RECENT RESULTS FROM GMSB SUSY SEARCHES AT DØ*

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Using approximately 41 pb$^{-1}$ of $p\bar{p}$ collisions, recorded with the DO detector during the TeVatron Run II, this document describes the search for minimal GMSB SUSY signal (with a neutralino as next-to-lightest supersymmetric particle) in $\gamma\gamma + E_T$ events. Since no deviation from the Standard Model is observed, a 95% confidence level upper limit on the signal cross-section is calculated. This is translated into a lower limit on the neutralino mass, yielding $m(\chi^0_1) > 66$ GeV in the context of the Snowmass GMSB model line 1.

This article describes the search for supersymmetry (SUSY) with gauge-mediated supersymmetry breaking (GMSB), or — more generally — SUSY with a light gravitino in the framework of the minimal supersymmetric Standard Model. Supersymmetric models with a light gravitino ($\tilde{G}$) are characterized by a supersymmetry breaking scale of the order of 100 TeV and a gravitino as the lightest supersymmetric particle. In these models, the phenomenology is usually driven by the nature of the next-to-lightest SUSY particle (NLSP) and by the small coupling to $\tilde{G}$. If the NLSP, which is assumed to be the lightest neutralino ($\chi^0_1$), has a non-vanishing 'Bino' component, it is unstable and decays into a photon and a gravitino: $\chi^0_1 \rightarrow \gamma \tilde{G}$. Since the gravitino escapes detection, large missing transverse energy ($E_T$) is expected.

Search for Supersymmetry in $\gamma\gamma + E_T$ Events

Around 41 pb$^{-1}$ of $p\bar{p}$ collisions at a center-of-mass energy of $\sqrt{s} = 1.96$ TeV, recorded with the DØ detector between September 2002 and January 2003, are examined for evidence of GMSB SUSY in $\gamma\gamma + E_T$ events. The data sample was taken by a combination of triggers requiring one or more highly-energetic electromagnetic clusters in the DØ calorimeter.

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Photons are reconstructed from energy depositions in the calorimeters. In order to minimize the background from hadronic jets and noise in the calorimeter, the electromagnetic clusters must have a shower shape consistent with that of a photon and only little energy is allowed to be detected in the vicinity of the cluster. The central tracking system must not have a reconstructed track pointing to the electromagnetic cluster in order to reject electrons. Only photons with a transverse energy of $E_T > 20\,\text{GeV}$ are considered. The precise calibration of the energy of electromagnetic showers is achieved using $Z \rightarrow ee$ events. The missing transverse energy is calculated from the jet and electromagnetic scale-corrected sum over all calorimeter cells.

All background sources of events with two photons and missing transverse energy can be divided into two main groups: The first group, where the missing transverse energy is due to mis-measurement, comprises QCD events with direct photons or hadronic jets, which have been mis-identified as photons, and Drell-Yan $Z + X \rightarrow ee + X$ processes with both electrons mis-identified as photons. The second group are background processes with true missing transverse energy due to neutrinos which escape detection. This sample is dominated by $W\gamma \rightarrow e\nu\gamma$ events. Additional contributions to this group come from $Wj \rightarrow e\nu^\ast\gamma$ events (where a hadronic jet is mis-identified as a photon), $Z \rightarrow \tau\tau \rightarrow ee + X$ processes, and $t\bar{t}$ and di-boson production, where the tracks of the final state electrons are not reconstructed, leading to fake photons.

A QCD-enriched event sample is obtained by inverting the shower-shape criterion for at least one of the two energy clusters. For these events, the $E_T$-resolution is expected to be very similar for events with real photons and with jets faking photons, since a jet, that mimics a photon, fragments into one or more neutral pions. The QCD sample is normalized to the diphoton sample at small transverse energies, $E_T < 20\,\text{GeV}$. Figure 1 shows the $E_T$-distribution for the $\gamma\gamma$ sample and the QCD background.

All Standard-Model backgrounds with true $E_T$ involve electrons and not photons. This contribution is measured with an electron-photon sample for which the QCD portion is subtracted in the same way as described above. The normalization of the electron-photon sample is determined from the measured probabilities of identifying an electron as an electron (photon). Table 1 shows the numbers of remaining events for various cuts on the missing transverse energy.

The Monte-Carlo events for the SUSY signal are processed through a full detector simulation and reconstructed the same way as the data.
Figure 1. Missing transverse energy distribution of $\gamma\gamma$ events and the QCD background. The QCD background is normalized to the $\gamma\gamma$ sample at $E_T < 20$ GeV.

Table 1. Number of $\gamma\gamma$ and background events for various cuts on $E_T$.

| $E_T > 25$ GeV | $E_T > 30$ GeV | $E_T > 35$ GeV |
|----------------|----------------|----------------|
| $\gamma\gamma$ events | 3 | 1 | 0 |
| QCD (with wrong $E_T$) | 6.0 ± 0.8 | 2.5 ± 0.5 | 1.6 ± 0.4 |
| $e + \nu + \gamma/j$ events | 0.6 ± 0.4 | 0.2 ± 0.2 | 0.0 ± 0.2 |

The SUSY signal has been generated for various points on the minimal-GMSB Snowmass slope with a neutralino NLSP. This model line has one free parameter, $\Lambda$, which determines the scale of SUSY breaking. The minimal GMSB parameters of this model line are the messenger mass scale $M = 2\Lambda$, the number of messenger fields $N_5 = 1$, the ratio of Higgs vacuum expectation values $\tan \beta = 15$, and the sign of the Higgsino mass term $\mu > 0$.

While each signal point has its own optimum cut on $E_T$, a common cut at $E_T > 30$ GeV is chosen. The signal acceptance varies between 3% and 17% for the mass points between $\Lambda = 35$ TeV and $\Lambda = 60$ TeV, respectively.

Conclusion

Since no excess of $\gamma\gamma$ events is observed, 95% confidence level (C.L.) upper cross-section limits are calculated and compared to the theoretical predictions (see Figure 2). The 95% C.L. lower limit on the parameter $\Lambda$ is 51 TeV, corresponding to lightest neutralino and chargino masses of 66 GeV.
and 116 GeV, respectively. The Run I limits in this channel using similar models were $m(\chi_1^0) > 75$ GeV in DØ and $m(\chi_1^0) > 65$ GeV in CDF.

The analysis described in this document has been updated by the DØ collaboration for the summer conferences in 2003, using data recorded between August 2002 and June 2003. This latest DØ result in the $\gamma\gamma + E_T$ channel, which is based on an integrated luminosity of $(128 \pm 13)$ pb$^{-1}$, yields a 95 % C.L. lower limit of $M(\chi_1^0) > 80$ GeV on the lightest-neutralino mass. With more and more data being collected at DØ Run II and with additional complementary analyses (see for instance reference [4]), the DØ collaboration will be able to probe for SUSY signal in the light of GMSB from various angles and it can be expected that the sensitivity reaches far into regions of the SUSY parameter space which have not been excluded yet.

References
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