

# Search for Chargino-Neutralino Associated Production via Tripletonic Final States with the DØ Detector

The DØ Collaboration<sup>1</sup>  
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Preliminary results from a search for the production of an associated lightest chargino,  $\tilde{W}_1$ , and second lightest neutralino,  $\tilde{Z}_2$ , pair with the DØ detector at Fermilab's  $p\bar{p}$  collider with  $\sqrt{s} = 1.8$  TeV are presented. Based on approximately 85  $pb^{-1}$  of data collected during the 1993-1995 Tevatron Runs we set a 95% C.L. upper limit on the chargino-neutralino cross section times branching fraction to any tripletonic final state ranging from 0.91  $pb$  to 0.19  $pb$  for wino masses ranging from 45 GeV/ $c^2$  to 96 GeV/ $c^2$ .

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## I. INTRODUCTION

Supersymmetry (SUSY), obtained by introducing spinor generators to supplement the usual (bosonic) generators of the Poincaré group, has a consequence of doubling the particle spectrum, *i.e.*, there is a supersymmetric particle (sparticle) for every known particle. However, in spite of this disadvantage, SUSY provides a viable solution to a number of theoretical problems such as the hierarchy fine tuning problem, unification of the couplings, and the need for a dark matter candidate.

In this search we are working with the so called Minimal Supersymmetric Standard Model (MSSM) frame work. We assume that R-parity is conserved, implying that sparticles are produced in pairs and there must be a lightest supersymmetric particle (LSP) which is stable. We assume that the lightest neutralino,  $\tilde{Z}_1$ , is the LSP.

One of the established techniques [1] of searching for SUSY at the Fermilab Tevatron is through the trilepton signature from decays of the lightest chargino,  $\tilde{W}_1$ , and second lightest neutralino,  $\tilde{Z}_2$ , produced in association. Leptons considered in this analysis are only electron and muon, therefore we have four channels:  $eee$ ,  $ee\mu$ ,  $e\mu\mu$ , and  $\mu\mu\mu$ .

This report will present an analysis similar to our recent publication [2] but with a different set of data, triggers and offline cuts. The data used in this analysis were collected with the DØ detector at the Fermilab Tevatron  $p\bar{p}$  collider operating at a center of mass

energy of 1.8 TeV during the 1993-1995 Tevatron Run.

## II. ANALYSIS

The DØ detector is a general purpose detector consisting of a central tracking system and a nearly hermetic uranium-liquid argon calorimeter surrounded by a toroidal muon spectrometer. The DØ detector and data collection system are described in detail elsewhere [3].

Combinations of single lepton and dilepton triggers were used for the four final states. These triggers included: a single muon with  $p_T^\mu > 15$  GeV/c; two muons with  $p_T^\mu > 3$  GeV/c; one muon with  $p_T^\mu > 8$  GeV/c plus one electromagnetic cluster with  $E_T^e > 7$  GeV; one electromagnetic cluster with  $E_T^e > 20$  GeV and missing transverse energy,  $\cancel{E}_T > 15$  GeV; and two electromagnetic clusters with  $E_T^{e(1)} > 12$  GeV,  $E_T^{e(2)} > 7$  GeV, and  $\cancel{E}_T > 7$  GeV. The integrated luminosities from each channel are shown in Table I.

To reduce trigger bias, offline we required the first or first two leading leptons (depending on the triggers) to have  $p_T^\mu$  or  $E_T^e$  2 GeV above threshold. We further required that any lepton in the event must have  $E_T^e > 5$  GeV or  $p_T^\mu > 5$  GeV/c. Electrons and muons in these events were then required to pass the following quality cuts.

Electrons were required to have transverse and longitudinal shower profiles consistent with an electron shower [4], to have a cluster track consistent with the passage of a charged particle, to have a track ionization ( $dE/dx$ ) consistent with a single charged particle, and to have an electromagnetic isolation  $\mathcal{I} < 0.15$ , where  $\mathcal{I} = [E_{tot} - E_{EM}]/E_{EM}$ ,  $E_{tot}$  is the total calorimeter cluster energy inside a cone of radius  $\mathcal{R} = 0.4$ , and  $E_{EM}$  is the electromagnetic energy inside a cone of  $\mathcal{R} = 0.2$ .  $\mathcal{R}$  is defined as  $\sqrt{\Delta\eta^2 + \Delta\phi^2}$ , where  $\eta$  and  $\phi$  are the pseudo rapidity and azimuthal angle, respectively.

Muons were required to have a separation from any jet of at least  $\mathcal{R} = 0.5$ , to be within  $|\eta^\mu| < 1.0$ , to be aligned with minimum ionization energy deposition in at least 50% of all calorimeter layers and in at least 60% of the hadronic calorimeter layers, and to have impact parameters in the  $rz$  (bend) and  $xy$  (non-bend) views consistent with the muon having been produced at the primary event vertex. To reduce cosmic ray background, muons were required to be in time with the beam crossing, and any muon pair back-to-back within 0.1 rad was rejected. We rejected muon events in which the muon was either parallel or anti-parallel to the  $\cancel{E}_T$  within 0.1 rad.

In addition to those requirements, we applied specific cuts on every channel. In the  $eee$  channel, to reduce the  $Z^0/\gamma$  + fake electron background, we rejected events having an electron pair with invariant mass between 81 and 101 GeV/c<sup>2</sup>, or having  $\cancel{E}_T < 15$  GeV, or having the first two leading electrons back-to-back within 0.2 rad. In the  $ee\mu$  channel, we rejected events having the first leading electron and muon back-to-back within 0.2 rad to reduce  $Z^0 \rightarrow \tau\tau$  + fake electron background. In the  $e\mu\mu$  channel we rejected events having two leading muons parallel within 0.2 rad to reject  $J/\psi$ . (The back-to-back cut on muon pairs mentioned above also reduced  $Z^0 \rightarrow \mu\mu$  + fake electron background in this channel). Finally, in the  $\mu\mu\mu$  channel, we required  $\cancel{E}_T > 10$  GeV and rejected events having any muon pair with invariant mass less than 5 GeV/c<sup>2</sup> to reject heavy flavor production and  $J/\psi$ , respectively. Applying all requirements described above, we found no events passed in any channel.

To analyze the  $\widetilde{W}_1\text{-}\widetilde{Z}_2$  signal characteristics, we generated Monte Carlo (MC) simulated events for each channel and for various  $\widetilde{W}_1$  masses,  $M_{\widetilde{W}_1}$ , ranging from 45 to 96 GeV/c<sup>2</sup> using ISAJET 7.13 [5], which incorporated the latest implementation of ISASUSY [6]. These MC

TABLE 1. Candidate and predicted background in each final state

| Channel                                        | $eee$           | $ee\mu$         | $e\mu\mu$       | $\mu\mu\mu$     |
|------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| $\int \mathcal{L} dt \text{ (pb}^{-1}\text{)}$ | 85.0            | 85.0            | 80.2            | 67.4            |
| Candidates                                     | 0               | 0               | 0               | 0               |
| Background                                     | $0.34 \pm 0.07$ | $0.65 \pm 0.36$ | $0.16 \pm 0.04$ | $0.20 \pm 0.04$ |

events followed the mass relation common to many supergravity (SUGRA) inspired SUSY models:  $M_{\tilde{W}_1} \approx M_{\tilde{Z}_2} \approx 2M_{\tilde{Z}_1}$  [7]. These events then were processed with a full simulation of the DØ detector based on the GEANT [8] program.

Detection efficiencies were determined using a combination of data and MC simulations. Kinematic and geometric acceptances were determined from MC simulations, trigger efficiencies were determined from MC simulations and data, while particle identification efficiencies were determined from data. Since there exist mass correlations among  $\tilde{W}_1$ ,  $\tilde{Z}_2$ , and  $\tilde{Z}_1$ , efficiencies can be parametrized as a function of  $M_{\tilde{W}_1}$ . Total efficiencies range from 0.5 to 9.7%, Fig. 1 shows trigger+kinematic and total efficiencies for each final state.

Backgrounds were estimated from both data and MC simulations. Standard Model processes having three or more isolated charged leptons are expected to be small compared to instrumental backgrounds. The dominant background sources are primarily  $Z^0$  plus fake electron and heavy flavor production. The total background for each final state is shown in Table I.

### III. RESULTS AND CONCLUSION

To interpret the null search result, we present a 95% confidence level upper limit on the cross section for producing  $\tilde{W}_1$ - $\tilde{Z}_2$  pairs times branching fraction into any one of the trileptonic final states. We combined the results from the four channels in the calculation of the limit, assuming that all four channel have the same branching fraction due to lepton universality. The uncertainty in this calculation (ranging from 9.6% to 24%) includes statistical and systematic uncertainties in the overall detection efficiencies (including systematic errors in the energy scale corrections) and the uncertainty in the luminosity (5%).

We used a Bayesian approach [9], assuming a flat prior probability distribution for the signal cross section and gaussian distributions for statistical and systematic errors, to construct the limit. Fig. 2 shows the resulting limit (labelled Run 1B). For comparison we also show, discussed in Ref. [10], two theoretical curves corresponding to the light slepton scenario (the upper dashed curve) and the heavy slepton scenario (the lower dashed curve). In the light slepton scenario,  $\tilde{W}_1$  and  $\tilde{Z}_2$  will decay mostly into sleptons which will subsequently decay into leptons plus  $\tilde{Z}_1$ 's. This enhances the trilepton production significantly. Also shown in Fig. 2 are our published result (labelled Run 1A), and the current and published results combined (labelled Run 1A + 1B).

In conclusion, we find no candidate events consistent with  $\tilde{W}_1$ - $\tilde{Z}_2$  associated production and subsequent decay into trileptonic final states in 85  $\text{pb}^{-1}$  of data. This result is consistent with the Standard Model prediction and leads to upper limits on  $\sigma(\tilde{W}_1\tilde{Z}_2) * BF(\tilde{W}_1 \rightarrow l\bar{\nu}\tilde{Z}_1) * BF(\tilde{Z}_2 \rightarrow l\bar{l}\tilde{Z}_1)$  ranging from 0.91  $\text{pb}$  for  $M_{\tilde{W}_1} = 45 \text{ GeV}/c^2$  to

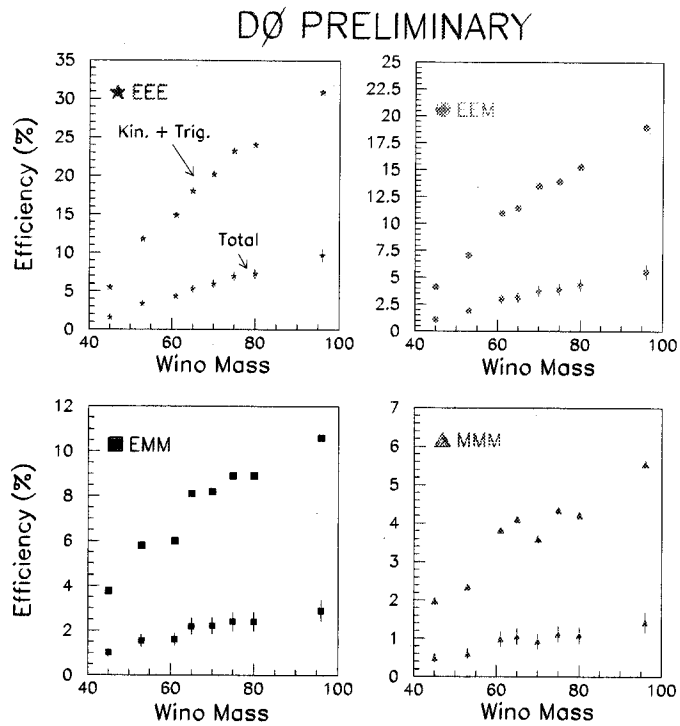


FIG. 1. Signal detection efficiencies for every final state as a function of  $\widetilde{W}_1$  mass

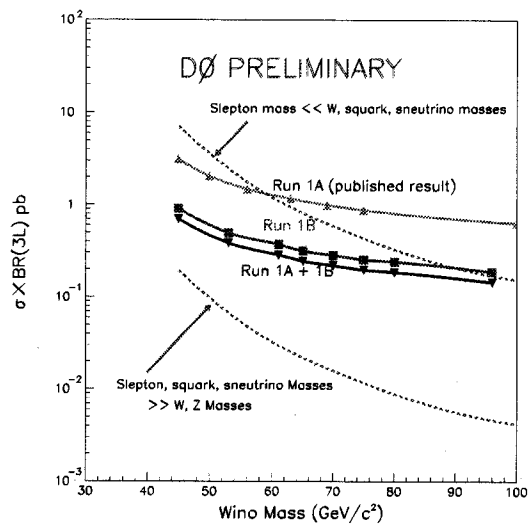


FIG. 2.  $\widetilde{W}_1$ - $\widetilde{Z}_2$  cross section times branching fraction into any trilepton final state as a function of  $\widetilde{W}_1$  mass

0.19 pb for  $M_{\tilde{W}_1} = 96 \text{ GeV}/c^2$ .

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### REFERENCES

- \* Visitor from IHEP, Beijing, China.
- † Visitor from Univ. San Francisco de Quito, Ecuador.
- 1. P. Nath and R. Arnowitt, *Mod. Phys. Lett.* **A2**, 331 (1987); R. Barbieri *et al.*, *Nucl. Phys.* **B367**, 28 (1991); H. Baer and X. Tata, *Phys. Rev.* **D47**, 2739 (1993).
- 2. DØ Collaboration, S. Abachi *et al.*, *Phys. Rev. Lett.* **76**, 2228 (1996).
- 3. DØ Collaboration, S. Abachi *et al.*, *Nucl. Instrum. Methods Phys. Res., Sect. A* **338**, 185 (1994), and references therein.
- 4. DØ Collaboration, M. Narain *et al.*, in *Proceedings of the APS/DPF Conference, Fermilab 1992*, edited by R. Raja and J. Yoh (World Scientific, Singapore, 1992); R. Englemann *et al.*, *Nucl. Instrum. Methods Phys. Res., Sect. A* **216**, 45 (1983).
- 5. F.E. Paige and S. D. Protopopescu, in *Supercollider Physics*, p. 41, ed. D. Soper (World Scientific, 1986).
- 6. H. Baer *et al.*, in *Proceedings of the Workshop on Physics at the Current Accelerators and Supercolliders*, p. 703, ed. J. Hewett *et al.* (Argonne National Laboratory, 1993).
- 7. See, e.g., P. Nath and R. Arnowitt, *Phys. Lett.* **B289**, 368 (1992); H. Baer *et al.*, *Phys. Rev.* **D50**, 4508 (1994); J. Lopez, D. Nanopoulos, and A. Zichichi, *Int. J. Mod. Phys.* **A10**, 4241 (1995).
- 8. F. Carminati *et al.*, CERN Program Library Long Writeup W5013 (1993) (unpublished), version 3.15.
- 9. Particle Data Group, L. Montanet *et al.*, *Phys. Rev.* **D50**, 1173 (1994).
- 10. J. Lopez *et al.*, *Phys. Rev.* **D48**, 2062 (1993).

