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IMPLICATIONS OF A SYSTEMATIC STUDY OF THE CERN MONOJETS FOR SUPERSYMMETRY*

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ABSTRACT

We report on a comprehensive study of supersymmetric processes which could give events similar to those observed at the CERN $Sp\bar{p}S$ collider. The present limited data seem to suggest a gluino mass $\lesssim$ 20 GeV and a scalar-quark mass of 100 – 120 GeV, although certain other supersymmetric masses are not yet excluded. With this choice of masses we also predict that other events with different characteristics should be observed. An essential ingredient of our analysis is the inclusion of events originating from a perturbatively generated gluino distribution function inside the proton.

Theoretical attempts to overcome certain fundamental problems underlying the Standard Model (the "hierarchy"[1] and "naturalness"[2] problems) suggest that new physics beyond the Standard Model must appear[3] at an energy scale of order 1 TeV. The CERN $S\bar{p}pS$ Collider is the first of a new generation of accelerators that will begin to approach this scale. Thus, there is anticipation in the theoretical community that we may be on the verge of uncovering new physics.

Numerous models have been constructed in recent years that attempt to deal with the problems mentioned above; among these are supersymmetric theories. There has been considerable theoretical work to determine the likely signatures of supersymmetric partners which could distinguish them from Standard Model physics.[4] In particular, much attention has been given to the production of scalar-quarks and gluinos at the CERN Collider.[5–12] A key feature of most supersymmetric models is that there exists a lightest stable supersymmetric particle which is electrically neutral and behaves very much like a neutrino; in particular it would escape the detectors at the CERN collider. For simplicity, we shall assume that this particle is the photino, $\tilde{\gamma}$ (although our results are more general than this assumption). Thus one of the fundamental signals of supersymmetry is the existence of a new weakly-interacting neutral particle. This implies that an experimental signature for this new physics would be events with unbalanced energy and momentum.

Such events are indeed seen at the CERN collider by the UA1[13] and UA2[14] collaborations. They are characterized by one or more large transverse momentum hadronic jets and substantial missing transverse energy. One discusses energy and momentum transverse to the beam direction, since some longitudinal energy always escapes down the beam pipe. Of the events mentioned above, the UA2 events[14] all contain an accompanying electron, whereas most of the UA1 events[13] contain no observed lepton. We shall focus here entirely on the UA1 events and consider the UA2 events elsewhere.[15]

The most striking of the UA1 events are those where there is exactly one large p_T jet and substantial missing transverse energy – these are called monojet events. From the experimental point of view, there are two aspects of isolating a sample of such events. First, how does one define "substantial" missing transverse energy? One must be careful since measurement error on an event which conserves transverse energy can lead to the appearance of missing p_T. Second, how does one define a hadronic "jet"? In order to deal with these issues, the experimentalists impose a series of cuts and jet selection criteria to obtain the final data set. We summarize these cuts now.

The relevant variables include E_T, the total scalar transverse energy, which is found by summing transverse energy over all calorimeter cells, and E_T^{miss}, the missing transverse energy in the event. For the hadronic jets, E_T^{jet} is the transverse energy and $\eta = -\log \tan(\theta/2)$ is the pseudorapidity.

The missing energy cuts are: (a) $E_T^{miss} > 4\sigma$ with $\sigma = 0.7 \times \sqrt{E_T}$. This cut attempts to eliminate events with missing energy which result from non-uniform calorimetry and other mismeasurements. (b) $E_T^{miss} > E_\circ$ where the UA1 collaboration has chosen $E_\circ = 15\,GeV$, although we will impose a more severe constraint below. (c) E_T^{miss} must not point to within $\pm 20°$ of the vertical (due to the absence of calorimetry in the vertical direction).

The jet energy is defined by choosing a jet axis and adding up all energy within a cone defined by $[(\Delta\phi)^2 + (\Delta\eta)^2] \leq 1$. It is required that the most energetic jet have energy $E_T^{jet} \gtrsim 25\, GeV$. This particular cut was changed slightly over the course of the run, and we have accounted for this change appropriately.

All additional jets are counted as jets only if $E_T^{jet} \geq 12\, GeV$. By this definition, monojets have one jet with $E_T^{jet} \geq 25\, GeV$ and no additional jets with $E_T^{jet} \geq 12\, GeV$. Dijets have in addition to the leading jet exactly one additional jet with $E_T^{jet} \geq 12\, GeV$, etc.

Having implemented all the cuts described above, the UA1 collaboration quotes the following number of events which passed the cuts during their 1983 run[13] (corresponding to $113\, nb^{-1}$ of data): 17 monojets, 5 dijets and 3 three-(or more)-jet events. The UA1 collaboration then notices that a large fraction of events lie close to the 4σ cut on missing energy. By additional analysis, they argue that 11 of 17 monojets, 5 of 5 dijets and 2 of 3 three-jet events are consistent with the tail of QCD background.

We arrive at the same conclusion simply by imposing one further cut: we demand that $E_T^{miss} \geq E_\circ$ where $E_\circ = 32\, GeV$. We would then be left with 6 monojets, no dijets and one three-jet event. These events are well isolated and are more likely to live in a background-free region. UA1 has very recently reported from their 1984 run[16] preliminary results of an additional 8 monojets and 8 dijets for $130\, nb^{-1}$. At the time of this writing, they have discussed in detail only those events (4 monojets and 4 dijets) which satisfy $E_T^{miss} > 40\, GeV$. Note that 5 of the 1983 monojets also have $E_T^{miss} > 40\, GeV$. Our goal in this work is to attempt to answer the question: Can the monojets be a result of the production of supersymmetric particles? We summarize in this Letter the results of a comprehensive study; details will be given elsewhere.[15, 17]

Supersymmetric particle couplings are precisely determined by the model, since they are related by supersymmetry to known couplings of ordinary particles. Model dependence only comes in due to the necessity of supersymmetry breaking. This leads to supersymmetric masses and mixing angles which are a priori unknown, and which we therefore take to be free parameters (which will eventually be measured by experiment). Our bias, which follows from low-energy supergravity models,[18] is that (at least) five flavors of scalar-quarks are approximately degenerate in mass, and for these flavors the $\widetilde{q}_L - \widetilde{q}_R$ mixing and mass splitting are small. We also take $M_{\widetilde{\gamma}} = 0$.

We have attempted to calculate <u>every</u> supersymmetric process which could lead to monojet and dijet events of the type observed by UA1. The signatures of these processes are always dependent on whether $M_{\widetilde{q}} > M_{\widetilde{g}}$ or $M_{\widetilde{g}} > M_{\widetilde{q}}$. We also considered on-shell $W^{\pm}$ and Z° production followed by decay to $\widetilde{q}\widetilde{q}$.

For $M_{\widetilde{q}} > M_{\widetilde{g}}$,

$$\widetilde{q} \longrightarrow \begin{cases} q\widetilde{g} & B = r/(1+r) \\ q\widetilde{\gamma} & B = 1/(1+r) \end{cases} \tag{1}$$

$$\widetilde{g} \longrightarrow q\bar{q}\widetilde{\gamma} \tag{2}$$

where B is branching ratio and $r = (4/3)\alpha_s/\alpha e_q^2$. For this case, we studied the production of the following supersymmetric final states:

$$\widetilde{g}\widetilde{g}, \qquad \widetilde{g}\widetilde{q} \qquad and \qquad \widetilde{\gamma}\widetilde{g}. \tag{3}$$

The relevant cross-sections for the elementary subprocesses can be found in ref. 5. In addition, if the gluino is light enough, it would be perturbatively generated as a component of the proton.[6, 19] We calculated the gluino structure function for various gluino masses, so that we could investigate

$$\widetilde{g} + q \rightarrow \widetilde{q} \qquad with \qquad \widetilde{q} \rightarrow q\widetilde{g}, \tag{4}$$

and

$$\widetilde{g} + q \rightarrow \widetilde{q} \qquad with \qquad \widetilde{q} \rightarrow q\widetilde{\gamma}. \tag{5}$$

The process $\widetilde{g} + g \rightarrow \widetilde{g}$ can produce no events surviving the cuts. (Note that in this case, $Q^2 = M^2_{\widetilde{g}}$ unless we consider off-mass-shell production, and the gluino structure function is zero for $Q^2 < 4M^2_{\widetilde{g}}$.) The production of $\widetilde{q}\widetilde{q}$ leads to an 8-body final state with no events able to survive the cuts and is not reported here.

For $M_{\widetilde{g}} > M_{\widetilde{q}}$ the gluino and scalar-quark decay via:

$$\widetilde{g} \rightarrow q\widetilde{q} \tag{6}$$

$$\widetilde{q} \rightarrow q\widetilde{\gamma}. \tag{7}$$

For this case, we have studied the production of

$$\widetilde{q}\widetilde{q}, \qquad \widetilde{g}\widetilde{g}, \qquad \widetilde{\gamma}\widetilde{q} \qquad and \qquad \widetilde{q}\widetilde{g}. \tag{8}$$

We employ the formalism of the QCD-improved parton model.[20] We generate events using a Monte Carlo integration technique and decay all final-state supersymmetric particles. We interpret all final-state quarks as "hadronic jets". We then implement the UA1 cuts and jet criteria as outlined. As a result of these cuts, a "theoretical" n-body event usually becomes a monojet or a dijet. Finally, we obtain cross-sections and various differential distributions for monojets and multijet events which survive the cuts.

There are quite a number of subtleties in the above procedure which we briefly comment on below. Our Monte Carlo program produces a final state of quarks whereas in the real world only hadrons are seen. These hadrons presumably come both from the quarks produced at large p_T as well as from the quarks left behind in the protons (the "spectators"). Thus, it is unclear how we can predict numerical values for the total scalar transverse energy, E_T, on an event-by-event basis. Although minimum bias events at the CERN Collider[21] (events containing no large p_T activity) tend to have a distribution in E_T averaging about 20-25 GeV, ordinary QCD two-jet events have the property that when the two jets are removed, the remaining energy in the event has an E_T that is roughly twice that of minimum bias.[22] Furthermore, if one removes the leading jet from the monojets, the remaining event has an E_T that averages around 50 GeV (with large variation).

If the monojets are due to supersymmetry, then the difference between E_T and E_T^{jet} (i.e.- 50 GeV on average) is presumably due to two sources. One source would be hadrons resulting from the supersymmetric particle decay which did not pass the UA1 jet cut, $E_T^{jet} \geq 12\, GeV$. The second source would in part consist of similar mechanisms which led to the excess E_T observed in two-jet events mentioned above. Thus, when we obtain events from our Monte Carlo we have chosen to identify E_T as

$$E_T = \sum_i E_{T_i} + E_s \tag{9}$$

where E_{T_i} consist of all final-state quarks whether or not they end up in jets which pass the UA1 cuts. E_s is a transverse energy distribution which corresponds to what is observed in minimum-bias events scaled up so as to give an average which we have taken to be 40 GeV.

Given the method described above, we have computed cross-sections and distributions for monojets, dijets, etc. originating from the supersymmetric processes which successfully pass the UA1 cuts. We reiterate that we have imposed an additional cut that $E_T^{miss} \geq 32\,GeV$ or $\geq 40\,GeV$. This is more likely to place us in a "background-free" region and allows us to obtain more reliable bounds on possible supersymmetric masses.

In obtaining our results we have not multiplied by the so-called "K-factor". Other possible sources of uncertainty come from the gluino structure function calculation which assumes $\Lambda = 0.29\,GeV$ and the gluon structure function of Ref. 20 . We should also point out that our calculated monojet rate from the production of a pair of light gluinos or light scalar-quarks is less than that reported elsewhere,[8-12] due primarily to our improved handling of UA1 cuts as described above. As a result we find that $\tilde{g}\tilde{g}$ production does not rule out $M_{\tilde{g}} < 40\,GeV$.

For the supersymmetric processes and analysis described above, our results for monojet total cross-sections are summarized in Fig. 1 Current data would lead us to expect the allowed regions to be roughly 2-10 events per 100 nb^{-1}

in Fig. 1. We would like to emphasize that the uncertainty in our calculation increases significantly for $M_{\tilde{g}} \lesssim 5\,GeV$ for several reasons. Although the total cross-sections for processes such as $\tilde{g}\tilde{g}$ increase rapidly as $M_{\tilde{g}}$ decreases, virtually nothing passes the cuts; as a result one needs to generate an extremely large number of Monte Carlo events to get good statistics. For these low masses one is very sensitive to the fragmentation of the gluino into a supersymmetric hadron because of the E_T^{miss} cut. Similar problems arise if this supersymmetric hadron first decays strongly before the gluino decays.

It is important to note that Fig. 1 shows the sums of monojets from all possible processes irrespective of the shapes of distributions. In fact we find that different supersymmetric processes for fixed $M_{\tilde{g}}$ and $M_{\tilde{q}}$ can lead to quite different distributions. Not surprisingly it is the masses of the produced particles which most strongly affect the distributions. For $\tilde{g}\tilde{g}$ or $\tilde{q}\tilde{q}$ production these masses must be less than about 50 GeV to obtain monojet rates large enough to explain the data. For $\tilde{g}\tilde{q}$ production one can choose $M_{\tilde{g}}$ small and thereby allow $M_{\tilde{q}}$ to be as large as 100 – 120 GeV.[11] For such masses an even larger contribution[6] comes from $\tilde{g} + q \rightarrow \tilde{q}$ for which the largest monojet contribution comes from the decay $\tilde{q} \rightarrow q + \tilde{g}$. For $M_{\tilde{g}}$ (or $M_{\tilde{q}}$) $\lesssim 50\,GeV$ the curves for $\tilde{g}\tilde{g}$ (or $\tilde{q}\tilde{q}$) always peak at significantly lower values of E_T^{miss}, E_T^{jet} and m_T (the transverse mass) as compared to $\tilde{g}\tilde{q}$ and processes given by eqs. (4) and (5) with large $M_{\tilde{q}}$ and small $M_{\tilde{g}}$. Reasonable rates for the sum of all processes can be obtained for $M_{\tilde{q}} \approx 100 - 120\,GeV$ and $M_{\tilde{g}} \lesssim 20\,GeV$. The gluino mass strongly affects the rate, because the gluino structure function drops very rapidly with $M_{\tilde{g}}$ (for these Q^2), but the shapes of the distributions are dominated by $M_{\tilde{q}}$.

Fig. 2 shows the m_T distribution for $M_{\tilde{q}} = 40\,GeV$ and $M_{\tilde{g}} = 80\,GeV$ where $\tilde{q}\tilde{q}$ production is the dominant contribution. The data[13,16] include points from experimental runs at both $\sqrt{s} = 540$ and $630\,GeV$. The curves show the calculated distributions for $\sqrt{s} = 540\,GeV$; but one should note that rates can increase by as much as a factor of 2 in going to the higher energy. However, the shapes of the distributions are essentially unchanged, and the rates can be readjusted by small changes in the relevant supersymmetric masses. Fig. 3 shows the m_T distribution for the sum of all processes when $M_{\tilde{q}} = 110\,GeV$ and $M_{\tilde{g}} = 10\,GeV$. The largest contributions here are from $\tilde{g} + q \rightarrow \tilde{q}$ and $\tilde{g}\tilde{g}$ production. Increasing the cut for E_T^{miss} from 32 to 40 GeV decreases the number of $\tilde{g}\tilde{g}$ events (which populate the low E_T^{jet}, E_T^{miss} and m_T regions) by a factor of 4. Of course, the events below $E_T^{miss} = 40\,GeV$ still should be found unless the efficiency for finding such events is lower than the efficiency for events with larger E_T^{miss}, or unless fragmentation effects (discussed earlier) push some events below the cuts. In Figs. 2 and 3 we show the impact of this choice of the E_T^{miss} cut for the m_T distribution. While adequate fits are obtained for the $E_T^{miss} > 40\,GeV$ cut, we clearly predict that the events below the dashed curves must also be found. Note that for $E_T^{miss} > 32\,GeV$, the m_T distribution of Fig. 3 is significantly harder than that of Fig. 2. Similarly, we have found that the E_T^{jet} distribution in the case of Fig. 3 peaks about $10\,GeV$ higher than in the case of Fig. 2. Although data are limited, we feel that the existing data for $E_T^{miss} > 32\,GeV$ are more likely to be consistent with the curves of Fig. 3 than with those of Fig. 2.

Almost all monojets are produced centrally with $|\eta| < 1.5$. The monojets from $\widetilde{g}\widetilde{g}$ production ordinarily occur when the two quark jets from one of the gluino decays coalesce. This results in an invariant mass distribution for these monojets which peaks just below the gluino mass. By contrast we find that the monojets from $\widetilde{g}+q \rightarrow \widetilde{q}$ and $\widetilde{q}\widetilde{q}$ rarely involve coalescence and are therefore more narrow.

Current data indicate roughly less than or equal to 1 dijet per monojet.[23] In the case of a heavy $\widetilde{q}$ and light $\widetilde{g}$, the dijet events usually come from $\widetilde{q} \rightarrow q + \widetilde{g}$. The q gives a hard jet passing the $E_T^{jet} \gtrsim 25\,GeV$ cut whereas the gluino leads to a softer jet. For $M_{\widetilde{q}} \approx 110\,GeV$ and $M_{\widetilde{g}} \approx 10\,GeV$ we find that the dijet to monojet ratio is 60% for $E_T^{miss} > 32\,GeV$ and 20% for $E_T^{miss} > 40\,GeV$. This clearly indicates that the dijets from this source should have less E_T^{miss} than the monojets have. The dijets which do survive the 40 GeV cut have m_T = 100 – 120 GeV, and are usually separated by nearly 180°. For the $\widetilde{q}\widetilde{q}$ case ($M_{\widetilde{q}} = 40\,GeV$) the dijet to monojet ratio is about 65% for either cut. Dijets from this source would have $m_T = 80 - 150$ GeV and are separated by $70° - 170°$. The recently reported dijet events[16] have considerably more missing energy than the observed monojets, and this large E_T^{miss} is difficult to explain for any choice of supersymmetric masses. However, we have not included in our calculations certain effects which may substantially alter our conclusions about the dijets. For example, other dijets may result from monojets due to QCD effects such as gluon radiation or the emergence of the second (unstruck) gluino from the proton. Further details concerning the dijets will be provided elsewhere.[15,17]

We have not calculated two possible backgrounds: (a) $Z^\circ + g$ production with $Z^\circ \rightarrow \nu\overline{\nu}$ or (b) $W \rightarrow \nu\tau$ production. However, the former process is not expected to contribute appreciably to the observed events.[24] Background from the latter process can be eliminated by taking $E_T^{miss} \gtrsim 40\,GeV$. We have calculated distributions and rates for the hypothesis of Glashow and Manohar,[25] (where monojets arise from Z decay into light scalars) and find that it is roughly consistent with the data (although no dijets from this source survived the cuts).

If $M_{\tilde{g}}$ and $M_{\tilde{q}}$ are in the range suggested in Fig 3, two other predictions can be made. In many models, the supersymmetric partner of the W ($\tilde{w}$) will be light enough so that $\tilde{q} \to q\tilde{w}$ will have a non-negligible branching ratio. If $\tilde{w} \to e\tilde{\nu}$ (where the $\tilde{\nu}$ escapes undetected), then one will find events with an isolated lepton, jet and missing transverse energy. We also expect that a gluino-gluino bound state of mass equal to $2M_{\tilde{g}}$ will lead to a small enhancement in ordinary two-jet events at that mass,[26] which may be observable by a dedicated search.

In a longer paper[15] we will show dijet distributions and examine new CERN data at $\sqrt{s} = 630\,GeV$. The next step in our program is to account for fragmentation and hadronization effects so that we may more realistically analyze the experimental observations.

In conclusion we have studied a large variety of supersymmetric processes and find that there is only a small range of $M_{\tilde{q}}$ and $M_{\tilde{g}}$ values which may be able explain the observed monojets with large E_T^{miss}. The data appear to suggest that the monojets come mainly from the decay of a massive (100 − 120 GeV) object such as a scalar-quark. However, we cannot yet rule out the region $M_{\tilde{q}} \approx 40\,GeV$ and $M_{\tilde{g}} \approx 80\,GeV$. In order to obtain appropriate rates when $M_{\tilde{q}} \approx 110\,GeV$ from $\tilde{g} + q \to \tilde{q}$ (for which we have calculated the gluino structure function), we find that the gluino must be $\lesssim$ 20 GeV in mass. Since in this case $M_{\tilde{g}}$ is small, we predict that $\widetilde{g}\widetilde{g}$ events must also be observed; these will populate the low m_T region under the dashed curve in Fig. 3 and will also have lower E_T^{jet} and E_T^{miss}. The number of such $\widetilde{g}\widetilde{g}$ events might be smaller than shown if the fragmentation of the (light) gluinos results in fewer events passing the cuts. Estimations of dijet contributions are more difficult to make, in part because some dijets presumably are due to QCD corrections to monojet events. The fact that the observed dijets have more E_T^{miss} than the monojets have may be indicative of these effects.

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REFERENCES

1. H. Georgi, H.R. Quinn and S. Weinberg, *Phys. Rev. Lett.* **33**, 451 (1974); E. Gildener, *Phys. Rev.* **D14**, 1667 (1976).

2. K. Wilson, *Phys. Rev.* **D3**, 1818 (1971); G. 't Hooft, in *Recent Developments in Gauge Theories,* Proc. NATO Advanced Summer Institute, Cargese 1979, eds. G. 't Hooft, *et. al.* (Plenum, New York, 1980), p. 135.

3. L. Susskind, *Phys. Rev.* **D20**, 2619 (1979); E. Witten, *Nucl. Phys.* **B185**, 513 (1981); M. Veltman, *Acta Phys. Pol.* **B12**, 437 (1981).

4. H.E. Haber and G.L. Kane, Physics Reports, to be published.

5. P.R. Harrison and C.H. Llewellyn Smith, *Nucl. Phys.* **B213**, 223 (1983) (E: **B223**, 542 (1983); I. Antoniadis, L. Baulieu and F. Delduc, *Z. Phys.* **C23**, 119 (1984); S. Dawson, E. Eichten and C. Quigg, *FERMILAB-PUB-83/82-THY* (1984), to be published in *Phys. Rev. D.*

6. M.J. Herrero, L.E. Ibanez, C. Lopez and F.J. Yndurain, *Phys. Lett.* **132B**, 199 (1983); **145B**, 430 (1984).

7. H.E. Haber and G.L. Kane, *Phys. Lett.* **142B**, 212 (1984); G. Altarelli and R. Ruckl, *Phys. Lett.* **144B**, 126 (1984); N.D. Tracas and S.D.P. Vlassopulos, *Phys. Lett.* **149B**, 253 (1984).

8. J. Ellis and H. Kowalski, *Phys. Lett.* **142B**, 441 (1984); *Nucl. Phys.* **B246**, 189 (1984).

9. E. Reya and D.P. Roy, *Phys. Rev. Lett.* **51**, 867 (1983) (E: **51**, 1307 (1983); *ibid.* **53**, 881 (1984); *Phys. Lett.* **141B**, 442 (1984); Dortmund

preprint, DO-TH 84/19 (1984).

10. V. Barger, K. Hagiwara and J. Woodside, *Phys. Rev. Lett.* **53**, 641 (1984); V. Barger, K. Hagiwara and W.-Y. Keung, *Phys. Lett.* **145B**, 147 (1984).

11. V. Barger, K. Hagiwara, W.-Y. Keung and J. Woodside, Wisconsin preprint MAD/PH/197 (1984).

12. A.R. Allan, E.W.N. Glover and A.D. Martin, *Phys. Lett.* **146B**, 247 (1984); A.R. Allan, E.W.N. Glover and S.L. Grayson, Durham, preprint DTP/84/28 (1984).

13. G. Arnison, *et. al.*, *Phys. Lett.* **139B**, 115 (1984).

14. P. Bagnaia, *et. al.*, *Phys. Lett.* **139B**, 105 (1984).

15. R.M. Barnett, H.E. Haber and G.L. Kane, preprint in preparation.

16. M. Mohammedi, invited talk at the 1st Annual Aspen Winter Physics Conference, Aspen, Colorado, Jan. 6-12, 1985.

17. H.E. Haber, SLAC-PUB-3550 (1985), to appear in the Proceedings to the 1984 DPF Meeting, Santa Fe, New Mexico, November, 1984;

18. For reviews of the low-energy supergravity approach see: H.P. Nilles, *Phys. Rep.* **110**, 1 (1984); P. Nath, R. Arnowitt and A.H. Chamseddine, *Applied N=1 Supergravity*, The ICTP Series in Theoretical Physics- Volume I (World Scientific, Singapore, 1984).

19. B.A. Campbell, J. Ellis and S. Rudaz, *Nucl. Phys.* **B198**, 1 (1982); I. Antoniadis, C. Kounnas and R. Lacaze, *Nucl. Phys.* **B211**, 216 (1983); C. Kounnas and D.A. Ross, *Nucl. Phys.* **B214**, 317 (1983); S.K. Jones and

C.H. Llewellyn Smith, *Nucl. Phys.* **B217**, 145 (1983); M.J. Herrero, C. Lopez and F.J. Yndurain, *Nucl. Phys.* **B244**, 207 (1984).

20. The necessary formalism has been summarized in: E. Eichten, I. Hinchliffe, K. Lane and C. Quigg, *Rev. Mod. Phys.* **56**, 579 (1984). We have used their parton distribution functions in our work.

21. G. Arnison, *et. al.*, CERN-EP/82-122 (1982).

22. G. Arnison, *et. al.*, *Phys. Lett.* **132B**, 214 (1983); J. Sass, in *Antiproton-Proton Physics and the W Discovery*, Proc. of the International Colloquium of the CNRS, Third Moriond Workshop, March, 1983, ed. by J. Tran Thanh Van (Editions Frontieres, France, 1983), p.295.

23. It is now thought that the UA1 analysis of the 1983 data (Ref. 12) was not very sensitive to dijets. See C. Rubbia, invited talk given at the 1984 DPF Meeting, Santa Fe, New Mexico, November, 1984 and Ref. 16.

24. A. Ballestrero and G. Passarino, *Phys. Lett.* **148B**, 373 (1984); G. Altarelli, R.K. Ellis, M. Greco and G. Martinelli, *Nucl. Phys.* **B246**, 12 (1984).

25. S.L. Glashow and A. Manohar, Harvard preprint HUTP-84/A080.

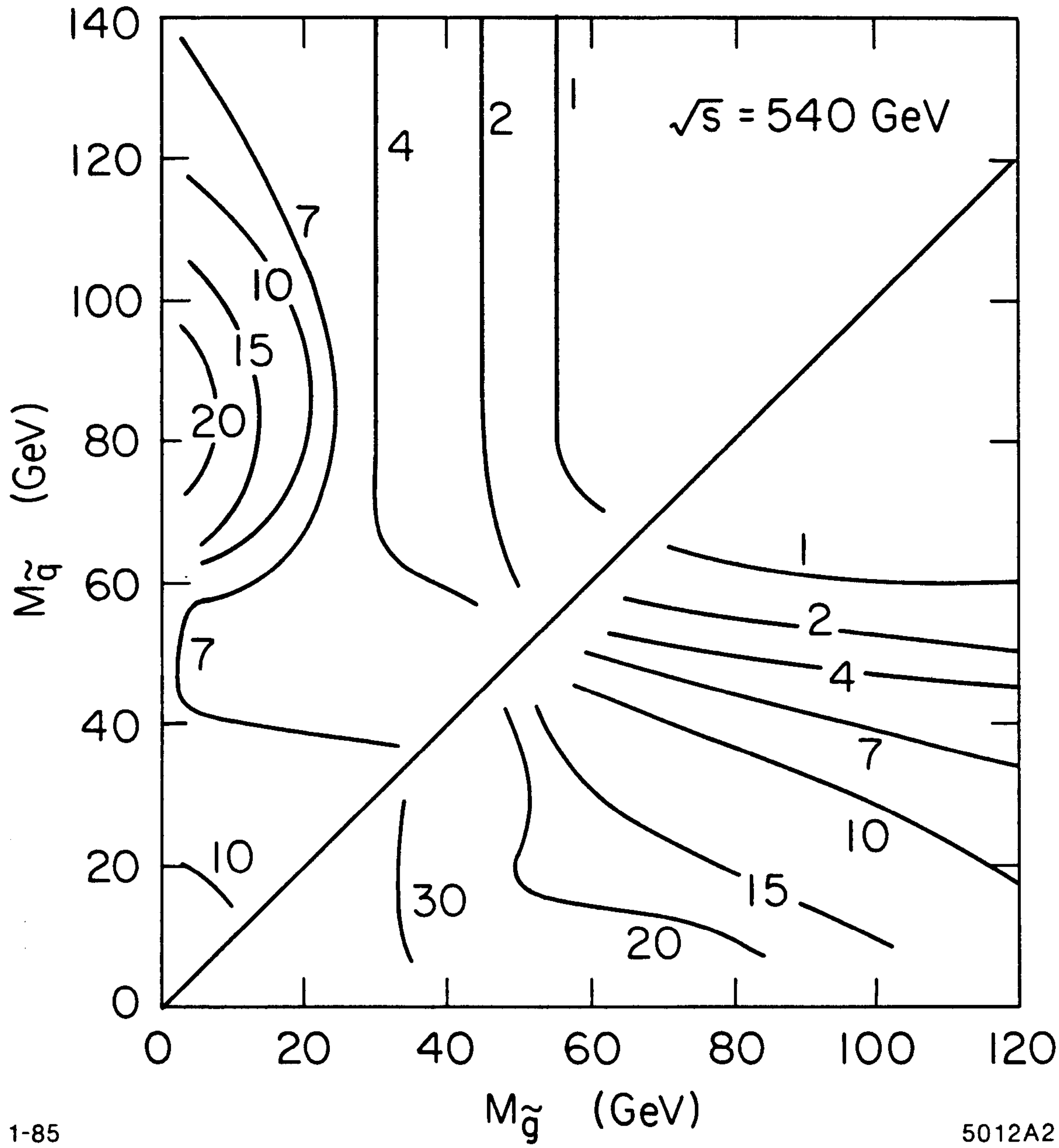
26. T. Goldman and H.E. Haber, to appear in Proc. Los Alamos Workshop on Supersymmetry in Physics, to be published in Physica D.

FIGURE CAPTIONS

1. The number of monojet events at $\sqrt{s} = 540\,GeV$ per $100\ nb^{-1}$ passing the UA1 cuts plus the $E_T^{miss} > 32\,GeV$ cut are shown as a contour plot as a function of $M_{\tilde{g}}$ and $M_{\tilde{q}}$. This number is the total from all supersymmetric sources irrespective of whether the distributions from a given source fit the observed distributions. As discussed in the text the uncertainty in this number is large for $M_{\tilde{g}}$ (or $M_{\tilde{q}}$) $\lesssim 5\,GeV$.

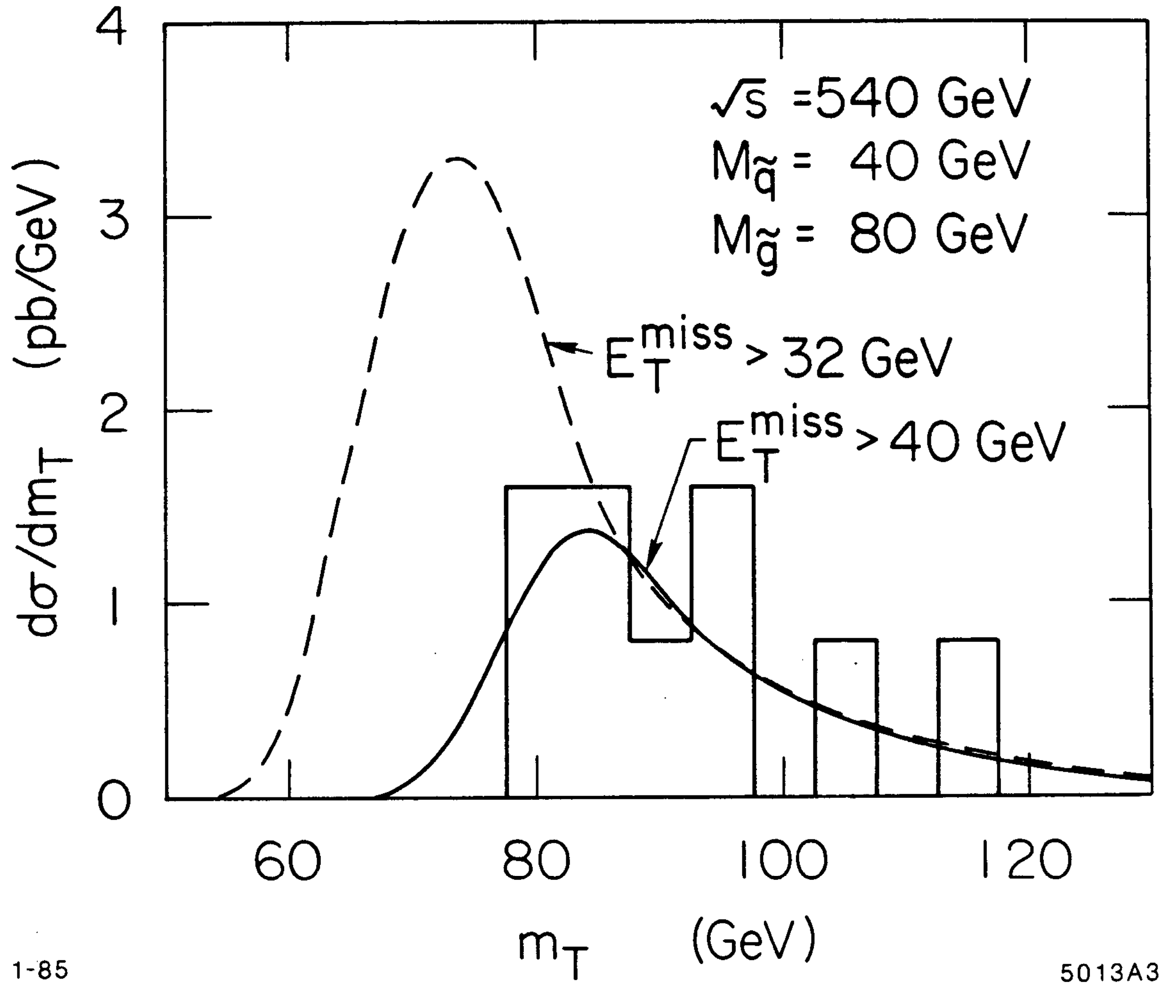
2. The transverse mass distribution ($m_T = [2E_T^{jet}E_T^{miss}(1-\cos\theta)]^{\frac{1}{2}}$) in $p\overline{p}$ scattering from monojet events passing the UA1 cuts and $E_T^{miss} > 32\,GeV$ (dashed) and $E_T^{miss} > 40\,GeV$ (solid). The curves show the sums of contributions from all supersymmetric processes when $M_{\tilde{q}} = 40\,GeV$ and $M_{\tilde{g}} = 80\,GeV$. The contributions are mostly from $\tilde{q}\tilde{q}$ production. The histogram shows the data from Refs. 13 and 16 for $E_T^{miss} \geq 40\,GeV$.

3. The transverse mass distribution in $p\overline{p}$ scattering from monojet events passing the UA1 cuts and $E_T^{miss} > 32\,GeV$ (dashed) and $E_T^{miss} > 40\,GeV$ (solid). The curves show the sums of contributions from all supersymmetric processes when $M_{\tilde{q}} = 110\,GeV$ and $M_{\tilde{g}} = 10\,GeV$. The contributions at low m_T below the dashed curve come largely from $\tilde{g}\tilde{g}$ production while those at high m_T come largely from the process given by eq. (4). The histogram shows the data from Refs. 13 and 16 for $E_T^{miss} \geq 40\,GeV$.



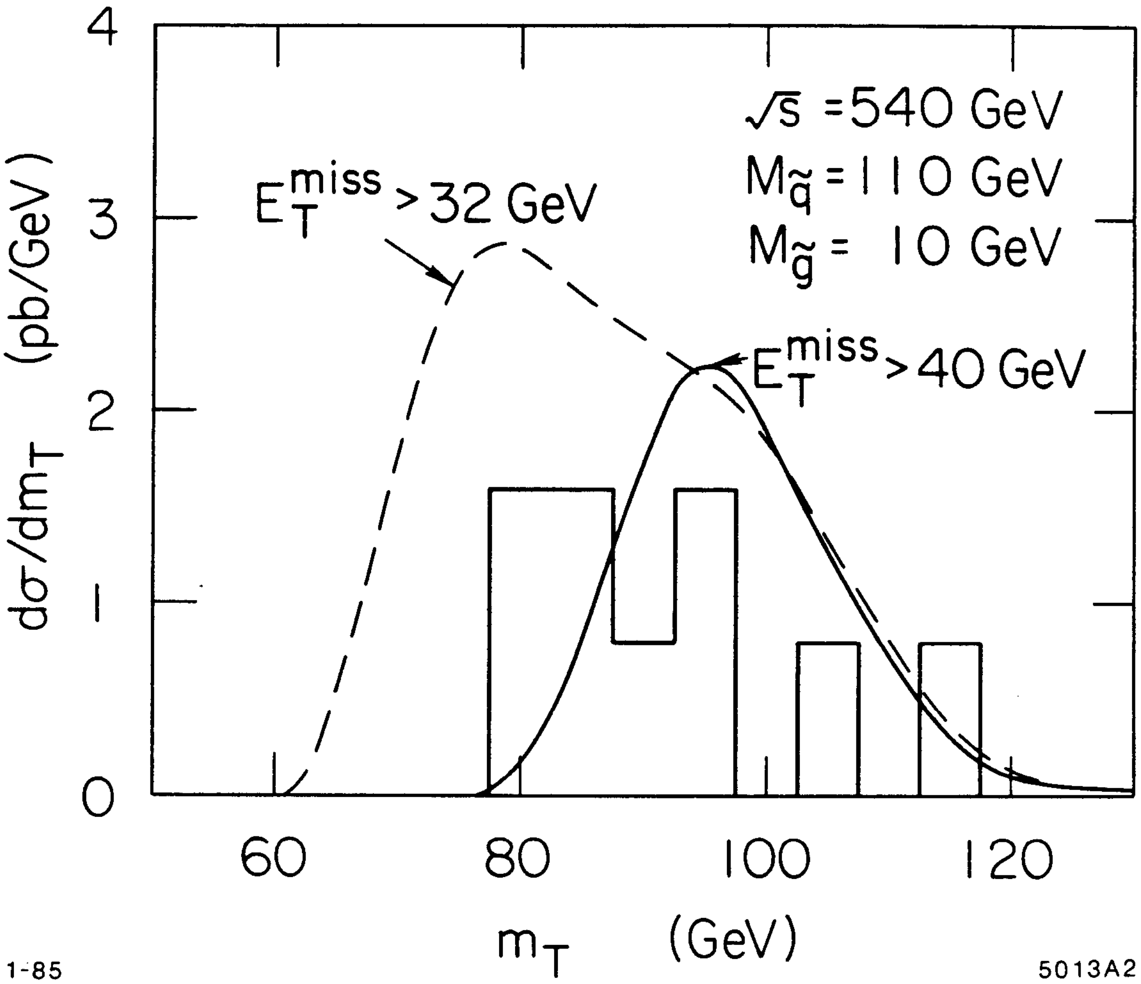
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
$M_{\tilde{q}}$ (GeV)
$M_{\tilde{g}}$ (GeV)
$\sqrt{s}$ = 540 GeV
1
2
4
7
10
15
20
30
1-85
5012A2

Fig. 1



4
3
2
1
0
$d\sigma/dm_T$ (pb/GeV)
60
80
100
120
m_T (GeV)
$\sqrt{s}$ =540 GeV
$M_{\tilde{q}}$ = 40 GeV
$M_{\tilde{g}}$ = 80 GeV
$E_T^{miss} > 32$ GeV
$E_T^{miss} > 40$ GeV
1-85
5013A3

Fig. 2



4
3
2
1
0
dσ/dm_T (pb/GeV)
√s =540 GeV
Mq̃ = 110 GeV
Mg̃ = 10 GeV
E_T^miss > 32 GeV
E_T^miss > 40 GeV
60
80
100
120
m_T (GeV)
1-85
5013A2

Fig. 3