Dimuons from Gauge Fermions Produced in $p\bar p$ Collisions

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In a supersymmetry scenario with a mass hierarchy $m_{\tilde g} \approx m_{\tilde q} > m_{\tilde\omega} > m_{\tilde l}$, gluino–scalar-quark pair production followed by the decay chain $\tilde g \to \tilde q \bar q$ $(\bar{\tilde q} q)$, $\tilde q \to \tilde\omega q$, $\tilde\omega \to \tilde\mu \nu$ $(\mu\tilde\nu)$, $\tilde\mu - \mu\tilde\gamma$ leads to like-sign and unlike-sign dimuons with comparable rates and possibly little accompanying hadronic activity; such events will often contain strange particles. Predictions are made for the dimuon distributions. The possible relevance to dimuon observations by Arnison *et al.*, is addressed.

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In experiments at the CERN $p\bar p$ collider, anomalous events are found[1,2] which are unexplained by standard model sources. Of particular theoretical interest are the monojet plus missing transverse momentum ($\bar p_T$) events reported by Arnison *et al.* (UA1 Collaboration)[1] which have been interpreted[3-5] as possible evidence for the production of supersymmetric particles.[6] If scalar quarks (s-quarks) ($\tilde q$) or gluinos ($\tilde g$) are strongly produced, then their decays to photinos ($\tilde\gamma$) could explain the $\bar p_T$, since the photino interacts feebly and would be undetected by the calorimeters. Three specific supersymmetric scenarios have been suggested, namely (i) $\tilde g\tilde g$ production[3] with masses $m_{\tilde q} > m_{\tilde g} \approx 40$ GeV and $\tilde g \to q\bar q\tilde\gamma$ decays; (ii) $\tilde q\tilde g$ production[4] with masses $m_{\tilde q} \approx 100$ GeV, $m_{\tilde g} \approx 3$ GeV, $\tilde q \to q\tilde\gamma$ decays, and a long-lived gluino; (iii) $\tilde q\bar{\tilde q}$ and $\tilde q\tilde g$ production[5] with $m_{\tilde g} > m_{\tilde q} \approx 40$ GeV and $\tilde q \to q\tilde\gamma$ decays. In this Letter we address striking consequences of scenario (iii) involving dilepton events.

In grand-unified supersymmetry models with scalar particle (s-particle) mass relations $m_{\tilde l} = m_{\tilde q}$ and $m_{\tilde g} = m_{\tilde W} = m_{\tilde B}$ at large scales $\mu \sim O(10^{16}\ \text{GeV})$ coming from soft supersymmetry breaking, the masses at low scales $\mu \sim O(M_W)$ are calculable from the renormalization-group equations.[7] For $m_{\tilde g} > m_{\tilde q}$ tight mass constraints are obtained[8]:

$$m_{\tilde g}/m_{\tilde q} \lesssim 1.1, \quad m_{\tilde l}/m_{\tilde q} \lesssim 0.45, \quad m_{\tilde\gamma}/m_{\tilde g} \simeq 0.15, \tag{1a}$$

which in scenario (iii) imply that

$$m_{\tilde q} \sim 40\ \text{GeV}, \quad m_{\tilde l} \sim 18\ \text{GeV}, \quad m_{\tilde g} \sim 45\ \text{GeV}, \quad m_{\tilde\gamma} \sim 6\ \text{GeV}. \tag{1b}$$

This approximate value of the scalar electron (s-electron) mass is already below the lower bound set by e^+e^- experiments,[9] namely $m_{\tilde e} > 22$ GeV.

The present limit on the lowest W-fermion–Higgs-fermion ($\tilde\omega$) mass from e^+e^- experiments[9,10] is $m_{\tilde\omega} > 22$ GeV. As recently stressed by Hall and Raby,[11] it is possible that an $\tilde\omega$ is lighter than the s-quarks, thus permitting $\tilde q \to q\tilde\omega$ decay, with subsequent $\tilde\omega$ decays

$$\tilde\omega \to e\tilde\nu_e \to e(\nu_e\tilde\gamma), \quad \tilde\omega \to \tilde e\nu_e \to (e\tilde\gamma)\nu_e. \tag{2}$$

Here we assume that $\tilde\nu \to \nu\tilde\gamma$ is the dominant $\tilde\nu$ decay mode.[12] The $\tilde\omega \to e\bar p_T$ branching fraction is 0.33.

The partial widths for $\tilde q \to q\tilde\omega$ and $\tilde q \to q\tilde\gamma$ decays in

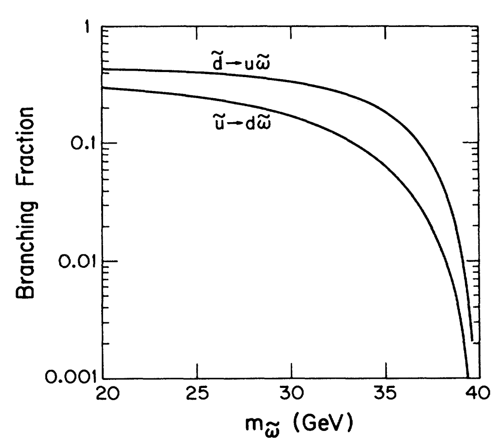

FIG. 1. Branching fraction for the decays $\tilde q \to q\tilde\omega$ vs the $\tilde\omega$ mass for $m_{\tilde q} = 40$ GeV. A mixing angle $\beta = \pi/4$ in Eq. (3) and equal initial $\tilde q_L$ and $\tilde q_R$ populations are assumed.

the light-m_q approximation are

$$\Gamma(\tilde{q}_L \to q\tilde{\omega}) = \frac{1}{4}\alpha\frac{\sin^2\beta}{\sin^2\theta_W} m_{\tilde{q}}\left[1-\left(\frac{m_{\tilde{\omega}}}{m_{\tilde{q}}}\right)^2\right]^2,$$

$$\Gamma(\tilde{q}_R \to q\tilde{\omega}) = 0, \tag{3}$$

$$\Gamma(\tilde{q} \to q\tilde{\gamma}) = \tfrac{1}{2}\alpha e_q^2 m_{\tilde{q}}[1-(m_{\tilde{\gamma}}/m_{\tilde{q}})^2]^2,$$

where $\sin^2\beta$ is the W-fermion, Higgs-fermion mixing. The expected $\tilde{u} \to d\tilde{\omega}$ and $\tilde{d} \to u\tilde{\omega}$ branching fractions from Eq. (3), based on equal initial $\tilde{q}_L$ and $\tilde{q}_R$ populations of mass 40 GeV, are shown in Fig. 1 versus $m_{\tilde{\omega}}$ for mixing angle $\beta = \pi/4$. For $m_{\tilde{q}} - m_{\tilde{\omega}} \gtrsim 5$ GeV, the $\tilde{d} \to u\tilde{\omega}$ decay mode occurs at the $\gtrsim 20\%$ level.

In $p\bar{p}$ collisions dilepton events would result from $\tilde{\omega}^{\pm}$ through the following subprocesses:

$$q\bar{q} \to \tilde{\omega}^+\tilde{\omega}^-, \tag{4a}$$

$$gg, q\bar{q}' \to \tilde{q}\bar{\tilde{q}}', \tag{4b}$$

$$qg \to \tilde{q}\tilde{g}, \tag{4c}$$

$$gg, q\bar{q} \to \tilde{g}\tilde{g}, \tag{4d}$$

$$qq' \to \tilde{q}\tilde{q}', \tag{4e}$$

$$q\bar{q}' \to \tilde{\omega}\tilde{g}, \tag{4f}$$

$$gq \to \tilde{\omega}\tilde{q}', \tag{4g}$$

where q represents either a quark or antiquark and q' may differ from q. The strong decay

$$\tilde{g} \to \tilde{q}\bar{q}, \bar{\tilde{q}}q \tag{5}$$

followed by $\tilde{q} \to q\tilde{\omega}$ leads to both $\tilde{\omega}^+\tilde{\omega}^-$ and $\tilde{\omega}^{\pm}\tilde{\omega}^{\pm}$ final states in Eq. (4). We evaluated the $\tilde{\omega}$-pair production cross sections in $p\bar{p}$ collisions at $\sqrt{s} = 630$ GeV, as in the work of Barger and co-workers,[13,14] folding in the $\tilde{q} \to q\tilde{\omega}$ branching fractions of Fig. 1. Only the $\tilde{q}_L$ contribute to $\tilde{\omega}\tilde{\omega}$ production; the appropriate statistical factors are taken into account. With masses $\tilde{q}(40)$ and $\tilde{g}(40+\epsilon)$, the cross sections obtained for $m_{\tilde{\omega}} = 25$ (35) GeV are given in Table I. The $\tilde{\omega}^+\tilde{\omega}^-$ give $l^+l^-\bar{p}_T$ events[11] and $\tilde{\omega}^+\tilde{\omega}^+$ give $l^+l^+\bar{p}_T$ events. The above $\tilde{q}$ and $\tilde{g}$ masses give an estimated cross section for monojets with missing $p_T > 40$ GeV of order 200 pb, which would be reduced by detection efficiency factors; should the monojet signal prove to be smaller than this, the $\tilde{q}$ and $\tilde{g}$ masses would have to be raised and our $\tilde{\omega}\tilde{\omega}$ signals reduced accordingly.

TABLE I. $\tilde{\omega}$-pair production cross sections at $\sqrt{s} = 630$ GeV for $m_{\tilde{\omega}} = 25$ (35) GeV.

	$\sigma(\tilde{\omega}^+\tilde{\omega}^-)$ (nb)	$\sigma(\tilde{\omega}^+\tilde{\omega}^+) + \sigma(\tilde{\omega}^-\tilde{\omega}^-)$ (nb)
(a)	0.14 (0.13)	0
(b)	0.18 (0.03)	0.05 (0.006)
(c)	0.18 (0.03)	0.18 (0.03)
(d)	0.07 (0.01)	0.07 (0.01)
(e)	0.02 (0.002)	0.02 (0.003)
(f)	0.01 (0.004)	0.01 (0.004)
(g)	0.01 (0.001)	0
Total	0.55 (0.20)	0.33 (0.05)

Provided that the $\tilde{g}$ and $\tilde{q}$ are approximately degenerate in mass, the $\tilde{q}$ and $\bar{\tilde{q}}$ from Eq. (5) will have approximately the $\tilde{g}$ momentum, and the $\bar{q}$ or q will be soft. To the extent that $\tilde{\omega}$ is close in mass to $\tilde{q}$, the q from $\tilde{q} \to q\tilde{\omega}$ decay will also have low p_T. Hence, all mechanisms above have the potential to lead to "quiet" dileptons, with little associated hadronic activity [the subprocess (a) of Eq. (4) always gives quiet dileptons]. This is a feature of many of the dimuon events reported by Arnison *et al.*[15]

The $\tilde{g}$ decay in Eq. (5) is flavor blind, and so $\tilde{u}\bar{u}$, $\tilde{d}\bar{d}$, $\tilde{s}\bar{s}$, and $\tilde{c}\bar{c}$ final states are about equally probable. Since the decay $c \to s$ also leads to strange quarks, the final state of subprocess (c) is likely to contain strange particles. In this connection it is interesting to note that UA1 finds[15] one $\mu^+\mu^+\Lambda$ event and one $\mu^-\mu^-\bar{\Lambda}$ event with little hadronic p_T.

Next we consider the kinematics of dimuon events resulting from $\tilde{\omega}$ pair production and decay. All of the subprocesses in Eq. (4) give comparable momenta to the $\tilde{\omega}$, so we specialize to subprocess (c) which gives the largest same-sign dilepton rate. The major difference in the various sources is the amount of hadronic activity accompanying the dimuons, which will be small in the case that $\tilde{g}$ and $\tilde{\omega}$ are close to $\tilde{q}$ in mass. We here take masses $\tilde{q}(40)$, $\tilde{g}(40+\epsilon)$, $\tilde{l}(20)$, and $\tilde{\gamma}(6)$ with the two choices $\tilde{\omega}(25)$ and $\tilde{\omega}(35)$. We impose transverse-momentum and rapidity acceptance cuts on the muons used by the UA1 collaboration[15]:

$$|p_{T1}|, |p_{T2}| > 3 \text{ GeV}, \quad |p_{T1}| + |p_{T2}| > 10 \text{ GeV}, \quad |\eta_1| < 1.2, \quad |\eta_2| < 1.8. \tag{6}$$

Predicted distributions are shown in Fig. 2 for the dimuon invariant mass $m(\mu\mu)$, the cluster transverse mass[16] $M_T(\mu\mu, \bar{p}_T)$, the azimuthal difference $\Delta\phi(\mu\mu)$ between the muons in the transverse plane, and the transverse momenta of the individual muons $p_T(\mu)$, the dimuon pair $p_T(\mu\mu)$, and the hardest jet $p_T(j_1)$ defined with use of the UA1 jet algorithm for overlapping jets. The $\bar{p}_T$ distribution is about the same as the $p_T(\mu\mu)$ distribution. In the calculations all transverse momenta are corrected, event by event, to include effects of multiple gluon emission by the incident partons, as in the work of Barger *et al.*[17] The $\bar{p}_T$ and $M_T(\mu\mu, \bar{p}_T)$ results include Gaussian experimental errors in $\bar{p}_T$ with root mean square error of 4 GeV, as in Barger *et al.*[18]

We note that the $\tilde{\omega}(25)$ and $\tilde{\omega}(35)$ cases are qualita-

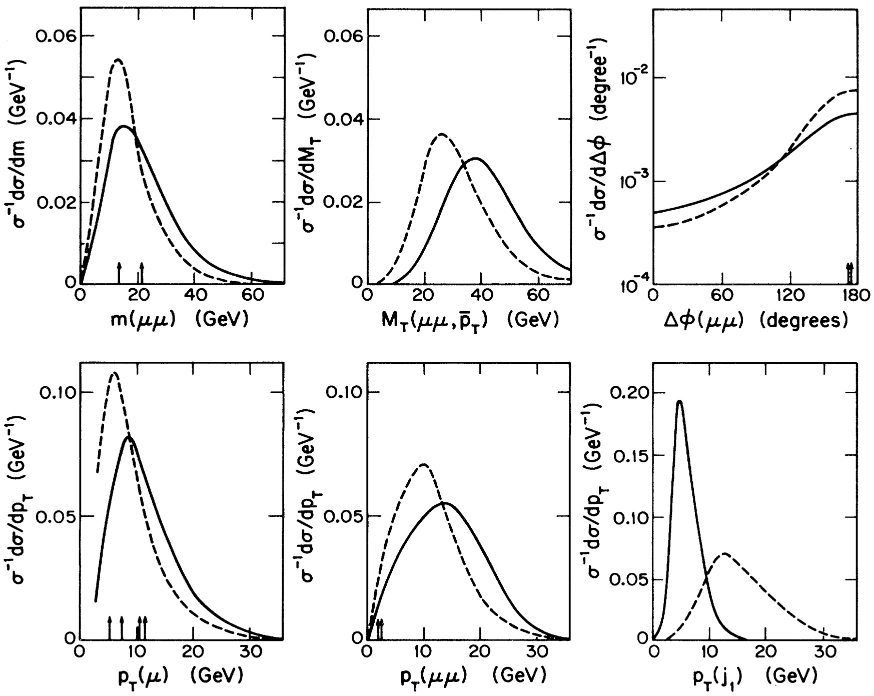

FIG. 2. Predicted distributions in dimuon events resulting from $\tilde{q}\tilde{g}$ production and the decays $\tilde{g}\rightarrow\tilde{q}\bar{q}$, $\tilde{q}\rightarrow\tilde{\omega}q$, $\omega\rightarrow\tilde{\mu}\nu(\mu\tilde{\nu})$, and $\tilde{\mu}\rightarrow\mu\tilde{\gamma}$, with $m_{\tilde{g}}\simeq m_{\tilde{q}}=40$ GeV, and $m_{\tilde{\omega}}=35$ GeV (solid curves), 25 GeV (dashed curves). These calculations for $p\bar{p}$ collisions at $\sqrt{s}=630$ GeV include the acceptance cuts of Eq. (5). The vertical arrows denote data values of the UA1 $\mu^+\mu^+\Lambda$ and $\mu^-\mu^-\overline{\Lambda}$ events (Ref. 15). The predicted $\bar{p}_T$ distribution is about the same as that for $p_T(\mu\mu)$.

tively similar in all distributions but $M_T(\mu\mu,\bar{p}_T)$ and $p_T(j_1)$. The heavier-$\tilde{\omega}$ case has much softer accompanying jets. The hardest jet has $p_T<10$ GeV in more than 90% of events for $\tilde{\omega}(35)$ and in less than 20% of events for $\tilde{\omega}(25)$.

The characteristics of the distributions in Fig. 2 can be used in the search for $\tilde{\omega}$ pair production, once sufficient statistics have accumulated. By requirement of muon isolation, the heavy-quark backgrounds from $c\bar{c}$, $b\bar{b}$, and $t\bar{b}$ production[19] can be suppressed relative to the $\tilde{\omega}\tilde{\omega}$ signal; this is especially the case for like-sign dimuons where these backgrounds are much smaller in the absence of large B^0-$\bar{B}^0$ mixing.

The decays of Z bosons are a potential source of unlike-sign dileptons[11,20,21]:

$$Z\rightarrow\tilde{\mu}\bar{\tilde{\mu}}\rightarrow\mu^+\mu^-\tilde{\gamma}\tilde{\gamma}, \tag{7a}$$

$$Z\rightarrow\tilde{\omega}^+\tilde{\omega}^-\rightarrow\mu^+\mu^-\nu\bar{\nu}\tilde{\gamma}\tilde{\gamma}. \tag{7b}$$

Here we omit the phase-space–suppressed $Z\rightarrow\tilde{q}\bar{\tilde{q}}$ contribution. The rate for (7a) is determined by the s-particle masses, whereas the rate for (7b), which is a component of subprocess (a) in Eq. (4), depends also[20] on the mixing angle β. For six mass-degenerate scalar lepton (s-lepton) flavors at 20 GeV, and six degenerate s-quark flavors at 40 GeV, the predicted branching fractions are

$$B(Z\rightarrow\tilde{\mu}\bar{\tilde{\mu}})\simeq 0.01,$$
$$B(Z\rightarrow\tilde{\omega}^+\tilde{\omega}^+)\simeq 0.10, \tag{8}$$

for $m_{\tilde{\omega}}=25$–35 GeV and mixing angle $\beta=\pi/4$. The corresponding total width from Z decay to s-particles is $\Delta\Gamma\simeq 0.8$ GeV. The distributions from this $\tilde{\omega}$-pair source are fairly similar to those in Fig. 2.

We conclude with some remarks on the possible relevance to UA1 dimuon observations:

(i) UA1 finds four like-sign and seventeen unlike-sign dimuons[15] with the acceptance cuts of Eq. (6). Some of these events can be identified with conventional physics sources such as Drell-Yan, ψ, and Υ (which give $\mu^+\mu^-$ events with muons isolated from hadrons), and $b\bar{b}$, $c\bar{c}$ (which give nonisolated muons). However, in addition there are like-sign events with both muons isolated and little hadronic activity (as well as unlike-sign events with isolated muons and jets) that may represent new physics; in the $\mu^+\mu^+\Lambda$ event, $m(\mu\mu)\simeq 22$ GeV, and in the $\mu^-\mu^-\overline{\Lambda}$ event $m(\mu\mu)\simeq 14$ GeV. One e^+e^- candidate event with $m(ee)\simeq 22$ GeV has also been reported.[15]

(ii) The 40-GeV s-quark supersymmetry scenario proposed to explain the UA1 monojets has the potential to give such isolated dileptons, both like-sign and unlike-sign. The dominant production subprocesses are $\tilde{\omega}^+\tilde{\omega}^-$, $\tilde{q}\bar{\tilde{q}}'$, and $\tilde{q}\tilde{g}$ production with the decay chain $\tilde{g} \to \tilde{q}\bar{q}$ $(q\bar{\tilde{q}})$, $\tilde{q} \to \tilde{\omega}q$, $\tilde{\omega} \to \tilde{\mu}\nu$ $(\mu\tilde{\nu})$, $\tilde{\mu} \to \mu\tilde{\gamma}$. An $\tilde{\omega}$ mass between that of the s-quarks and s-leptons is necessary. Depending on the masses, and the contributing subprocesses, dilepton events with and without jets are possible. Figure 2 compares the model with the quiet UA1 same-sign dimuon events[15]; the situation that both events lie close together in $p_T(\mu\mu)$ and $\phi(\mu\mu)$ is admittedly somewhat unlikely in our model; future data with higher statistics will clarify its relevance.

(iii) The expected dimuon cross sections from $\tilde{\omega}$-pair production are obtained by multiplication of the $\sigma(\tilde{\omega}\tilde{\omega})$ values in Table I by $[B(\tilde{\omega} \to \mu\bar{p}_T)]^2 = \frac{1}{9}$ and the dimuon acceptance, which is about 0.5 for $\tilde{\omega}(25)$ and 0.7 for $\tilde{\omega}(35)$. The results obtained for $m_{\tilde{\omega}} = 25$ (35) GeV are as follows:

Source	$\sigma(\mu^+\mu^-)$ (nb)	$\sigma(\mu^+\mu^+)+\sigma(\mu^-\mu^-)$ (nb)
Z^0	0.01 (0.01)	0
Hadronic	0.03 (0.004)	0.03 (0.003)

For an integrated luminosity of 400 nb^{-1}, expected by the end of the current CERN collider run, a number of dimuon events of $\tilde{\omega}$-pair origin are possible.

(iv) The vertical arrows on the horizontal axis in Fig. 2 represent the data values for the UA1 $\mu^+\mu^+\Lambda$ and $\mu^-\mu^-\bar{\Lambda}$ events. The data values occur at probable regions for all distributions except $p_T(\mu\mu)$.

(v) It is natural to often find strange particles with dileptons of this origin due to the flavor-blind $\tilde{g} \to \tilde{q}\bar{q}$ decay.

(vi) If $\tilde{\omega}$-pair production is a significant dilepton source, there must also exist similar μe events. The acceptance for electrons is more restrictive than that for muons so that $N(ee) < \frac{1}{2}N(\mu e) < N(\mu\mu)$. For $p_T(e) > 10$ GeV and muon acceptance given by Eq. (5), we estimate the event proportions $N(ee):N(\mu e):N(\mu\mu) \approx 1:8:8$ for $\tilde{\omega}(25)$ and 1:3:3 for $\tilde{\omega}(35)$.

(vii) Cross-section predictions are sensitive to the $\tilde{q}$ and $\tilde{g}$ masses, and those given here are illustrative rather than definitive. With $m(\tilde{q}) \approx 40$ GeV and $m(\tilde{g}) \approx 50$ GeV, the predicted rate for high-$\bar{p}_T$ monojet and dijet events is somewhat large compared to present experimental indications (assuming a high detection efficiency). It may eventually be appropriate to increase the $\tilde{q}$ and $\tilde{g}$ masses, with consequent reduction in the supersymmetric dilepton rates.

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[1]G. Arnison *et al.* (UA1 Collaboration), Phys. Lett. **139B**, 115 (1984).

[2]P. Bagnaia *et al.* (UA2 Collaboration), Phys. Lett. **139B**, 105 (1984).

[3]E. Reya and D. P. Roy, Phys. Lett. **141B**, 442 (1984), and Phys. Rev. Lett. **52**, 881 (1984); H. E. Haber and G. L. Kane, Phys. Lett. **142B**, 212 (1984); J. Ellis and H. Kowalski, Phys. Lett. **142B**, 441 (1984).

[4]V. Barger, K. Hagiwara, W.-Y. Keung, and J. Woodside, Phys. Rev. Lett. **53**, 641 (1981).

[5]V. Barger, K. Hagiwara, and W.-Y. Keung, Phys. Lett. **145B**, 147 (1984); J. Ellis and H. Kowalski, Nucl. Phys. **B246**, 189 (1984); A. R. Allan, E. W. N. Glover, and A. D. Martin, Phys. Lett. **146B**, 247 (1984).

[6]For recent reviews see, e.g., D. V. Nanopoulos, CERN Report No. TH-3995/84 (unpublished); H. E. Haber and G. L. Kane, Phys. Rep. **117**, 75 (1985); S. Dawson, E. Eichten, and C. Quigg, Phys. Rev. D **31**, 1581 (1985).

[7]C. Kounnas, A. B. Lahanas, D. V. Nanopoulos, and M. Quiros, Phys. Lett. **132B**, 135 (1983), and Nucl. Phys. **B236**, 438 (1984).

[8]J. Ellis and M. Sher, Phys. Lett. **148B**, 309 (1984).

[9]R. Prepost, in *Proceedings of the Twenty-Second International Conference on High-Energy Physics, Leipzig, East Germany, 1984,* edited by A. Meyer and E. Wieczorek (Akademie der Wissenschaften der DDR, Zeuth, East Germany, 1984); S. Wagner, talk at 1984 Annual Meeting of the Division of Particles and Fields, Santa Fe, New Mexico, 31 October–3 November 1984 (to be published).

[10]B. Adeva *et al.*, Phys. Rev. Lett. **53**, 1806 (1984).

[11]L. Hall and S. Raby, Phys. Lett. **153B**, 433 (1985).

[12]R. M. Barnett, C. S. Lackner, and H. E. Haber, Phys. Lett. **126B**, 64 (1983).

[13]V. Barger, W.-Y. Keung, R. J. N. Phillips, and R. Robinett, Phys. Lett. **131B**, 372 (1983).

[14]V. Barger, K. Hagiwara, W.-Y. Keung, and J. Woodside, Phys. Rev. D **31**, 528 (1985).

[15]G. Arnison *et al.* (UA1 Collaboration), CERN Report No. EP/85-19 (unpublished); G. Bauer and C. Rubbia, talk at 1984 Annual Meeting of the Division of Particles and Fields, Santa Fe, New Mexico, 31 October–3 November, 1984 (to be published); C. Rubbia, talk at Fourth Topical Workshop on $p\bar{p}$ Collider Physics, Bern, Switzerland 5–8 March 1984 (to be published).

[16]V. Barger, A. D. Martin, and R. J. N. Phillips, Phys. Lett. **125B**, 339 (1983).

[17]V. Barger, H. Baer, A. D. Martin, E. W. N. Glover, and R. J. N. Phillips, Phys. Rev. D **29**, 2020 (1984).

[18]V. Barger, H. Baer, K. Hagiwara, A. D. Martin, and R. J. N. Phillips, Phys. Rev. D **29**, 1923 (1984).

[19]V. Barger and R. J. N. Phillips, Phys. Lett. **143B**, 259 (1984).

[20]V. Barger, W.-Y. Keung, R. J. N. Phillips, and R. Robinett, Phys. Rev. D **28**, 2192 (1983).

[21]A. H. Chamseddine, P. Nath, and R. Arnowitt, Phys. Lett. **129B**, 445 (1983).