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SEARCH FOR SQUARKS AND GLUINOS IN D0

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ABSTRACT

Based on 7.1 pb^{-1} of single interaction event data collected by the DØ Detector at Fermilab during the 1992-1993 $p\bar{p}$ collider run at $\sqrt{s} = 1.8$ TeV, results are presented of a search for supersymmetric partners of the quark and gluon, the squark and gluino, using missing E_T and jets as the signature. Limits are set on the squark and gluino masses in the context of the Minimal Supersymmetric Standard Model including the effect of cascade decays of the squark and gluino.

1. Introduction

A spacetime symmetry, supersymmetry (SUSY) links bosons to fermions, introducing supersymmetric partners (sparticles) to all the SM particles. In combination with Grand Unification Theories, SUSY results in models which successfully unify the U(1), SU(2) and SU(3) couplings at 10^{16} GeV yet remain consistent with the experimental proton lifetime limits. Together with the natural solution offered to the fine-tuning problem, SUSY remains an attractive extension to the Standard Model (SM).

A search was conducted for the SUSY partners of quarks and gluons, the squarks $\tilde{q}$ and gluinos $\tilde{g}$, under the framework of the Minimal Supersymmetric Standard Model (MSSM),[1] a supergravity-GUT inspired SUSY model. In such models, the SUSY parameters can be reduced to five, chosen at the low energy scale to be: the squark and gluino masses, the Higgs mass mixing parameter, μ, the charged Higgs mass, and the ratio of the two vacuum expectation values of Higgs doublets, tanβ. With the addition of the top quark mass, all supersymmetric mass relations, couplings and mixings are calculable. The model enforces conservation of R-parity which implies sparticles be produced in pairs, and that the Lightest Supersymmetric Particle (LSP) must be absolutely stable.

2. Data Set and Event Selection

Data corresponding to a total integrated luminosity of 13.8 ± 1.6 pb^{-1} was collected by the DØ Detector during its 1992-1993 run. DØ is a general purpose detector consisting of a non-magnetic central tracking system and nearly hermetic liquid argon calorimeter surrounded by a toroidal muon spectrometer. A detailed description can

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be found elsewhere.[2] Data for this analysis came in under a set of missing E_T ($\not\!\!E_T$) triggers: one requiring 30-GeV $\not\!\!E_T$ in hardware and 35-GeV in software, plus additional triggers with a softer (20/25-GeV) $\not\!\!E_T$ requirement but either a one or three 20-GeV jet requirement. A preliminary filtering of these triggers produced an initial data set of 9625 events.

To ensure unambiguous missing E_T assignments, we demanded events be identified as having only one primary vertex. An algorithm that combined timing information from a set of counters together with event scalar Et and the number of vertices found by tracking, was used to select single interaction events. Its use effectively reduced our data set to a *single interaction equivalent luminosity* of 7.1 ± 0.9 pb^{-1}, with 3730 surviving events.

A requirement of $\not\!\!E_T > 75$ GeV ensured full efficiency of our triggers and drastically reduced the backgrounds.[3] A total of 107 events survive this cut. The requirement of 3 jets with $E_t > 25$ GeV left 47 events.

In the region of $1.1 < |\eta| < 1.4$ electromagnetic calorimeter coverage is incomplete. Electrons and photons here tend to remain unidentified, artificially enhancing the number of jets found. Rejecting events having their highest Et jet in this region reduces our set to 45 events.

Badly mismeasured jets can produce false $\not\!\!E_T$, but such events usually show a correlation between the jet and $\not\!\!E_T$ directions. Defining $\delta\phi_k$ as the azimuthal angle between jet k, $k = 1,2,3$, and the $\not\!\!E_T$, we require $\sqrt{(\pi - \delta\phi_1)^2 + (\delta\phi_2)^2} > 0.5$, and $(\pi - \delta\phi_k) > 0.1$. A total of 30 events pass the correlation cuts.

Since leptons are not a part of our signal, and in fact, vector boson production in association with jets is a major background, we reject events with identified electrons or muons to reduce background.

Once some final jet clean up cuts are applied to reject clusters formed around noisy calorimeter cells, we end up with 17 candidate events. Scanning displays of this final set reveals one case of a cosmic ray interacting within the calorimeter. When reconstructed as a jet from the nearby interaction vertex, this excess contribution of energy inflated the $\not\!\!E_T$ sufficiently to pass our cut. In addition, two events were found where the the hard scattering vertex from which the jets originate was missed, in favor of a distant soft scatter vertex. When these events are reconstructed with the correct primary vertex, each fails the 75 GeV $\not\!\!E_T$ cut. We reject these anomalies, leaving a final sample of 14 surviving candidate events.

3. Background

To estimate our vector boson associated background, we generated W/Z plus n jet samples using the Monte Carlo (MC) generator VECBOS, interfaced with ISAJET to dress up the final parton states. Events were then passed through a GEANT simulation of the DØ detector, reconstructed and subjected to our selection criteria. From 7.1 pb^{-1} a total of $16.7 \pm 1.7^{+7.0}_{-6.6}$ W/Z events can be expected to make it into our final candidate sample.

To estimate the QCD contribution, we fit the $\not\!\!E_T$ spectrum of a set of single low jet Et triggers, and then determined the fraction of such events that passed a 3-jet requirement, as a function of $\not\!\!E_T$. We predict a total of 0.42 ± 0.37 events in our sample

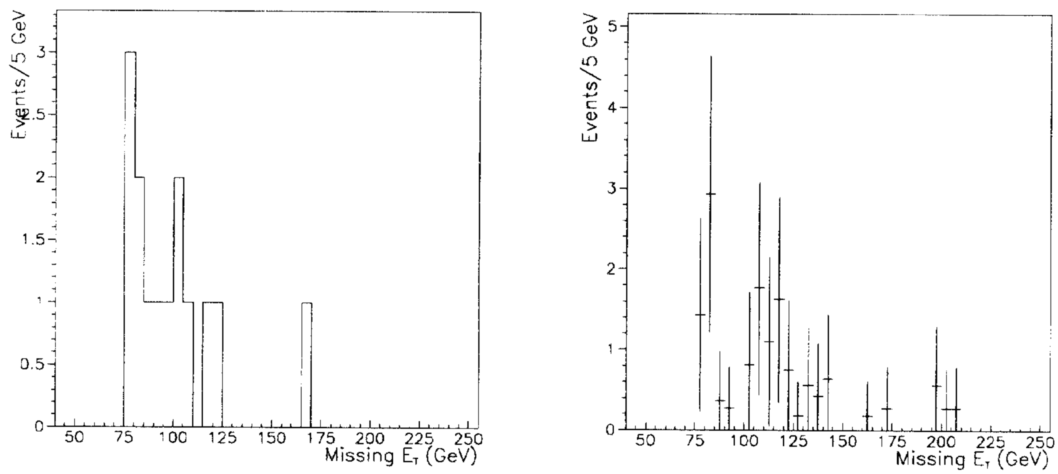

Fig. 1. The missing Et spectrum of the final 14 SUSY candidates (left) and the normalized sum of the MC contributions (right).

from this source.

The combined background total of $17.5 \pm 1.7^{+7.0}_{-6.6}$, is consistent with the 14 observed candidates. The $\not\!\!E_T$ spectrum of these candidates is shown in figure 1. Thus, we observe no excess of events unexplained by the SM.

4. Conclusions

Events were generated for a grid of $\tilde{q}/\tilde{g}$ mass pairs using ISASUSY.[5] The low energy MSSM input parameters for the generator were chosen as: $\tan\beta = 2.0$, $\mu = -250$ GeV/c^2, and $m_{H^+} = 500$ GeV/c^2. We also choose the top quark mass to be 140 GeV/c^2. Branching fractions for the squark and gluino decay modes are only slowly varying functions of these parameters. Signal efficiencies ϵ were determined by running events through a simulation of our trigger, applying event selection cuts, and interpolating between grid points. Typical signal efficiencies were 10-20%.

Observed cross section limits were then computed from the observed signal:

$$\sigma = \frac{((N - n_{QCD})/L) - \sigma_{vis}}{\epsilon}$$

where N is the number of observed candidates, n_{QCD} is the predicted QCD background, and σ_{vis} is the predicted W and Z background cross section. We inflate σ by one overall systematic error interval to produce a conservative limit.

To present our cross section limit as a gluino and squark mass limit we calculated production cross sections using SUSYXS,[5] a standalone form of an ISASUSY subroutine. Inputs included the EHLQ structure function[6] with an α_s and factorization scale set at $\hat{s}$ (variation in the scale from $4\hat{s}$ to $\hat{s}/4$ produced a ± 10 GeV change in mass limits). Figure 2 shows the region in the $m_{\tilde{g}}$-$m_{\tilde{q}}$ plane excluded by our search at both the 90% and 95% confidence levels.

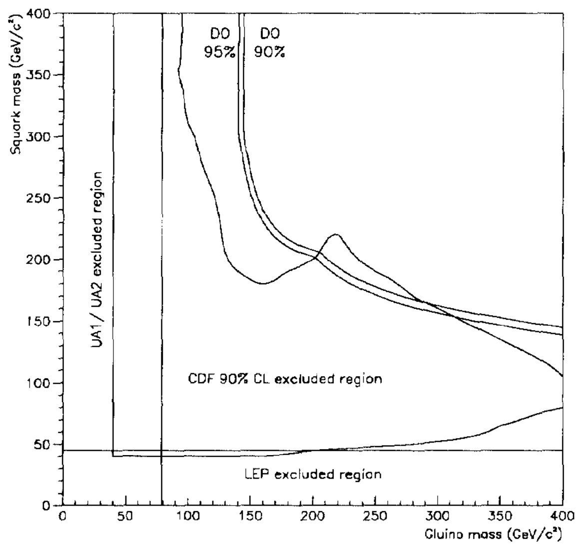

Fig. 2. Current squark and gluino mass limits. Shown are the D0 90% and 95% confidence level exclusion contours, together with the most recent CDF limit.[7]

In the limit of $m_{\tilde{q}} >> m_{\tilde{g}}$, gluino pair production dominates over other processes, and the gluino decay patterns become insensitive to further increase in squark mass. In this region we produce an asymptotic limit of $m_{\tilde{g}} > 146$ GeV/c^2. In the case of equal squark and gluino masses, we produce a limit $m_{\tilde{g}} = m_{\tilde{q}} > 205$ GeV/c^2.

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