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MULTILEPTON SIGNALS FROM $W^{\pm}$ AND Z^0 DECAYS TO
GAUGINOS AT $\bar{p}p$ COLLIDERS

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A B S T R A C T

One of the interpretations of the CERN mono-jet events requires the squark mass to be about 40-50 GeV implying a slepton mass around 20-30 GeV in a wide variety of models. If, in this scenario, the wino ($\tilde{W}$) and zino ($\tilde{Z}$) masses are light enough so that the decays $W \rightarrow \tilde{W}\tilde{Z}$ and $Z \rightarrow \tilde{W}\tilde{W}$ are allowed, a variety of spectacular dilepton and trilepton signals are expected to occur at a substantial rate and with negligible backgrounds. We present rates and distributions for these multilepton events which may be used to pin down the gaugino masses.

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The UA1 collaboration¹⁾ has recently reported the observation of monojet events with large missing transverse momentum ($\cancel{p}_T$). These events are difficult to understand within the standard model. Such events, however, have a rather natural explanation within the framework of supersymmetry (SUSY) since the lightest SUSY particle (being essentially stable and weakly interacting) serves as a source of $\cancel{p}_T$. Three distinct SUSY mechanisms proposed as an explanation of these monojets are, (i) squark pair production with $m_{\tilde{q}} \approx 40-50$ GeV and $m_{\tilde{g}} > m_{\tilde{q}}^2$, (ii) gluino pair production with $m_{\tilde{g}} \approx 40-50$ GeV³⁾, and (iii) $\tilde{q} \tilde{g}$ production with $m_{\tilde{q}} \approx 100$ GeV and $m_{\tilde{g}} \approx 5$ GeV⁴⁾.

A confirmation of any of these interpretations can only come via an analysis of other signatures which would be a consequence of the particular choice of sparticle masses invoked to explain the monojets. One needs, therefore, an idea of the sparticle masses. As a guide, we use the N=1 supergravity models with soft SUSY breaking terms that are induced by the super-Higgs' mechanism⁵⁾. Within this framework, the sparticle masses are fixed by the common scalar mass (m_0) at the Planck scale, the tree level gaugino mass $m_{\frac{1}{2}}$, the ratio (v_1/v_2) of the Higgs field vacuum expectation values and the Higgsino mixing mass term (ϵ)^{*}). Fixing the squark mass between 40-50 GeV, requiring the selectron to be heavier than 20 GeV⁶⁾ and, finally, requiring $m_{\tilde{g}} > m_{\tilde{q}}$ fixes m_0 and $m_{\frac{1}{2}}$ ^{7),8)}. We also take $v_1/v_2 = 1$, the value favoured by the $m_{\tilde{q}} \approx 40-50$ GeV interpretation of the collider data. The slepton masses, for such a scenario, are given by,

$$20 \text{ GeV.} \lesssim m_{(\tilde{e}, \tilde{\mu}, \tilde{\tau})_{L,R}} \lesssim 30 \text{ GeV.} \quad (1)$$

As has already been pointed out⁹⁾, sleptons in this mass range could be produced in the decay of the W and Z bosons at the CERN collider. A recent analysis¹⁰⁾ has shown that these would lead to very distinctive signatures, thereby providing for the $m_{\tilde{q}} = 40-50$ GeV scenario, the crucial test alluded to earlier.

The only free parameter remaining is ϵ , the Higgsino mixing parameter. This enters only in the gaugino-Higgsino sector and does not affect the matter sparticle masses. Thus, in order to pin down the value of ϵ , we are naturally led to study the eigenstates of the gaugino-Higgsino system. For small values of $m_{\frac{1}{2}}$

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^{*}) The scalar trilinear (and bilinear) coupling parameters affect only the top squark mass and will not be relevant for this paper.

($m_{\frac{1}{2}} \approx 12$ GeV if $m_{\tilde{q}} \approx 40$ GeV⁹⁾), there is a charged fermion eigenstate of the gaugino-Higgsino system with a mass smaller than the W-boson mass (M_W) and a neutral eigenstate (other than the state which is almost the photino) with a mass less than M_Z ¹¹⁾. In this paper, we will refer to these as the wino ($\tilde{W}$) and the zino ($\tilde{Z}$). Moreover, there is a range of values of ϵ for which the states are accessible in $W \rightarrow \tilde{W}Z$ and $Z \rightarrow \tilde{W}\tilde{W}$ decays. Further, for this range of ϵ , the states $\tilde{W}(\tilde{Z})$ contain a substantial gaugino component leading to large couplings¹²⁾ since the gaugino is a (weak) isotriplet^{*}). Finally, we note that for a photino mass $\lesssim 10$ GeV, a zino of mass smaller than about 30-35 GeV is ruled out by the PETRA data¹³⁾. Thus, if the winos and zinos are accessible via the decay of the gauge bosons, their masses are almost bracketed by the slepton and squark masses in the scenario we are discussing. They will, therefore, decay via the two-body lepton-slepton mode^{**)}. Assuming that all sleptons have identical masses, the branching ratio for the wino or zino decay into (s)muons or (s)electrons is 2/3. The following reactions are accessible:

$$W \rightarrow \tilde{W} \tilde{Z}, \quad \tilde{W} \rightarrow \begin{matrix} \ell \tilde{\nu} \\ \tilde{\ell} \bar{\nu} \end{matrix} \rightarrow \ell \tilde{\gamma} \bar{\nu}, \quad \tilde{Z} \rightarrow \begin{matrix} \tilde{\ell}' \bar{\ell}' \rightarrow \ell' \bar{\ell}' \tilde{\gamma} \\ \tilde{\ell}' \ell' \rightarrow \bar{\ell}' \ell' \tilde{\gamma} \end{matrix}, \quad (2a)$$

and

$$\tilde{Z} \rightarrow \tilde{W} \tilde{\bar{W}}, \quad \tilde{\bar{W}} \rightarrow \begin{matrix} \bar{\ell} \tilde{\nu} \\ \bar{\ell} \nu \end{matrix} \rightarrow \bar{\ell} \nu \tilde{\gamma}, \quad \tilde{W} \rightarrow \begin{matrix} \ell' \tilde{\nu} \\ \tilde{\ell}' \bar{\nu} \end{matrix} \rightarrow \ell' \tilde{\gamma} \bar{\nu}, \quad (2b)$$

where $(\ell, \ell') = (e \text{ or } \mu)$.

For the range of slepton masses considered, the sneutrino decays invisibly via $\tilde{\nu} \rightarrow \nu \tilde{\gamma}$ ¹⁴⁾. Reaction (2a) leads to spectacular trilepton + $\cancel{p}_T$ signatures¹⁵⁾ whereas (2b) yields oppositely charged leptons, possibly from different families together with $\cancel{p}_T$. Moreover, these processes have very little hadronic activity

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*) There is also another light neutral state which is dominantly Higgsino. We will not consider it here.

**) In our calculations, we have fixed $m_{\tilde{q}} = 40$ GeV. When the wino (zino) mass exceeds 40 GeV, the $q\bar{q}$ decays become possible. We have incorporated these in our computations. If $m_{\tilde{q}} = 50$ GeV, the leptonic signals are even bigger.

and are essentially free of standard model backgrounds. A study of these reactions, incorporating experimental acceptances and detector resolutions, forms the subject of this paper.

The relevant Lagrangian is,

$$\mathcal{L}_{Wqq} = \frac{-g}{\sqrt{2}} \left[\bar{u} \gamma^\mu \left(\frac{1-\gamma_5}{2} \right) d W_\mu^+ + \bar{d} \gamma^\mu \left(\frac{1-\gamma_5}{2} \right) u W_\mu^- \right], \quad (3a)$$

$$\mathcal{L}_{Zq\bar{q}} = e \bar{q} \gamma^\mu (\alpha_q + \beta_q \gamma_5) q Z_\mu, \quad (3b)$$

$$\begin{aligned} \mathcal{L}_{W\tilde{W}\tilde{Z}} = & i \left[\left(\frac{g}{\sqrt{2}} N_1 f_- + g\sqrt{2} N_1 f_+ \frac{M_{\tilde{Z}}}{\mu_-} \cos\theta_w \right) - g f_+ \sin\theta_w \epsilon_1 \right] \tilde{W} \gamma^\mu \tilde{Z} W_\mu \\ & - \delta \left(\frac{g f_-}{\sqrt{2}} N_2 - g f_+ N_2 \sqrt{2} \frac{M_{\tilde{Z}}}{\mu_+} \cos\theta_w \right) \tilde{W} \gamma_5 \gamma_\mu \tilde{Z} W_\mu + h.c. \end{aligned} \quad (3c)$$

$$\mathcal{L}_{Z\tilde{W}\tilde{W}} = -e \cot\theta_w \left(1 - \frac{1}{2} f_-^2 \sec^2\theta_w \right) \tilde{W} \gamma^\mu \tilde{W} Z_\mu, \quad (3d)$$

$$\begin{aligned} \mathcal{L}_{\tilde{Z}l\tilde{l}} = & ie \left[\frac{N_1 M_{\tilde{Z}}}{\mu_-} (\tan\theta_w - \cot\theta_w) + \sqrt{2} \epsilon_1 \right] \tilde{l}_L^\dagger \tilde{Z} \frac{1-\gamma_5}{2} l \\ & + ie \left[\frac{2N_1 M_{\tilde{Z}}}{\mu_-} \tan\theta_w + \sqrt{2} \epsilon_1 \right] \tilde{l}_R^\dagger \tilde{Z} \frac{1+\gamma_5}{2} l + h.c. \end{aligned} \quad (3e)$$

$$\mathcal{L}_{\tilde{W}l\tilde{l}} = -g f_+ \tilde{l}_L^\dagger \tilde{W}^c \frac{1-\gamma_5}{2} \nu + g f_+ \tilde{\nu}^\dagger \tilde{W} \frac{1-\gamma_5}{2} l + h.c. \quad (3f)$$

with

$$\alpha_u = \frac{1}{4} \tan\theta_w - \frac{5}{12} \cot\theta_w, \quad \alpha_d = \frac{1}{12} \tan\theta_w - \frac{1}{4} \cot\theta_w$$

and

$$\beta_u = -\beta_d = -\frac{1}{4} (\cot\theta_w + \tan\theta_w).$$

Equations (3c-f) have been obtained via the diagonalization of the gaugino-higgsino sector. The charged sector has been diagonalized exactly whereas the

neutral sector has been diagonalized in the approximation $m_{\frac{1}{2}} \ll M_W$ (which is true for the choice of parameters dictated by the $m_{\tilde{q}} = 40$ GeV scenario). The parameters $f_{\pm}$ are given by $f_{\pm} \equiv ((m_{\pm} \mp \mu_2)/(m_{\pm} + m_-))$ with $-\mu_2$ being the tree-level SU(2) gaugino mass and $m_{\pm}$ the eigenvalues in the charged sector equal to $m_{\pm} = [((m_1 - \mu_2/2)^2 + M_W^2)^{\frac{1}{2}} \pm (m_1 + \mu_2/2)]$ ($2m_1 \equiv -\epsilon$ the Higgsino mixing term). The parameters $\mu_{\pm}$ (these are eigenvalues in the neutral sector if bare gaugino masses vanish) and N_1 and N_2 are as defined by Dicus et al.¹⁵⁾, $\delta \equiv (2N_1 N_2 / (\mu_+ + \mu_-)) \times (\mu_1 \sin^2 \theta_w + \mu_2 \cos^2 \theta_w)$ and $\epsilon_1 \equiv (N_1 M_Z / \sqrt{2} \mu_-^2) \sin 2\theta_w (\mu_2 - \mu_1)$. (Here, $-\mu_1$ is the U(1) gaugino mass. We assume grand unification so that $\mu_1/\mu_2 = 5/3 \tan^2 \theta_w$.) Finally, the particle masses are $m_{\tilde{W}} \equiv m_-$, $m_{\tilde{Z}} = \mu_- - (\mu_+/\mu_+ + \mu_-)(\mu_1 \sin^2 \theta_w + \mu_2 \cos^2 \theta_w)$ and $m_{\tilde{Y}} = -(\mu_1 \cos^2 \theta_w + \mu_2 \sin^2 \theta_w)$.

We now turn to the various multilepton + $\cancel{p}_T$ signatures that can arise from the reactions in (2). In our calculations we have incorporated the same UA1-inspired cuts¹⁶⁾ and experimental resolutions¹⁶⁾ as in Ref. 10). We have also used the same structure functions¹⁷⁾, c.m. parton smearing and a QCD motivated factor $K = 1.4$ as in Ref. 10). Trileptons can come only via $W \rightarrow \tilde{W}Z$ decays, whereas dileptons, in addition to coming from $Z \rightarrow \tilde{W}\tilde{W}$ decays also come from $W \rightarrow \tilde{W}Z$ decays, with one of the three leptons not satisfying the cuts. This latter process, therefore, is a potential source of same sign dileptons + $\cancel{p}_T$ ^{*)}. We emphasize that such multilepton events, unlike those discussed in Ref. 18) would have almost no hadronic activity. For definiteness, we have fixed $|\mu_2| = 10$ GeV, corresponding to $m_{\tilde{Y}} = 5.9$ GeV a value favoured by the $m_{\tilde{q}} = 40$ GeV interpretation of the monojets⁸⁾. Our results are insensitive to this particular choice as $m_{\tilde{Y}}$ enters only through the slepton decay.

The topological cross-sections for various trilepton signatures as a function of zino (wino) mass^{**) are shown in Fig. 1. The main difference between the}

*) If $m_{\tilde{\chi}} > m_{\tilde{W}}, m_{\tilde{Z}}$ ⁴⁾ the winos and zinos will decay via the three body modes into either quarks or leptons.¹⁴⁾ In this case, although the signatures we are discussing will be present, the leptonic modes will be reduced by the branching ratio into leptons. Further, the distributions will be altered since the decay now proceeds via virtual slepton (squark) and virtual gauge bosons. In addition there will be jet + lepton + $\cancel{p}_T$ modes¹⁵⁾.

**) We eliminate the Higgsino mixing parameter in favour of $m_{\tilde{Z}}$ which we vary freely. $m_{\tilde{Y}}$ is fixed by $m_{\tilde{Z}}$.

electrons and muons comes from their different p_T cuts ($|p_{Te}| > 10$ GeV, $|p_{T\mu}| > 3$ GeV)^{10),16)}. The muons are, therefore, much more likely to escape the cut than the electrons. This accounts for the magnitudes of the various trilepton signals; trilepton cross-sections with more electrons tend to be smaller. Increasing the slepton mass to 30 GeV causes a sharp drop in the trimuon cross-section for small $m_{\tilde{Z}}$ (and hence, $m_{\tilde{W}}$) since muons from $\tilde{W} \rightarrow \mu\tilde{\nu}$ are cut out leaving only those from $\tilde{W} \rightarrow \tilde{\mu}\nu$. The $e\mu\mu$ signal is not affected by this as the electrons from $\tilde{W} \rightarrow \tilde{e}\nu$ are cut out for both values of slepton mass. The μee signal, since the muon originates at the wino, is again affected by the increase in the slepton mass whereas the trielectron signal is not. For small values of $m_{\tilde{Z}}$, the latter two signals are further damped since they both entail the decay $\tilde{Z} \rightarrow \tilde{e}e$ and the 'e' from the zino escapes the cut. This accounts for the shapes of the trilepton distribution for low values of $m_{\tilde{Z}}$. The fall-off in the cross-section for larger values of $m_{\tilde{Z}}$ is dominantly governed by the decrease of the $W \rightarrow \tilde{W}\tilde{Z}$ cross-section, and hence, is the same in Fig. 1a and Fig. 1b.

We see that the trimuon and $e\mu\mu$ cross-sections are quite large. The former exceeds 10 pb almost up to $m_{\tilde{Z}} = 44$ GeV and peaks at $\sim 30(20)$ pb for $m_{\tilde{Z}} = 25(30)$ GeV. We emphasize that such quiet trilepton events have essentially no standard model backgrounds and, if present, would be expected to show up in the analysis of last year's CERN collider data. Seeing only one or two such events would probably herald new physics^{*)}.

We now turn to Fig. 2 which shows dilepton $+ \cancel{p}_T$ cross-sections. The same sign (SS) dileptons come from $W \rightarrow \tilde{W}\tilde{Z}$ only whereas the opposite sign (OS) dileptons come also from $Z \rightarrow \tilde{W}\tilde{W}$ decays. The smallness of the SS dimuons is due to the fact that in Fig. 2a it is difficult to cut out the third muon; the increase of the dimuon cross-section in Fig. 2b is precisely due to the drop of the trimuon cross-section in Fig. 1b. The SS dielectron cross-sections can be similarly explained. The SS $e\mu$ cross-section is bigger since it comes from missing a muon in $e\mu\mu$ production or missing the electron in μee production, the latter being obviously more dominant.

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*) We have assumed 100% detection efficiency - in a real detector, a muon can be missed although within the acceptance. We can speculate that trimuons with a muon missed due to detection efficiency could account for the same sign dimuon events reported by the UA1 collaboration¹⁹⁾. (As seen from Fig. 2, the same sign dimuon signal from a muon outside the acceptance is too small.)

Turning to opposite sign dileptons, we note that most (>75%) of the $e\mu$ pairs come from $Z \rightarrow \tilde{W}\tilde{W}$ whereas the processes $Z \rightarrow \tilde{W}\tilde{W}$ and $W \rightarrow \tilde{W}\tilde{Z}$ contribute roughly equally to e^+e^- or $\mu^+\mu^-$ pairs. The shapes of the curves for low zino masses are again a reflection of the different cuts on e and μ . The kink in the curves at $m_{\tilde{Z}} \sim 47$ GeV signals the fact that the $W \rightarrow \tilde{W}\tilde{Z}$ becomes kinematically suppressed whereas the $Z \rightarrow \tilde{W}\tilde{W}$ is still possible. The cross-over of the $\mu\mu$ and $e\mu$ curves reflects the fact that from the decay $Z \rightarrow \tilde{W}\tilde{W}$, $e\mu$ pairs are twice as likely as $\mu\mu$ pairs; as a result, when the $W \rightarrow \tilde{W}\tilde{Z}$ contribution to $\mu\mu$ is kinematically suppressed, the $e\mu$ pairs begin to dominate.

We see that the OS dilepton cross-sections are very large. For e^+e^- or $\mu^+\mu^- + \cancel{p}_T$ there is an additional source viz. the decay of Z into slepton pairs followed by the decay of the sleptons. This has been calculated in detail in Ref. 10) where backgrounds to the signals have also been discussed. Here, we emphasize the very striking opposite sign $e\mu + \cancel{p}_T$ signal. The cross-section for this exceeds 10 pb for $m_{\tilde{Z}} \lesssim 52$ GeV. (A possible background from the production and decay of sequential charged heavy leptons is expected to be less than 0.5 pb^{20} .) This signal is essentially free of standard model backgrounds; observation of any such events would be a likely indication of supersymmetry. Moreover, non-observation of such events may provide better bounds on wino masses than are currently available.

Finally, we turn to an analysis of the distribution of the leptons produced. We have chosen $m_{\tilde{Z}} = 40$ GeV (corresponding to $m_{\tilde{W}} \approx 35$ GeV) and $m_{\tilde{\chi}} = 25$ GeV as representative values of the masses. Shown in Fig. 3 are the invariant mass and $\cancel{p}_T$ distributions for those dilepton and trilepton signals for which the total cross-section exceeds ≈ 10 pb. The dilepton distributions may be compared to the corresponding distributions obtained from the direct decay of the gauge bosons into sleptons¹⁰⁾. The relevant standard model backgrounds are also shown in Ref. 10. The distribution in opening angle between the opposite sign dileptons is shown in Fig. 4. The $e\mu$ distribution is marginally sharper due to the fact that the bulk (85%) of $e\mu$ events comes from $Z \rightarrow \tilde{W}\tilde{W}$ decays compared to 55% (67%) for e^+e^- ($\mu^+\mu^-$) decays. These are much flatter than the distributions from the direct decays of the Z -boson into sleptons as may be expected.

In summary, we have shown that in models with slepton masses of 0(20-30GeV), as would be required⁷⁾ in a wide class of models by the $m_{\tilde{q}} = 40$ -50 GeV interpretation of the CERN monojet events, the presence of winos and zinos with masses such that the decays $W \rightarrow \tilde{W}\tilde{Z}$ and $Z \rightarrow \tilde{W}\tilde{W}$ are kinematically accessible, would lead

to spectacular trilepton $+p_T^{15)}$ and dilepton $+p_T$ signatures. Such events should be accompanied by very little hadronic activity. The trileptons all come from $W \rightarrow \tilde{W}Z$ whereas the decay $Z \rightarrow \tilde{W}\tilde{W}$ leads to the possibility of oppositely charged different flavour dileptons¹²⁾ and hence could be distinguished from $Z \rightarrow \tilde{\ell}\tilde{\ell}$ decays^{9),10)}. The cross-sections for these striking events are large, and indeed if the decays of the gauge bosons into winos (zinos) is allowed, it will lead to several such events in last years CERN data sample. Observation of such events would pin down the Higgsino mass mixing parameter whereas the non-observation of these could provide better limits on wino and zino masses, if indeed the sleptons are light as suggested by the $m_{\tilde{q}} = 40-50$ GeV interpretation²⁾ of the CERN collider data.

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REFERENCES

- 1) UAl Collaboration, G. Arnison et al., Phys. Lett. 139B (1984) 115.
- 2) J. Ellis and H. Kowalski, Phys. Lett. 142B (1984) 441; Nucl. Phys. B246 (1984) 189; CERN Preprint TH-4072 (1985).
- 3) E. Reya and D.P. Roy, Phys. Lett. 141B (1984) 442; Phys. Rev. Lett. 53 (1984) 881.
- 4) M.J. Herrero, L.E. Ibáñez, C. López and F.J. Yndurain, Phys. Lett. 132B (1984), 199; 145B (1984) 430.
V. Barger, K. Hagiwara, J. Woodside and W.Y. Keung, Phys. Rev. Lett. 53 (1984) 641.
- 5) For reviews of supergravity models see:
J. Ellis, CERN Preprint TH-3802 (1984);
H.-P. Nilles, Phys. Rep. 110C (1984) 1;
D.V. Nanopoulos, CERN Preprint TH 3995 (1984).
For phenomenology, see H.E. Haber and G.L. Kane - Univ. of Michigan Preprint UM-HE-TH-83-17 (1984).
- 6) S. Yamada, Proc. 1983 International Symposium on Lepton and Photon Interactions at High Energies, eds. D.G. Cassel and D.L. Kreinick (Cornell, 1983) p. 525.
- 7) C. Kounnas, A.B. Lahanas, D.V. Nanopoulos and M. Quirós, Phys. Lett. 132B (1983) 95; Nucl. Phys. B236 (1984) 438.
- 8) J. Ellis and M. Sher, Phys. Lett. 148B (1984) 309.
For more recent analyses of the mass spectra see:
L.E. Ibáñez, C. López and C. Muñoz, CERN Preprint TH-4071 (1984);
K. Enquist, D.V. Nanopoulos and A.B. Lahanas, CERN Preprint TH-4095 (1985).
- 9) R. Barbieri, N. Cabibbo, L. Maiani and S. Petrarca, Phys. Lett. 127B (1983) 458;
N. Cabibbo, L. Maiani and S. Petrarca, Phys. Lett. 132B (1983) 195;
R.M. Barnett, K.S. Lackner and H.E. Haber, Phys. Rev. Lett. 51 (1983) 176, Phys. Rev. D29 (1984) 1381.
- 10) H. Baer, J. Ellis, D. Nanopoulos and X. Tata, Phys. Lett. B (to be published).
- 11) S. Weinberg, Phys. Rev. Lett. 50 (1983) 387;
R. Arnowitt, A. Chamseddine and P. Nath, Phys. Rev. Lett. 49 (1982) 970; 50 (1983) 232.
J. Ellis, J. Hagelin, D. Nanopoulos and M. Srednicki, Phys. Lett. 127B (1983) 233.
- 12) P. Nath, R. Arnowitt and A. Chamseddine, Phys. Lett. 129B (1983) 445, Harvard Preprint, HUTP-83/A077 (1983);
D.A. Dicus, S. Nandi, W. Repko and X. Tata, Phys. Rev. Lett. 51 (1983) 1030;
T. Schimert, C. Burgess and X. Tata, Phys. Rev. D (to be published);
V. Barger, W-Y. Keung and R. Phillips, Univ. of Wisconsin Preprint MAD/PH/219 (1984).

- 13) Mark J. Collaboration, B. Adeva et. al., Phys. Rev. Lett. 53 (1984) 1806.
Jade Collaboration, W. Bartel et. al., Phys. Lett. 146B (1984) 126.
- 14) R.M. Barnett, H.E. Haber and K. Lackner, Phys. Lett. 126B (1983) 64.
- 15) D.A. Dicus, S. Nandi and X. Tata, Phys. Lett. 129B (1983) 451.
See also P. Nath et al., Ref. 12).
- 16) UAl Collaboration, private communication.
- 17) D.W. Duke and J. Owens, Phys. Rev. D30 (1984) 49.
- 18) V. Barger and R. Phillips, Phys. Rev. D30 (1984) 1890, Phys. Lett. 143B (1984) 259.
- 19) UAl Collaboration, talk presented by N. Ellis at the Nineteenth Rencontre de Moriond, Vol 1, ed. J. Tran Thanh Van (1984).
- 20) H. Baer, V. Barger and R. Phillips, Univ. of Wisconsin Preprint MAD/PH/213 (1985).

FIGURE CAPTIONS

- Fig. 1 : The topological cross-sections for various trilepton signatures that arise from the decay of the winos and zinos produced via $W^{\pm} \rightarrow \tilde{W}\tilde{Z}$ as a function of the zino (wino) mass and for slepton masses of 25 GeV (a) and 30 GeV (b).
- Fig. 2 : The topological cross-sections for various dilepton signatures that arise from the decay of winos and zinos produced via $W \rightarrow \tilde{W}\tilde{Z}$ and $Z \rightarrow \tilde{W}\tilde{W}$. We have added together the contribution of W^+ , W^- and Z . The slepton mass is 25 GeV in (a) and 30 GeV in (b). The contribution of $Z \rightarrow \tilde{\chi}\tilde{\chi}$ (see Ref. 10) has not been included in the opposite sign $\mu\mu$ and ee signatures. The dashed curves correspond to same sign (SS) dileptons and the solid curves to opposite sign (OS) dileptons.
- Fig. 3 : The distribution of the invariant mass m_I of the trilepton or the dilepton system (a) and $\cancel{p}_T$, the missing momentum in the plane transverse to the beam (b) for those topologies in Figs. 1 and 2 where the total cross-section exceeds 10 pb. The zino mass is fixed at 40 GeV (corresponding to a wino mass of 35 GeV) and the slepton mass at 25 GeV.
- Fig. 4 : The distribution in azimuthal opening angle between oppositely charged dileptons. The wino, zino and slepton masses are fixed at the same values as in Fig. 3.

Fig. 1

Fig. 2

Fig. 3

Fig. 4