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Status and Future prospects for Supersymmetry at the Tevatron

N. Amos
Fermilab, Batavia, Illinois 60510
K. De
University of Michigan, Ann Arbor, Michigan
A. White
University of Florida, Gainesville, Florida 32611
P. Yamin
Brookhaven National Laboratory, Long Island, New York

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ABSTRACT

We investigate the potential for discovery of supersymmetry during the next Tevatron Collider run in the light of new results from LEP and CDF.

I. INTRODUCTION

This work was carried out for subgroups 2.4.4 and 1.4 (Beyond the Standard Model). Important new results from LEP and CDF were discussed in subgroup 1.4 and will be summarized here since they define the conditions under which the present studies were performed. The purpose of the present paper is to explore the potential gluino mass search region for the next Tevatron collider run in the light of the new results from CDF and LEP which already significantly constrain the parameters of the minimal SUSY model.

II. NEW RESULTS

The latest (preliminary) CDF results (ref.1) presented at this workshop show limits on the gluino and squark masses of approximately 150 and 170 GeV respectively. These results were obtained without the possiblity of cascade decays of these particles which are expected to weaken the limits by 10-20% (ref.6). Nevertheless, these new results represent a significant extension of the limits over the earlier CDF results (ref.2) and put important new constraints on the parameters of the minimal supersymmetric extension of the Standard Model.

The other major source of new results reievant to the search for supersymmetry are the LEP experiments. A summary of the latest LEP results is presented in these Proceedings (see section on Beyond the Standard Model). The minimal SUSY model has a small number of parameters that can be varied during model calculations. These parameters are the gluino mass, a supersymmetric Higgs mass (mu) and the ratio (called tan(beta)) of the vacuum expectation values of the two Higgs fields. A plot of the current and future LEP exclusion regions in a gluino mass vs. supersymmetric Higgs mass (mu) shows that almost the entire positive mu sector can already be excluded for gluino masses less than 200 GeV. Since, as this paper will show, the next collider run can probably only search up to 200 GeV, we have chosen a value of mu for our calculations which is negative. (It should be noted that previous calculations (at Snowmass '88 and the Breckenridge workshop '89 (Refs. 3,4) used positive values for mu). For the work presented here, a value of -300. was used for mu. Additionally, our previous calculations used a value for tan(beta) of 1.5. New Higgs sector results from LEP have shown that 1.5 is excluded and we have chosen to use a value of 2.0.

III. OUR STUDIES

We have chosen to use two gluino masses, 150 and 200 GeV. The 150 GeV case corresponds approximately to the latest preliminary CDF limit, while for the 200 GeV case we expect (Ref.1) O(50) gluino pair events before cuts for 25 inverse picobarns of accumulated data - a conservative expectation for the next Tevatron collider run. We therefore used 200 GeV in the hope that a useful number of events would remain after cuts were applied.

In this range of masses many new decay branching ratios start to attain significant values and the direct gluino decay to p pbar and photino drops accordingly. It is therefore important to account correctly for these new decays in our simulation. To this end we took full advantage of the work carried out by a number of people (Ref.3,4) at recent workshops to produce a com-

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plete set of branching ratios for gluinos and squarks of any mass in a form that is directly readable by our standard physics generator ISAJET . During the present workshop further improvements were made, and detailed checking of the entire decay calculation procedure was carried out.

IV. SIMULATION DETAILS

In order to generate specific predictions we have used ISAJET with a simple detector simulation which contains the basic characteristics of the D0 detector at Fermilab:

$$|\eta| < 4.5$$

$$\delta\eta \times \delta\phi = 0.1 \times 0.1$$

$$\text{e.m. resolution} = 20\% / \text{sqrt(E)}$$

$$\text{hadronic resolution} = 50\% / \text{sqrt(E)}$$

In addition we have used a cone jet algorithm with a cone radius of 0.7, and a minimum accepted jet Et of 5 GeV.

Our signal consisted of gluino pairs produced as

$p\,\bar{p} \rightarrow$ gluino gluino + X at 2 TeV

with subsequent decay of the gluinos via cascade decays. Most theoretical arguments prefer m(squark) > m(gluino) and we have set m(squark) = 2m(gluino).

Following experience from our earlier calculations and CDF analysis results, we chose to study two background processes:

- QCD heavy quark production with decay to high Pt charged leptons or neutrinos.

As reported in earlier papers (Refs.3,4) a special version of ISAJET (called ISALEP) was developed which produces an enriched sample of heavy quarks with semi-leptonic decays, while correctly taking account of the associated cross-section. We have used this procedure again in the present work and have generated events in the Pt range 50 - 500 GeV/c.

- Z + jets, with Z $\rightarrow$ neutrinos.

recent work by CDF (Ref.2) has shown that this is the dominant irreducible physics background remaining after cuts (to be described below) are applied. Other related backgrounds such as W $\rightarrow$ e nu from W + jets are successfully removed using specific selection criteria.

V. RESULTS

The results for a gluino mass of 150 GeV, before cuts, of the ISAJET and simple detector simulation runs are shown in Fig. 1.

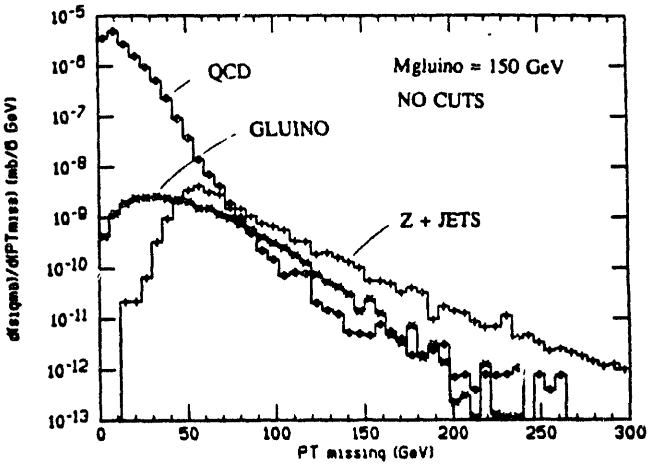

Fig. 1. The missing Et spectrum before cuts from gluino pairs of mass 150 GeV, and QCD and Z-boson backgrounds at the Tevatron

We use the missing Et distribution as our primary parameter. Charcteristically the QCD heavy quark background exceeds the signal out to about 80 GeV, but the main feature is the dominance of the Z + jets background beyond the same point in missing Et. There are various ways that have been used to reduce these backgrounds based on the expected signal and background charcteristics. The number of jets in the signal is generally higher than for the backgrounds, and the Pt of the hardest jet in the event is higher on average for the signal events. In addition the SUSY events tend to have a more spherical topology than the background events. We have combined these expected differences into a series of cuts the effects of which are seen in Fig. 2. It may be seen that the QCD background is significantly lowered with respect to the signal, and that the Z + jets background now also falls below the signal. However, the Z + jets events remain the dominant background after cuts. We have attempted to estimate the signal that would be expected after background subtraction in the region of missing Et between 65 and 120 GeV. the result is 66 events for a luminosity of 4.4 inverse picobarns (corresponding to the luminosity for the CDF data reported in Ref.2). This is to be compared with an independent

CDF estimate with somewhat different cuts and detector simulation of 37 events for the same missing Et interval. We take this as reasonably good agreement considering the differences in the two procedures.

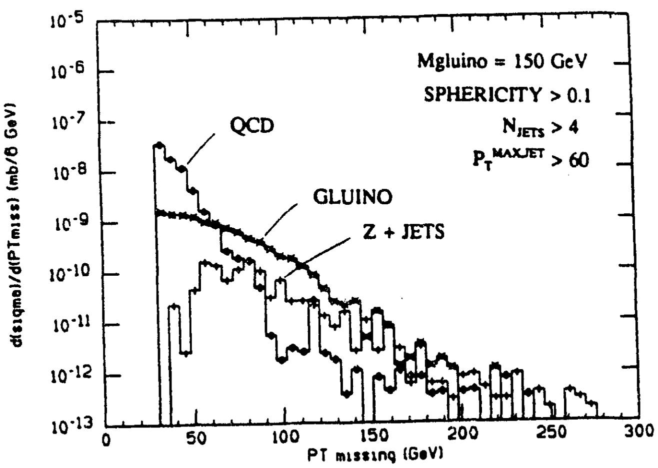

Fig. 2. The missing Et spectrum after cuts from gluino pairs of mass 150 GeV, and QCD and Z-boson backgrounds at the Tevatron

The calculations above were repeated for a gluino mass of 200 GeV and the results, after cuts are shown in Fig. 3.

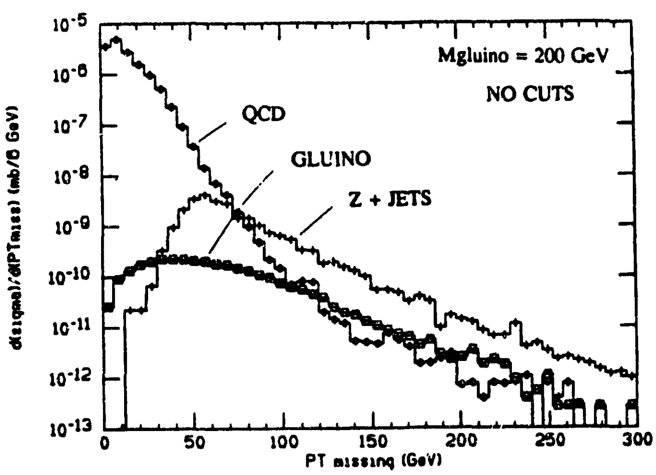

Fig. 3. The missing Et spectrum after cuts from gluino pairs of mass 200 GeV, and QCD and Z-boson backgrounds at the Tevatron

It is seen that over a region where the QCD background is well suppressed (approximately 90 to 170 GeV) the Z + jets background is at the same level as the signal. The estimated excess cross-section after background subtraction is less than 1 pb. which would yield only 25 events before application of efficiency factors. Thus 200 GeV probably represents the practical limit of gluino mass reach with cascade decays to be expected from the next collider run.

VI. CONCLUSIONS

Guided by recent results from LEP and CDF we have simulated the expected signal from the minimal Supersymmetry model for gluino masses of 150 and 200 GeV produced in a simple represenetation of the D0 detector. Also simulated were the QCD heavy quark and Z plus multijets backgrounds. Our results show that we may expect to access a region up to 200 GeV in gluino mass in the next Tevatron collider run.

VII. REFERENCES

[1] H. Baer, A. White et al. in these Proceedings.

[2] see e.g. V. Barnes, Aspen Winter meeting, 1990.

[3] Proceedings of the 1988 Snowmass Workshop on High Energy Physics in the 1990's.

[4] Proceedings of the 1989 Breckenridge Workshop on Physics at Fermilab in the 1990's

[5] H.Baer et al. *Phys. Rev.* **D41**, 906 (1990).

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