Status of SUSY Searches at DØ [a]

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DØ is very active in searches for SUSY. The current status of SUSY searches at DØ will be presented in this paper. Results on searches for squarks and gluinos through multijet plus missing transverse energy signatures will be covered. Also current results on a search for light scalar SUSY top will be presented. Finally, the search for SUSY gauginos through leptonic signatures will be discussed. Preliminary results on excluded mass spaces and cross sections are given.

1 New Phenomena at DØ

DØ is involved with many searches for new phenomena. Non-SUSY searches include searches for leptoquarks and extended gauge bosons such as W' bosons, Z' bosons, and right handed W bosons. We also look for excited quarks, evidence of a composite structure of quarks through a total event energy signature, fourth generation b quarks and leptons, and bosonic Higgs which couples to two photons.

For SUSY we do direct searches for squarks, gluinos, the lightest charged gaugino, and the next lightest neutral gaugino. These particles decay to final states containing quarks, leptons, and for R-parity conserving SUSY theories lightest neutral gauginos. R-parity is the SUSY quantum number (-1 for SUSY particles and +1 for Standard Model (SM) particles) which if conserved provides for a lightest SUSY particle (LSP) that is stable (Cold Dark Matter candidate). Conservation of R-parity also requires that SUSY particles be produced in pairs. Most of the SUSY searches at DØ, including those discussed in this paper, assume R-parity conservation. This report will give an overview of analyses and results for: 1) searches for squarks and gluinos (excluding the scalar top) through hadronic signatures, 2) a separate search in a hadronic channel for scalar tops which could be much lighter than the other squarks due to mass splitting, and 3) searches for gauginos through leptonic signatures. These analyses are based on approximately 13 pb^{-1} of data taken in 1992-1993.

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2 Searches for Squarks and Gluinos

Searches for squarks and gluinos have been done in the hadronic channels. We assume for these analyses that pair produced squarks and gluinos cascade decay through intermediate gauginos to final state quarks, gluons, and LSP's. We also assume that the squark masses are degenerate and that the slepton masses are much heavier than the masses of the squarks. This last assumption is necessary in order to have the branching fractions to hadronic channels less sensitive to the choice of SUSY parameters. The expected signature is multijets and large $\not{E}_T$. There are two search analyses for hadronic signature of squarks and gluinos: a three jet analysis [1] where three jets with $\mathrm{E}_T > 25$ GeV and $\not{E}_T > 75$ Gev are required and a four jet analysis [2] where four jets with $\mathrm{E}_T > 20$ GeV and $\not{E}_T > 65$ GeV are required. In both analyses we require there be only one vertex (single interaction) in the event because $\not{E}_T$ is not well defined for multi-interaction events. We also make jet-$\not{E}_T$ angular correlation cuts and require there be no high E_T leptons, since they are not part of the squark/gluino multijet signature. The single interaction cut reduces the integrated luminosity to an effective 7.4 pb^{-1}. The jet azimuthal correlation cuts are used to remove multijet events where the jet E_T of one or more jets is mismeasured producing large $\not{E}_T$. For example if the E_T of the leading jet is overestimated, the $\not{E}_T$ would point opposite the jet. With these cuts we have 14 candidate events (after three events were eliminated by eye scan) in the three jet search and 5 candidate events in the four jet search.

The backgrounds for squark and gluino signatures are primarily vector boson plus jet events where the lepton from the vector boson is missed, or the leptons are neutrinos from the decay of the Z^0 boson. Other less significant backgrounds come from multijet processes. The total number of vector boson backgrounds is estimated to be 14.2$\pm$4.4 events for the three jet search and 5.2$\pm$2.2 events for the four jet search. The number of multijet background is estimated to be 0.4$\pm$0.4 and 1.6$\pm$0.9 for the three and four jet searches. These estimates are determined from studies of the data and Monte Carlo. The numbers for the three jet search are an update of the number of expected background events previously reported [1].

There is no excess above expected background in either search. Subtracting these backgrounds (the multijet background for the four jet search is not subtracted), the 95% confidence level limit excluded contours given in Fig. 1 are determined. The signal efficiencies for the cuts used in the analyses are determined from ISAJET [3] Monte Carlo with a detailed detector simulation. The selection of SUSY parameters used in the Minimum Supersymmetric Standard Model (MSSM) to generate the signal events are:

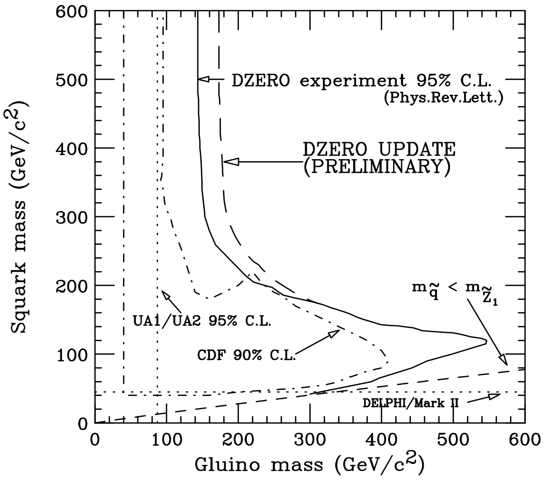

Figure 1: The DØ published and new preliminary updated 95% CL excluded squark versus gluino mass regions.

$\tan\beta = 2.0, \mu = -250GeV, m_{H+} = 500GeV$ with various values of the squark and gluino mass. Given in Fig. 1 are the published results from the three jet analysis and an updated limit derived from the combined three and four jet analyses. The new preliminary limit is 173 GeV/c^2 for the gluino mass for heavy squarks and 229 GeV/c^2 for the mass of the squark and gluino if they are equal.

3 Search for a Scalar Top

The SUSY scalar top is handled separately from the other squarks because the mass of the scalar top (stop) may be lighter than the mass of the other squarks due to mass splitting induced by the heaviness of the top quark and its effect on the Yukawa coupling to the Higgs. The signature for the stop squark depends in the mass of the stop. If the mass of the stop is heavy enough, then $\tilde{t} \rightarrow b\tilde{W}_1$ where $\tilde{W}_1$ denotes the lightest chargino. Otherwise, $\tilde{W}_1$ becomes virtual and the stop can have the three body decays $\tilde{t} \rightarrow bl\tilde{\nu}$ or $\tilde{t} \rightarrow b\nu\tilde{l}$ unless the sleptons, $\tilde{\nu}\tilde{l}$, are heavier that the stop. In this case the stop will primarily decay to an LSP and c quark, and the event signature for pair produced stops is large $\not\!\!E_T$ and acollinear jets. The search for this signature [4] from a low mass stop is reported here.

The analysis uses the following cuts: Single interactions, $\not\!\!E_T > 40$ GeV, two jets with $E_T > 30$ GeV, $90^\circ < \Delta\phi(j_1, j_2) < 165^\circ$, $10^\circ < \Delta\phi(j_1, \not\!\!E_T) < 125^\circ$, $10^\circ < \Delta\phi(j_{3,4}, \not\!\!E_T)$, and no leptons with $E_T > 10$ GeV. The single interaction

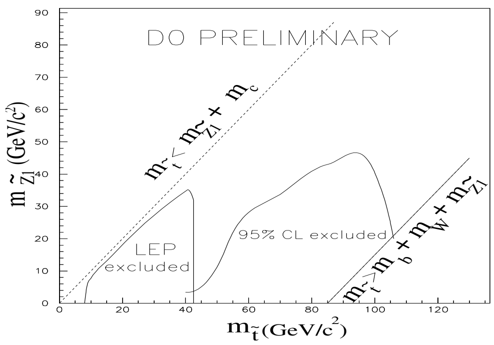

Figure 2: The DØ preliminary 95% CL excluded LSP versus stop mass region.

requirement reduces the integrated luminosity to an effective 7.4 pb^{-1}. The $\Delta\phi$ cuts reduce the backgrounds from QCD dijet events and from false $\not\!\!E_T$ coming from mismeasured jets. After these cuts there are two candidate events remaining.

The sources of background are the same as those for the squark/gluino search. The total number of background from vector bosons is 2.86 ± 0.93. The amount of background from multijet sources is negligible. The total expected background indicates that there is no excess above background for the stop signature. A 95% CL excluded LSP (denoted by $\tilde{Z}_1$) versus stop mass region is given in Fig. 2. The efficiency for the stop signal is determined from ISAJET Monte Carlo. The gap between the DØ limit and the LEP limit is due to the high $\not\!\!E_T$ trigger threshold used in taking the data used in this analysis. In the current 1994-95 Tevatron collider run, we have a trigger utilizing a much lower $\not\!\!E_T$ threshold, and we hope to cover this region.

4 Search for Gauginos

The signature for gaugino pair production that we have investigated [5] is that of three charged leptons (electrons and muons) and $\not\!\!E_T$ from associated pairs of the lightest chargino and the second lightest neutralino (denoted as $\tilde{Z}_2$). These are produced by the decay of an off-shell W boson from a $q\bar{q}$ scattering. We assume the gaugino pairs decay to off-shell W and Z bosons and LSP's with subsequent decay of the W and Z bosons to leptons. Since the signature involves three charged leptons and no jets, it is relatively free of Standard Model backgrounds. The only physics background is W and Z boson associated pair production; this background contributes negligibly. The major background is from Z boson plus fake electron where the sources of the fake electrons are photons, neutral pions, and jets.

The values of MSSM parameters used in this analysis are: μ = -500 GeV, $\tan\beta = 2$, $A_t = 0$ GeV, $m_{H_A} = 500$ GeV, $m_{top} = 170$ GeV, $m_{\tilde{q}} = 1000$ GeV, and $m_{\tilde{l}} = 200$ Gev but $m_{\tilde{\nu}} = 1000$ GeV. The mass of the charginos is varied by changing the mass of the gluino. One should note that the kinematics of the Monte Carlo samples for a given mass are insensitive to the choice of MSSM parameters which result in that mass. However, the parameters effect the branching fraction to leptons. From the decay of the gauginos one expects moderate lepton E_T's and moderate $\not{E}_T$. The third highest E_T lepton has, however, a rather soft E_T spectrum, so it is important that the threshold on the third lowest E_T lepton remain as low as possible in order to preserve the acceptance for the signal.

About 12 pb^{-1} of data is used in this analysis. The triggers require one or two leptons as follows: one muon with $p_T >$ 15 GeV/c, two muons with $p_T >$ 3 GeV/c, one muon with $p_T >$ 5 GeV/c plus one electron with $E_T > 7$ GeV, a single electron with $E_T > 20$ GeV, or two electrons with $E_T > 10$ GeV. Offline, threshold cuts 2 GeV above the trigger are required for the leading leptons. For the remaining leptons in the events the thresholds are set at 5 GeV. We require that the leptons pass quality criteria, be isolated, and have no angular correlations with other leptons that one expects in SM backgrounds. We require a $\not{E}_T$ cut of 10 GeV in the *eee* channel. We also require that there be no more than one electron in the forward detector. This cut reduces the background from photon conversions where the conversion rate in the forward detector approached 40% . With these cuts we see no candidates in any of the four channels containing three muons or electrons. The expected backgrounds range between 0.2 and 0.8 events. The efficiency for the signal is determined by a study of ISAJET Monte Carlo. The resulting no-background subtracted zero event 95% CL limit on the cross section as a function of the lightest chargino mass is given in Fig. 3. This limit is largely independent of the MSSM parameters assumed.

5 Conclusion

DØ has searched for SUSY and has excluded a significant amount of SUSY parameter space. In the near future we expect to have six to seven times the data used in the current analysis. With this amount of data we can expect to be able to probe a much larger portion of the parameter space, excluding it or discovering SUSY!

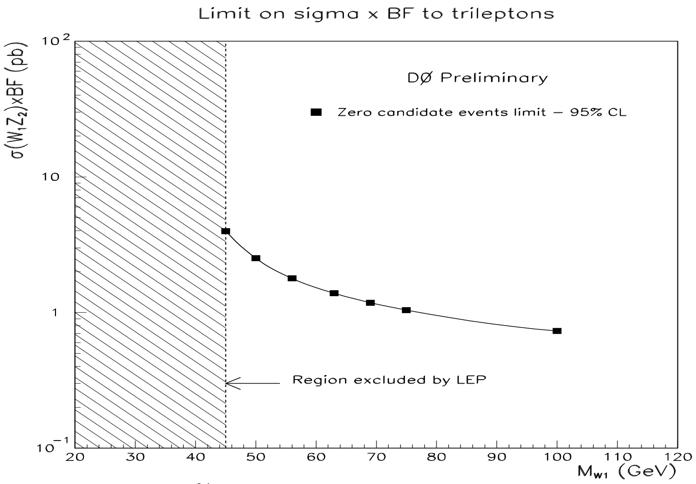

Figure 3: The DØ preliminary 95% CL upper limit on the cross section times the branching fraction to three leptons as a function of the lightest chargino mass.

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