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Searches for GMSB, AMSB and Split SUSY with the DØ Detector

Yuri Gershtein for the DØ Collaboration

Department of Physics, Florida State University, Tallahassee, FL 32303-4350

Abstract. We report on the recent searches for supersymmetry with gauge-mediated or anomaly-mediated breaking, as well as the search for split supersymmetry.

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INTRODUCTION

Models with supersymmetry (SUSY) have a lot of theoretical appeal. They allow for natural cancellation of quantum corrections to the mass of the Higgs boson, unification of the gauge forces, and, due to their connection to the string theory, provide a hope of eventual incorporation of gravity.

The most dramatic phenomenological consequence of SUSY is the existence of a new particle (superpartner) for every standard model (SM) particle. The superpartners of bosons are fermions and vice versa. None of the superpartners have yet been observed. One of the possible explanations is that the SUSY is a broken symmetry and the superpartners' masses are too large to be observed at the currently available energies. However, the mass limits are getting so high that some of the attractive SUSY features, like absence of fine-tuning of Higgs boson mass, seem to disappear.

Another possibility is that although superpartners are relatively light, their decays are much different from what most studied models like mSUGRA predicts. In this talk we will report on searches for SUSY with DØ experiment in somewhat unusual final states.

SPLIT SUPERSYMMETRY

Split SUSY is a relatively new variant of supersymmetry, in which the supersymmetric scalars are heavy (possibly GUT-scale) compared to the (SUSY) fermions [1]. Due to the scalars' high masses, the gluino decays are suppressed, and the gluino lifetime is determined by this SUSY-scalar mass scale (M_{SUSY}). The gluinos have time to hadronize into "R-hadrons", colorless bound states of a gluino and other quarks or gluons. At the Tevatron, R-hadrons could be pair produced through strong interactions and could live long enough (>10 ns) to reach and come to rest in the DØ calorimeters. Most of these stopped gluinos would later decay into a jet (from a gluon) and a neutralino (LSP). When the decay occurs during a bunch-crossing with very little other high-E_T activity, the signal signature is a largely empty event with a single high-E_T jet and thus large

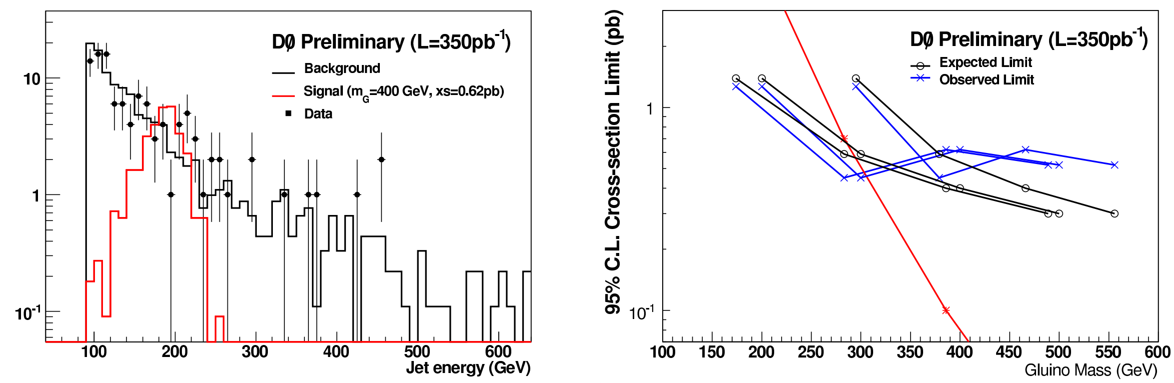

FIGURE 1. Left: a comparison of the data (black points) to the expected background (black histogram); simulated signal for $m_G = 400$ GeV and $m_{LSP} = 90$GeV at the exclusion limit of 0.7 pb is shown in red. Right: the 95 % C.L. upper limits expected (black, open circles) and observed (blue, crosses) on the cross-section of stopped gluinos decaying into a jet plus LSP, for three assumed LSP masses, 50, 90 and 200 GeV; the theoretical cross-section (red, stars) is also shown.

missing E_T.

The main experimental challenge here is to estimate and remove backgrounds from cosmic and beam-halo muons, in case when they emit a hard bremsstrahlung photon in the calorimeter. Fortunately, these backgrounds have two distinct characteristics: first, the shower from a photon is significantly narrower than response to a hadronic jet, and second, both these backgrounds involve muons that are detected in the DØ muons system. By selecting events with wide showers, no reconstructed primary vertex and without muon activity, we can get rid of most of the background. Since the size of the shower and efficiency of muon detection are uncorrelated, it is possible to estimate remaining background. The details can be found in [2].

Figure 1 shows the observed jet energy spectrum, as well as the expected signal and background contributions. Since the data is consistent with the background, we can set a limit on split SUSY parameters, also shown in figure 1.

CHARGED MASSIVE STABLE PARTICLES

Another interesting SUSY manifestation can be existence of long-lived charged massive particles (CMP). The lightest chargino can have a large lifetime if its mass difference with lightest neutralino is very small. Such is the case for models with anomaly-mediated SUSY breaking (AMSB) or in models without gaugino mass invariance [3]. Also, in models with gauge-mediated SUSY breaking, staus may be long-lived [4, 5].

The detector signature of a stable charged particle is quite dramatic. These particles will lose energy principally by ionization and will be able to traverse the entire detector, registering in the muon detectors. However, since these particles will be fairly massive (more than about 100 GeV), they will be traveling substantially slower than muons produced in beam collisions. The analysis looks for pairs of such particles by looking at the time of flight of muon candidates, which are measured with the scintillation counters.

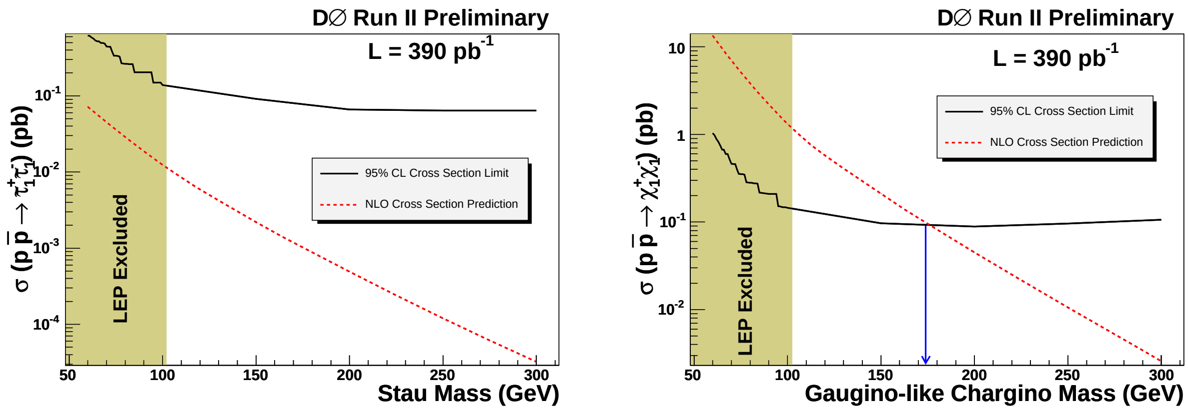

FIGURE 2. 95% C.L. cross-section limit (solid line) and NLO production cross-section (dashed line) vs. stau mass (left) or chargino mass (right).

The counter resolution varies from 2 to 4 ns, and they are situated from 1.5 to 5 meters from the interaction point, and muon candidates are required to have hits in two out of three layers of counters.

The main background is Drell-Yan where timing of both muons has been mismeasured. The time response to real muons can be reliably measured with data. For each muon, using all available timing information, a speed significance is constructed such that it is zero for particles moving with the speed of light, and has positive values for slower particles. Events with two muons with positive speed significance were selected, and a two-dimensional cut was made on the product of muon speed significances and invariant mass of the muon candidates (for details, see [6]). The observed number of events passing the cuts is consistent with expectations. We therefore set limits on the masses of gauginos and staus for a representative models which are shown in figure 2.

TWO PHOTONS AND MISSING ENERGY

In models with gauge-mediated supersymmetry breaking (GMSB) [4, 5] it is achieved by the introduction of new chiral supermultiplets, called messengers, which couple to the ultimate source of supersymmetry breaking, and also to the SUSY particles. At colliders, assuming R-parity conservation [7], superpartners are produced in pairs, and then each decays to the next-to-lightest SUSY particle (NLSP), which can be either a neutralino or a slepton. In the former case, which is considered in this note, the NLSP decays into a photon and a gravitino (the lightest superpartner in GMSB SUSY models, with mass less than $\tilde{1}$ keV) which is stable and escapes detection, creating imbalance of the transverse energy in the event. Therefore, the signal we are looking for is a final state with two energetic photons and large missing transverse energy ($\not{E}_T$).

Physics backgrounds to di-photons plus $\not{E}_T$ are small, and are neglected here. The instrumental backgrounds can be divided into two categories: the ones with and without true $\not{E}_T$. The latter are comprised mostly of QCD processes, with either real photons or jets mis-identified as photons. The former ones always involve electron-photon

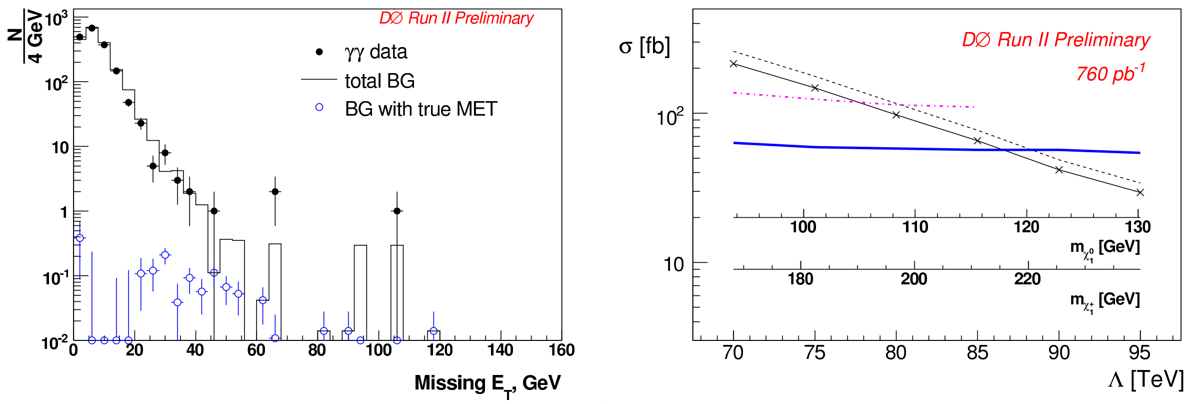

FIGURE 3. Left:$\not{E}_T$ distribution in the $\gamma\gamma$ sample (black filled points). Black histogram represents the total background, red dashed histogram is background from processes without true $\not{E}_T$ and blue open circles show the background from processes with true $\not{E}_T$. Right: 95% C.L. limit on GMSB SUSY Snowmass Slope obtained in this analysis (thick blue line) and in the previous DØ result (dot-dashed purple line). SUSY LO (NLO) cross-section is shown in black solid (dashed) line.

misidentification. The only significant sources of this background are $W(\rightarrow e\nu)\gamma$ and $W(\rightarrow e\nu)\,jet$ production, where the electron, and in the latter case, the jet are misidentified as photons. Both backgrounds were estimated using the data (see [8] for details)

Figure 3 shows the $\not{E}_T$ distribution in the di-photon data sample, as well as the background estimate. There are 4 events with $\not{E}_T$ above 45 GeV, while the expectation is 2.1 ± 0.7. We use this to set an upper limit on the Snowmass Slope SPS8 model [9]. The lightest chargino mass limit is 220 GeV, which significantly higher than previous CDF and DØ results [10].

REFERENCES

1. N. Arkani-Hamed, S. Dimopoulos, G.F. Giudice and A. Romanino, Nucl. Phys. B **709** 3 (2005)
2. DØ Collaboation, DØ Note 5058-CONF
3. J. Gunion and S. Mrenna, Phys. Rev. D **62**, 015002 (2000)
   C. Chen, M. Drees, J. Gunion, Phys. Rev. D **55**, 330 (1997)
4. P. Fayet, Phys. Rev. Lett. B **70**, 461 (1977); *ibid*. **86**, 272 (1979); *ibid*. **175**, 471 (1986)
5. M.Dine and A.E. Nelson, Phys. Rev. D **48**, 1277 (1993); H. Baer, M. Brhlik, C.H. Chen and X. Tata, Phys. Rev. D **55**, 4463 (1997); S. Dimopoulos, S. Thomas and J.D. Wells, Nucl. Phys. B **488**, 39 (1997); J.R. Ellis, J.L. Lopez and D.V. Nanopoulos, Phys. Lett. B **394**, 354 (1997); J.Feng and T. Moroi, Phys. Rev. D **58**, 035001 (1998)
6. DØ Collaboation, DØ Note 4746-CONF
7. G.R. Farrar and P. Fayet, Phys. Lett. B**79** (1978) 442
8. DØ Collaboation, DØ Note 5020-CONF
9. S. P. Martin, http://zippy.physics.niu.edu/modellineE.html;
   S. P. Martin, S. Moretti, J. M. Qian and G. W. Wilson, “Direct Investigations of Supersymmetry: Subgroup summary report,” in *Proceedings of the APS/DPF/DPB Summer Study on the Future of Particle Physics (Snowmass 2001),* edited by N. Graf, eConf **C010630**, p. 346 (2001);
10. Combination of CDF and D0 Limits on a Gauge Mediated SUSY Model Using Diphoton and Missing Transverse Energy Channel. V. Buescher *et. al.* hep-ex/0504004.