $m_{\tilde{\gamma}}$, from searches³⁾ for $e^+e^- \rightarrow (\tilde{\gamma}\tilde{\gamma})\gamma$. But it may be that the CERN $p\bar{p}$ collider now offers us something better, namely the "monojet" events observed⁴⁾ by the UA1 Collaboration. These are difficult to explain in the Standard Model. If due to $\text{jet} + (Z^0 \rightarrow \nu\bar{\nu})$, where are the corresponding $\text{jet} + (Z^0 \rightarrow \ell^+\ell^-)$ or jet-jet events? If due to $\text{jet}(s) + (\nu + \text{invisible } \ell^\pm)$, where are the corresponding $\text{jet}(s) + (\ell^\pm + \text{soft } \nu)$ events? We believe that the most attractive explanation of these monojets is the associated production of pairs of strongly interacting sparticles. Three alternative supersymmetric mechanisms proposed are: $\tilde{q}\bar{q}$ production with $m_{\tilde{q}} = 0(40)$ GeV⁵⁾, $\tilde{g}\bar{g}$ production with $m_{\tilde{g}} = 0(40)$ GeV⁶⁾, and $\tilde{g}\bar{q}$ production with $m_{\tilde{g}} = 0(5)$ GeV and $m_{\tilde{q}} = 0(100)$ GeV⁷⁾. We prefer the $m_{\tilde{q}} = 40$ GeV explanation because it gives narrower monojets and a harder missing p_T distribution than the $m_{\tilde{g}} = 40$ GeV models^{5),8),9)}, avoids the cosmologically dubious^{10),11)} $\tilde{\gamma}$ of mass $0(1)$ GeV inherent in the $m_{\tilde{g}} = 0(5)$ GeV model, and has no dangerous extra sources of additional missing energy events due to light $\tilde{g}\bar{g}$ production or to $\tilde{q} \rightarrow q\bar{g}$ decay.

If $m_{\tilde{q}} = 0(40)$ GeV, what can one say about other sparticle masses and experiments? Here we need theoretical models to guide us, and the most attractive ones around are those based on $N = 1$ supergravity with soft supersymmetry breaking terms induced by the super-Higgs effect¹²⁾. These models give light particle spectra characterized by relatively few parameters, namely the bare scalar mass m_0 (usually, but not necessarily, identified with the gravitino mass $m_{3/2}$), the bare gaugino mass $m_{1/2}$, the ratio v_1/v_2 of Higgs vacuum expectation values, a trilinear scaling coupling parameter A (and its bilinear cousin B , which may equal $A-1$), and a Higgsino mixing parameter ϵ . This last parameter only enters in the gaugino - Higgsino fermion sector, and does not affect matter sparticle masses. With the exception of the stop squarks $\tilde{t}$, these are also largely independent of A (and B). Moreover, many theoretical models¹²⁾ prefer $v_1/v_2 = 1$, which is also strongly favoured⁸⁾ by the $m_{\tilde{q}} = 0(40)$ GeV interpretation of the collider data. Thus the matter sfermion spectrum has a very restrictive form^{13),8)}:

$$m_{\tilde{q}}^2 = m_0^2 [1 + 7.4 \xi^2], \quad (1a)$$

$$m_{\tilde{\ell}_L}^2 = m_0^2 [1 + 0.5 \xi^2], \quad (1b)$$

$$m_{\tilde{\ell}_R}^2 = m_0^2 [1 + 0.15 \xi^2], \quad (1c)$$

in a large class of $N = 1$ supergravity models in which the sfermion masses are all m_0 in the grand unification symmetry limit. The differences between the masses (1) are renormalization effects analogous to those responsible for $m_b/m_\tau = 0(3)$ in conventional GUTs¹⁴⁾. If $m_{\tilde{g}} \gtrsim m_{\tilde{q}}$ as favoured in our interpretation of the collider data, then ξ must be 0(0.5 to 1.0), and the slepton masses (1b) and (1c) must⁸⁾ be close to the present experimental limit:

$$20 \text{ GeV} \lesssim m(\tilde{e}, \tilde{\mu}, \tilde{\tau})_{L,R} \lesssim 30 \text{ GeV}. \quad (2)$$

While a necessary consequence of the $m_{\tilde{q}} = 0(40)$ GeV interpretation, the bounds (2) have no reason to apply in the $m_{\tilde{g}} = 0(40)$ GeV⁶⁾ or $m_{\tilde{g}} = 0(5)$ GeV, $m_{\tilde{q}} = 0(100)$ GeV⁷⁾ scenarios. Evidence for sleptons in the range (2) would therefore be a decisive step in discriminating between different supersymmetric scenarios.

Here we concentrate on the search for "light" sleptons (2) in $W^\pm$ and Z^0 decays. The decays $W^\pm \rightarrow \tilde{\ell}^\pm \tilde{\nu}$ and $Z^0 \rightarrow \tilde{\ell}^+ \tilde{\ell}^-$ were proposed as good ways to look for supersymmetry in Refs. 15 and 16, respectively, where analytic formulae for these decays may be found. In this paper we present rates and distributions for these processes and the Standard Model backgrounds, incorporating detector resolutions and experimental cuts¹⁷⁾ modelled on those of UA1 (UA2 cuts for electrons are not dissimilar). We show that the $W^\pm \rightarrow \tilde{e}^\pm \tilde{\nu}$, $\tilde{e}^\pm \rightarrow e^\pm \tilde{\gamma}$ signal is as large as the $W^\pm \rightarrow e^\pm \nu$, $W^\pm \rightarrow \tau^\pm \nu$, $\tau^\pm \rightarrow e^\pm \nu \bar{\nu}$ backgrounds^{*)} in the region $10 \text{ GeV} < |p_{T_e}| < 30 \text{ GeV}$ and $-1 < \cos \theta_e < 0$, and has an observable rate. However, the $Z^0 \rightarrow \tilde{\ell}^+ \tilde{\ell}^-$, $\tilde{\ell}^+ \rightarrow \ell^+ \tilde{\gamma}$, $\tilde{\ell}^- \rightarrow \ell^- \tilde{\gamma}$ signal may be more promising. Although at most a handful of events could be expected in the current data set, they are very distinctive. They give

*) Charged leptons $L^\pm$ heavier than the $\tau^\pm$ would give lower backgrounds¹⁸⁾, and $Z^0 \rightarrow \tau^+ \tau^-$ or $L^+ L^-$ gives twice as many ($e\mu$) events as (ee) or ($\mu\mu$) events.

$\ell^+\ell^-$ pairs with invariant masses $O(40)$ GeV, large p_T and large missing p_T (unlike Drell-Yan pairs), with leptons which are not back-to-back in azimuth. The rates for $Z^0 \rightarrow \tilde{\ell}^+\tilde{\ell}^-$, $\tilde{\ell}^\pm \rightarrow \ell^\pm \tilde{\gamma}$ are much larger than for $Z^0 \rightarrow \tau^+\tau^-$, $\tau^\pm \rightarrow \ell^\pm \nu \bar{\nu}$ and can easily be distinguished from Drell-Yan pairs even when experimental resolutions¹⁷⁾ are taken into account.

It would be difficult to over-emphasize the significance of observing such a signature. While not being a necessary consequence of supersymmetry, it would surely be sufficient to convince many sceptics. The addition of one or two clean $\ell^+\ell^- + \text{missing } p_T$ events to the growing sample of jet + missing p_T events could be a convincing combination, much as the combination of one or two leptonic neutral current events¹⁹⁾ coupled with the larger but dirtier sample of hadronic neutral current events²⁰⁾ convinced sceptics of the reality of neutral currents in 1973.

We start with the process¹⁵⁾ $W^\pm \rightarrow \tilde{\ell}^\pm \tilde{\nu}$, $\tilde{\ell}^\pm \rightarrow \ell^\pm \tilde{\gamma}$. In the scenario^{5),8)} that we favour, the gluino weighs more than the sneutrino $\tilde{\nu}$, so that the dominant $\tilde{\nu}$ decay is²¹⁾ the invisible $\tilde{\nu} \rightarrow \nu \tilde{\gamma}$. Therefore the only detectable particle in the final state is the $\ell^\pm$, and the only observables are $|p_{T\ell}|$, missing p_T , denoted by p_T^{miss} , and $\cos\theta_\ell$, the angle between the outgoing lepton and the incoming proton. Table 1 shows the corresponding cross-sections for $W \rightarrow \ell \nu$, $W \rightarrow \tau \nu (\tau \rightarrow \ell \nu \bar{\nu})$, $W \rightarrow \tilde{\ell} \tilde{\nu} (\tilde{\ell} \rightarrow \ell \tilde{\gamma})$, $W \rightarrow \tilde{W} \tilde{\gamma} (\tilde{W} \rightarrow \ell \nu, \tilde{\ell} \rightarrow \ell \tilde{\gamma})$ and $W \rightarrow \tilde{W} \tilde{\gamma} (\tilde{W} \rightarrow \ell \tilde{\nu})$ for the cases $\ell = e, \mu$. In calculating these cross-sections, we make the following UAl-inspired¹⁷⁾ cuts:

$$\begin{aligned} |p_{Te}| &> 10 \text{ GeV.}, \quad |\eta_e| < 3; \\ |p_{T\mu}| &> 3 \text{ GeV.}, \quad |\eta_\mu| < 2 \end{aligned} \quad (3)$$

and incorporate the following experimental resolution functions¹⁷⁾:

$$\begin{aligned} \frac{\Delta E_e}{E_e} &= \begin{cases} 0.15/\sqrt{E_e} & \text{for } |\eta_e| < 1.5 \\ 0.18/\sqrt{E_e} & \text{for } 1.5 < |\eta_e| < 3, \end{cases} \\ \Delta(1/p_\mu) &= 0.005, \end{aligned} \quad (4)$$

where E_e and p_μ are expressed in units of GeV. Table 1 includes predictions for $m_{\tilde{\chi}} = 20, 25, 30$ GeV. The $W \rightarrow \tilde{W} \tilde{\gamma}$ processes in Table 1 are calculated assuming the following values of the SU(2) gaugino mass m_2 and the Higgsino mixing parameter ϵ :

$$\frac{m_2}{m_W} = \frac{1}{10} \quad , \quad \frac{\epsilon}{m_W} = 2 . \quad (5)$$

The choice of the first parameter is motivated by our favoured interpretation^{5),8)} of the $p\bar{p}$ collider data, and corresponds to $m_{\tilde{\gamma}} = 4.9$ GeV. The values of m_2 and $m_{\tilde{\gamma}}$ could⁸⁾ be increased by about 50% over these values, but this would have negligible effect on the supersymmetry signatures we discuss. The value of ϵ is much less clear, and the choice (5) is only meant for illustrative purposes. It gives $m_{W^\pm} = 41.5$ GeV, and serves to indicate that $W \rightarrow e\tilde{\nu}$ decay dominates over $W \rightarrow \tilde{W}\tilde{\gamma}$ decay²²⁾ for generic values of ϵ ^{*}).

Figure 1 shows the p_{T_λ} distributions for $W \rightarrow \lambda\nu$, $W \rightarrow \tau\nu(\tau \rightarrow \lambda\nu\bar{\nu})$, $W \rightarrow \tilde{\chi}\tilde{\nu}(\tilde{\chi} \rightarrow \lambda\tilde{\gamma})$ and $W \rightarrow \tilde{W}\tilde{\gamma}(\tilde{W} \rightarrow \lambda\nu\tilde{\gamma})$. We see that $W \rightarrow \lambda\nu$ dominates over $W \rightarrow \tilde{\chi}\tilde{\nu}$ even at relatively low values of $p_{T_\lambda} < 30$ GeV below the Jacobian peak, while $W \rightarrow \tau\nu$ is comparable with $W \rightarrow \tilde{\chi}\tilde{\nu}$. So how could a $W \rightarrow \tilde{\chi}\tilde{\nu}$ signal be picked out? A possible answer is provided by Fig. 2, which shows that $W \rightarrow \tilde{\chi}\tilde{\nu}(\tilde{\chi} \rightarrow \lambda\tilde{\gamma})$ peaks at negative values of $\cos\theta_\lambda$, while $W \rightarrow \lambda\nu$ and $W \rightarrow \tau\nu$ peak at positive values. This difference arises because the spin- $\frac{1}{2}$ ($\lambda\nu$) and ($\tau\nu$) final states remember the polarization of the W , while the spinless ($\tilde{\chi}\tilde{\nu}$) final states forget the W polarization. Therefore they are produced with a $\sin^2\theta$ distribution in the W rest frame, which then gets boosted to negative values of $\cos\theta_\lambda$ in the laboratory frame. This is because the $W^+(W^-)$ is mainly produced by $u\bar{d}(d\bar{u})$ collisions, and the u distribution in the proton is harder than the d distribution, resulting in a net positive longitudinal momentum for the $W^+(W^-)$ in the $p(\bar{p})$ direction. Figure 3 is a sketch of the $(p_{T_\lambda}, \cos\theta_\lambda)$ parameter space, indicating where the standard model $W \rightarrow \lambda\nu$ and $W \rightarrow \tau\nu(\tau \rightarrow \lambda\nu\bar{\nu})$ backgrounds²²⁾ tend to appear. Also indicated is a cut region

$$|p_{T_\lambda}| < 30 \text{ GeV} . \quad , \quad \cos\theta_\lambda < 0 . \quad , \quad (6)$$

which we propose to enhance the supersymmetric signal-to-background ratio. Shown in parentheses in Table 1 are the resulting cross-sections, incorporating as always the cuts (3) and the resolutions (4). We see that the signal-to-background ratio is about 1.5 to 1, and that the rates may be large enough for a signal to be unearthed in the current $p\bar{p}$ collider run.

^{*}) Note that the total increase in the $W^\pm$ and Z^0 decay widths due to sleptonic ($m_{\tilde{\chi}} \approx 25$ GeV) and squark ($m_{\tilde{q}} \approx 40$ GeV) decay modes is about 0.3 GeV in each case²³⁾, too small to be detected in present $p\bar{p}$ collider data.

The second reaction we consider is $Z^0 \rightarrow \tilde{\ell}^+ \tilde{\ell}^-$ ($\tilde{\ell}^+ \rightarrow \ell^+ \tilde{\gamma}$, $\tilde{\ell}^- \rightarrow \ell^- \tilde{\gamma}$). Cross-sections for this process and the background reactions γ^* , $Z^0 \rightarrow \ell^+ \ell^-$ and $Z^0 \rightarrow \tau^+ \tau^-$ ($\tau^+ \rightarrow \ell^+ \nu \bar{\nu}$, $\tau^- \rightarrow \ell^- \nu \bar{\nu}$) are presented in Table 2. The two photinos in the final state give a large missing p_T signature, as seen in Fig. 4. Also shown are the backgrounds from γ^* , $Z^0 \rightarrow \ell^+ \ell^-$ and $Z^0 \rightarrow \tau^+ \tau^-$ ($\tau^+ \rightarrow \ell^+ \nu \bar{\nu}$, $\tau^- \rightarrow \ell^- \nu \bar{\nu}$). The rate for the latter process is considerably lower than that for $Z^0 \rightarrow \tilde{\ell}^+ \tilde{\ell}^-$, and it gives a softer missing p_T spectrum. The Drell-Yan reaction γ^* , $Z^0 \rightarrow \ell^+ \ell^-$ would give no missing p_T in an ideal detector, but a real detector such as UA1 or UA2 has, in addition to the $\ell^\pm$ measurement errors (4), a non-zero resolution in the hadronic p_T . In plotting Fig. 4, we have parametrized this as¹⁷⁾

$$\Delta p_x, \Delta p_y = 0.4 \sqrt{E_T}, \quad (7)$$

where E_T is the total hadronic transverse energy in the event, taken to be 0(20) GeV for a minimum bias event. While the missing p_T signature is very clear for e^+e^- pairs (Fig. 4a), measurement errors on the muons can totally obscure it for $\mu^+\mu^-$ pairs (Fig. 4b). A similar effect is seen in Fig. 5, where the p_T of the Drell-Yan $\ell^+\ell^-$ pairs, which is already large for electrons (Fig. 5a), is broadened to drown the supersymmetric signal for $\mu^+\mu^-$ pairs (Fig. 5b). Figure 6 shows the corresponding effect for the $(\ell^+\ell^-)$ invariant mass distributions. The supersymmetric pairs peak around 40 GeV and are of comparable magnitude to the γ^* , Z^0 background in the trough between the low-mass and Z^0 peaks. The muon measurement errors apply to the magnitudes of their momenta (4), and not to their angles. Therefore one might expect the supersymmetric $(\mu^+\mu^-)$ signal to show up better in plots relying on angular information. This is seen in Fig. 7, where the excess of $\ell^+\ell^-$ pairs which are not back-to-back in azimuth, already present for e^+e^- pairs (Fig. 7a), is greatly enhanced for $(\mu^+\mu^-)$ pairs (Fig. 7b)*). The increase in the number of wide-angle pairs is due to the lower p_T cut for muons. This is also responsible for the small backward peak for γ^* , $Z^0 \rightarrow \mu^+\mu^-$ pairs in Fig. 7b, due to low-mass $(\mu^+\mu^-)$ pairs produced with $p_T(\mu^+\mu^-) \gtrsim 0(m_{\mu^+\mu^-}/2)$.

The simplest way to look for the $Z^0 \rightarrow \tilde{e}^+ \tilde{e}^-$ ($\tilde{e}^\pm \rightarrow e^\pm \tilde{\gamma}$) signal is in the scatter plot of $p_T(e^+e^-)$ versus the missing p_T . Scatter plots for γ^* , $Z^0 \rightarrow e^+e^-$, $Z^0 \rightarrow \tau^+ \tau^-$ ($\tau^\pm \rightarrow e^\pm \nu \bar{\nu}$) and $Z^0 \rightarrow \tilde{e}^+ \tilde{e}^-$ ($\tilde{e}^\pm \rightarrow e^\pm \tilde{\gamma}$) are shown in Figs 8a,b,c, respectively. The Drell-Yan pairs are at low missing p_T , even if their $p_T(e^+e^-)$ may be large. The $\tau^+\tau^-$ and $\tilde{e}^+\tilde{e}^-$ events are scattered around the $p_T(e^+e^-) = p_T(\text{missing})$ diagonal by measurement errors and the intrinsic Q_T of the Z-boson. The $\tau^+\tau^-$ events are

*) Notice that lepton pairs from $Z^0 \rightarrow \tau^+\tau^-$ are not only relatively few in number, but also tend to be produced back-to-back in azimuth. A possible background from heavy lepton pair-production via $Z^0 \rightarrow L^+L^-$ would share the former property, but not the latter.

typically at lower $|p_T|$, as well as being much less numerous than $\tilde{e}^+\tilde{e}^-$ events if $m_{\tilde{e}} \sim 20$ to 30 GeV, as can be seen from the cross-section calculations presented in Table 2. In the case of $(\mu^+\mu^-)$ pairs, measurement errors spread the Drell-Yan γ^* , $Z^0 \rightarrow \mu^+\mu^-$ pairs up into the $p_T \neq 0$ region of the plane in Fig. 8a, and the diagonal smear of the $\tilde{\chi}^+\tilde{\chi}^-$ signal in Fig. 8c is no longer visible. However, in these events the missing p_T vector is the vectorial sum of two Δp_μ measurement errors, one in each of the $\mu^\pm$ directions. Hence, to the extent that Drell-Yan pairs tend to come out back-to-back (Fig. 7b), we expect this missing p_T vector to be strongly correlated in angle with the $\mu^\pm$ directions. This is seen in Fig. 9, where we have selected events with $p_T > 6$ GeV so as to remove the azimuthally isotropic background at small p_T due to hadronic measurement errors (7). We see that the supersymmetric signal sticks out above the Drell-Yan γ^* , $Z^0 \rightarrow \mu^+\mu^-$ background if we select events with

$$p_T > 6 \text{ GeV.}, \quad 150^\circ > \Delta\phi(p_T, p_{T\mu}) > 40^\circ. \quad (8)$$

Hence, although one must work a little harder to get out the $Z^0 \rightarrow \tilde{\mu}^+\tilde{\mu}^- (\tilde{\mu}^+ \rightarrow \mu^+ \tilde{\gamma})$ signal, we believe it should be as distinctive as the $Z^0 \rightarrow \tilde{e}^+\tilde{e}^- (\tilde{e}^+ \rightarrow e^+ \tilde{\gamma})$ signal. We believe that the non-observation of such events would enable one to put a better limit on the slepton masses than is currently possible from e^+e^- experiments.

In summary, a search for $Z^0 \rightarrow \tilde{\chi}^+\tilde{\chi}^-$ decays may be a clean way of checking the $m_{\tilde{q}} = 0(40)$ GeV interpretation of the "monojet" events. Fashionable supergravity models with $m_{\tilde{q}} = 0(40)$ GeV predict^{13),8)} $m_{\tilde{\chi}} = 0(20 \text{ to } 30)$ GeV, and these could be seen in the present pp collider run. An eventual discovery of such events could be as crucial for the general acceptance of supersymmetry as the discovery of $\nu e \rightarrow \nu e$ scattering¹⁹⁾ was for the establishment of neutral currents²⁰⁾. Other supersymmetric decays of the $W^\pm$ and Z^0 into gaugino/Higgsino pairs may also be kinematically accessible²²⁾, but these are subject to greater uncertainties. For the moment, our best candidate for a "smoking gunino" is $Z^0 \rightarrow \tilde{\chi}^+\tilde{\chi}^-$ decay.

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Process	$m_{\tilde{\chi}}$	σ_e (nb)	σ_{μ} (nb)
$p\bar{p} \rightarrow W^- \rightarrow \ell^- + \cancel{p}_T$	-	0.254(0.010)	0.245(0.021)
$p\bar{p} \rightarrow W^- \rightarrow \tau^- \bar{\nu}_{\tau} \rightarrow \ell^- + \cancel{p}_T$	-	0.024(0.006)	0.036(0.011)
$p\bar{p} \rightarrow W^- \rightarrow \tilde{\ell}^- \bar{\tilde{\nu}} \rightarrow \ell^- + \cancel{p}_T$	20	0.039(0.019)	0.052(0.024)
	25	0.031(0.014)	0.041(0.020)
	30	0.021(0.010)	0.027(0.011)
$p\bar{p} \rightarrow W^- \rightarrow \tilde{W}^- \tilde{\gamma} \rightarrow \tilde{\ell}^- \bar{\tilde{\nu}} \gamma \rightarrow \ell^- + \cancel{p}_T$	20	0.008(0.005)	0.015(0.007)
	25	0.010(0.005)	0.015(0.007)
	30	0.012(0.005)	0.014(0.007)
$p\bar{p} \rightarrow W^- \rightarrow \tilde{W}^- \tilde{\gamma} \rightarrow \ell^- \bar{\tilde{\nu}} \gamma \rightarrow \ell^- + \cancel{p}_T$	20	0.013(0.006)	0.015(0.007)
	25	0.010(0.004)	0.014(0.006)
	30	0.006(0.003)	0.013(0.006)

Table 1 - Total cross-sections for single lepton plus missing energy events due to the decays of W bosons produced in $p\bar{p}$ collisions at $\sqrt{s} = 630$ GeV. The figures in parentheses are the resultant cross-sections after applying the cuts $p_{T\ell} < 30$ GeV and $\cos\theta_{\ell} < 0.0$, introduced in the text to maximize the supersymmetry signal to background ratio. In all calculations, we convolute subprocess cross-sections with the parton densities of Duke and Owens²⁴⁾ (Set 1) assuming an SU(4) sea. We multiply the cross-sections for all processes by a QCD motivated factor $K = 1.4$. We account for initial state soft gluon bremsstrahlung by giving the W and Z a Q_{π} distribution which approximates the results of Ref. 25). Throughout, we assume $m_{\tilde{\nu}} = m_{\tilde{\chi}}$, $M_W = 83$ GeV, $M_Z = 94$ GeV and $\sin^2\theta_W = 0.22$. In the case of a light sneutrino, the $W \rightarrow \tilde{\chi}\tilde{\nu}$ signal remains large for even higher slepton masses than those given in the above Table.

Process	$m_{\tilde{\chi}} \text{ (GeV)}$	$\sigma_e \text{ (nb)}$	$\sigma_{\mu} \text{ (nb)}$
$p\bar{p} \rightarrow \gamma^*, Z \rightarrow \ell^+\ell^- + \cancel{p}_T$	-	0.083	0.393
$p\bar{p} \rightarrow Z \rightarrow \tau^+\tau^- \rightarrow \ell^+\ell^- + \cancel{p}_T$	-	<0.001	0.001
$p\bar{p} \rightarrow \gamma^*, Z \rightarrow \tilde{\ell}^+\tilde{\ell}^- \rightarrow \ell^+\ell^- + \cancel{p}_T$	20	0.011	0.017
	25	0.009	0.014
	30	0.007	0.011
	35	0.005	0.007
	40	0.003	0.004

Table 2 - Total cross-sections for Z^0 production and decays into dileptons plus missing energy in $p\bar{p}$ collisions at $\sqrt{s} = 630 \text{ GeV}$. We have included both ℓ_L and ℓ_R in the calculations, and have assumed they have equal masses: this is not expected^{13),8)} to be exactly true [cf. Eqs. (1b) and (1c)], but the induced error is negligible. The parameters used in these calculations are the same as in Table 1, leading to $B(Z^0 \rightarrow \tilde{e}_R^+\tilde{e}_R^-) / B(Z^0 \rightarrow \tilde{e}_L^+\tilde{e}_L^-) = 0.64$. The non-observation of events corresponding to the above cross-sections may be used to put a new lower bound on slepton masses from $p\bar{p}$ collider data.

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FIGURE CAPTIONS

- Fig. 1 The momentum distribution of the lepton ℓ [$\ell=e$ in (a) and $\ell=\mu$ in (b)] transverse to the beam axis for $p\bar{p} \rightarrow W \rightarrow \ell$ at $\sqrt{s} = 630$ GeV. The curves labelled $e, \mu, \tau, W \rightarrow \tilde{\ell}, \tilde{W} \rightarrow \tilde{\ell}$ and $\tilde{W} \rightarrow \tilde{\nu}$ correspond to the decay modes $W \rightarrow e, W \rightarrow \mu, W \rightarrow \tau \rightarrow \ell, W \rightarrow \tilde{\ell} \rightarrow \ell, W \rightarrow \tilde{W} \rightarrow \tilde{\ell} \rightarrow \ell$ and $W \rightarrow \tilde{W} \rightarrow \ell$, respectively. The wino mass $M_{\tilde{W}} = 41.5$ GeV and the slepton mass $m_{\tilde{\ell}} = 25$ GeV. The total cross-sections are given in Table 1, where further calculational details may be found.
- Fig. 2 Distributions in $\cos\theta_{\ell}$, where $\ell = e$ in (a) and $\ell = \mu$ in (b); θ_{ℓ} is the angle between the outgoing negative lepton and the incoming proton beam. The labelling is as in Fig. 1.
- Fig. 3 Sketch of regions of greatest cross-sectional densities in scatter plot of $p_{\ell T}$ vs. $\cos\theta_{\ell}$ for Standard Model backgrounds $W \rightarrow e\nu$ and $W \rightarrow \tau\nu$, $\tau \rightarrow e\nu\nu$. Also shown is the proposed cut region for maximizing the SUSY $W \rightarrow \tilde{\ell}\tilde{\nu}$ signal relative to the indicated backgrounds. Rates after these cuts are given in Table 1.
- Fig. 4 Missing transverse momentum distributions relative to beam axis for $p\bar{p} \rightarrow \ell^+\ell^-$ at $\sqrt{s} = 630$ GeV where $\ell = e$ in (a), and $\ell = \mu$ in (b). The curves labelled $\ell, \tilde{\ell}$ and τ correspond to the decay modes $\gamma^*, Z \rightarrow \ell^+\ell^-$, $\gamma^*, Z \rightarrow \tilde{\ell}^+\tilde{\ell}^-$ and $Z \rightarrow \tau^+\tau^- \rightarrow \ell^+\ell^- + 4\nu$, respectively, where $m_{\tilde{\ell}} = 25$ GeV. The total cross-sections are given in Table 2.
- Fig. 5 Distributions in transverse dilepton momentum for final state electrons (a) and muons (b). Labelling and parameters are as in Fig. 4.
- Fig. 6 Distributions in dilepton invariant mass for final state electrons (a) and muons (b).
- Fig. 7 Distributions in azimuthal angle between lepton pairs for final state electrons (a) and muons (b).

Fig. 8 Scatter plots in transverse dilepton momentum versus transverse missing momentum ($p_T(e^+e^-)$ vs. $\cancel{p}_T$) illustrating regions of greatest cross-sectional density. The plots are for (a) $p\bar{p} \rightarrow \gamma^*, Z \rightarrow e\bar{e}$, (b) $p\bar{p} \rightarrow Z \rightarrow \tau^+\tau^- \rightarrow e^+e^- + 4\nu$ and (c) $p\bar{p} \rightarrow \gamma^*, Z \rightarrow \tilde{e}^+\tilde{e}^- \rightarrow e^+e^- + 2\tilde{\gamma}$ where $m_{\tilde{e}} = 25$ GeV. Plots are not normalized relative to each other.

Fig. 9 Distribution in azimuthal angle between lepton and missing p_T vector, for $\cancel{p}_T > 6$ GeV. The average distribution for $l = \mu^+$ and $l = \mu^-$ is plotted. The labelling and parameters are as in Fig. 4.

Fig. 1a

Fig. 1b

Fig. 2a

Fig. 2b

Fig. 3

Fig. 4a

Fig. 4b

Fig. 5a

Fig. 5b

Fig. 6a

Fig. 6b

Fig. 7a

Fig. 7b

Fig. 8

Fig. 9