SEARCH FOR SUPERSYMMETRIC $\widetilde{W}_1$ AND $\widetilde{Z}_2$ STATES USING THE DØ DETECTOR

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ABSTRACT

The status of a search for the pair production of the lightest chargino and second lightest neutralino states of the minimal supersymmetric model is presented. We have searched for four tri-lepton final states: eee, $ee\mu$, $e\mu\mu$, and $\mu\mu\mu$, all with missing transverse energy.

1. Introduction

The search for signals from Supersymmetry[1] at hadron colliders has largely been centered on the search for squark and gluino production, usually through events with large missing transverse energy ($\not\!\!E_t$). A promising alternative at the Tevatron is the search for production of the lightest chargino ($\widetilde{W}_1$) and next-to-lightest neutralino ($\widetilde{Z}_2$), with the assumptions that R-parity is conserved and the lightest neutralino ($\widetilde{Z}_1$) is the lightest supersymmetric particle (LSP). Although the mass limit established by LEP experiments,[2] $M_{\widetilde{W}_1} > 45$ GeV/c^2, excludes the on-shell process $\overline{p}p \to W^\pm \to \widetilde{W}_1 + \widetilde{Z}_2$, the off-shell process $W^\pm \to \widetilde{W}_1\widetilde{Z}_2$ can have a sizeable rate due to large $W\widetilde{W}_1\widetilde{Z}_2$ coupling.[3] The cross section for $\widetilde{W}_1\widetilde{Z}_2$ production[4] ranges from $\sim 10^3$ pb to ~ 1 pb for $M_{\widetilde{W}_1}$ between 40 and 100 GeV/c^2. The final states of the $\widetilde{W}_1$ and $\widetilde{Z}_2$ are similar to the final states of the $W^\pm$ and Z^0 with the addition of $\not\!\!E_t$ from the LSP's. The six possible event signatures are:

2 jets $+\not\!\!E_t$	4 jets $+\not\!\!E_t$
1 lepton $+\not\!\!E_t$	1 lepton + 2 jets $+\not\!\!E_t$
2 leptons + 2 jets $+\not\!\!E_t$	3 leptons $+\not\!\!E_t$

The tri-lepton channel is the cleanest and most free of Standard Model backgrounds. The branching fraction to three leptons, however, strongly depends on the masses of the sleptons, sneutrinos, and squarks. In certain supergravity inspired models,[5] the branching fraction to tri-lepton states may be enhanced, making this a particularly attractive

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search channel. In these models, mass relations between the sparticle states lead to $M_{\widetilde{W}_1} \sim \frac{1}{4}M_{\tilde{g}} - \frac{1}{3}M_{\tilde{g}}$. Thus a search for $\widetilde{W}_1$ of mass up to 100 GeV/c^2 is comparable in reach (in some subset of models) to searches for gluinos of 300 to 400 GeV/c^2.

We have searched for four final states: $eee + \not\!\!E_t$, $ee\mu + \not\!\!E_t$, $e\mu\mu + \not\!\!E_t$, and $\mu\mu\mu + \not\!\!E_t$. Studies using ISAJET[6] show that the leptons are generally centrally produced and that the lepton with the lowest p_t is fairly soft. Figure 1 shows the distribution of p_t, η, and $\not\!\!E_t$ for $\widetilde{W}_1\widetilde{Z}_2$ events.

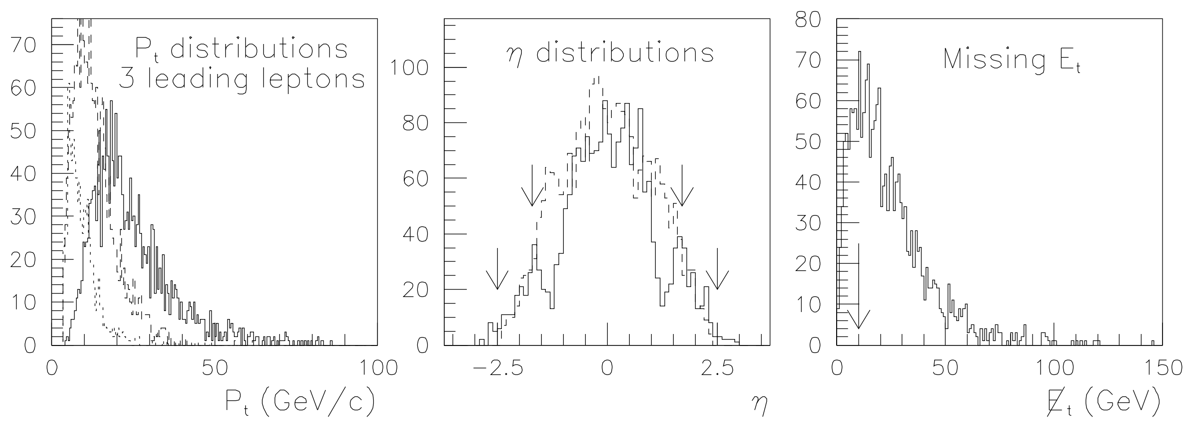

Figure 1. Transverse momentum distributions of the three leading leptons; the η distribution of electrons (solid) and muons (dashed); and the $\not\!\!E_t$ distribution for $\widetilde{W}_1\widetilde{Z}_2$ ISAJET events after detector simulation with $M_{\widetilde{W}_1} = 65$ GeV/c^2. The arrows show analysis cut locations.

2. The DØ Detector and Data Collection

The data, based on a total integrated luminosity of 13.8 ± 1.6 pb^{-1}, were collected during the 1992-1993 Tevatron run with the DØ Detector. DØ is a general-purpose detector consisting of a non-magnetic central tracking system, a finely segmented, nearly hermetic calorimeter, and a toroidal muon spectrometer. A detailed description of the detector can be found elsewhere.[7]

Six triggers were used in various combinations for the four channels:

- 1 muon with $p_t > 15$ GeV/c, $|\eta| < 1.7$
- 1 muon with $p_t > 15$ GeV/c, $|\eta| < 1.7$ and
  2 muons with $p_t > 10$ GeV/c, $|\eta| < 1.7$
- 2 muons with $p_t > 3$ GeV/c, $|\eta| < 1.7$
- 1 isolated EM object with $E_t > 20$ GeV
- 2 isolated EM objects with $E_t > 15$ GeV
- 1 EM object with $E_t > 7$ GeV and
  1 muon with $p_t > 5$ GeV/c, $|\eta| < 1.7$

3. Data Analysis

All channels were subject to offline trigger verification and required to have $N_e + N_\mu = 3$ and $\not{E}_t \geq 10$ GeV. Muons were required to have $p_t(\mu) > 5$ GeV/c, $|\eta_\mu| < 1.7$, and a matching minimum ionizing energy deposition in the calorimeter. Electrons were required to have $E_t(e) > 5$ GeV and $|\eta_e| < 2.5$ and were subject to calorimeter shape cuts. Both electrons and muons were required to be isolated. To retain efficiency, electron and muon identification was not as tight as possible, particularly for low energy electrons and the third muon in the $\mu\mu\mu$ channel. After applying the selection criteria, one event remains, an $ee\mu$ event. Both electrons in the event have associated tracks in the central detector; $E_{t1} = 37.3 \pm .7$ GeV, $E_{t2} = 7.9 \pm .3$ GeV, $\eta_1 = 2.0$ and $\eta_2 = 1.9$. The muon is confirmed by the presence of a minimum ionizing track in the calorimeter; $p_t = 14.5 \pm 2.9$ GeV/c and $\eta = 1.1$. The $\not{E}_t = 38.7 \pm 2.7$ GeV. The kinematics of this event are not really consistent with that expected from $\widetilde{W}_1\widetilde{Z}_2$ decay since all of the leptons are forward. The topology is suggestive of the process $Z^0 \rightarrow \tau\tau + \gamma$, $\tau\tau \rightarrow e\mu$, where the photon converts and fakes an electron. The dE/dx of both of the electrons is consistent with the dE/dx of a conversion pair.

3.1. *Efficiency*

A preliminary detection efficiency for each of the four channels was determined using ISAJET generated events. One thousand events for each of the four channels and for five $\widetilde{W}_1$ masses were generated and processed through detailed detector and trigger simulations and the standard DØ reconstruction program. Further work on the systematic errors associated with low energy lepton efficiency is necessary. Preliminary values of the efficiency range from ~3% in the $e\mu\mu$ channel for $M_{\widetilde{W}_1} = 45$ GeV/c^2 to ~15% in the eee channel for $M_{\widetilde{W}_1} = 100$ GeV/c^2. The MSSM parameters used as input to ISAJET are shown in the table:

Parameter	Value	Decription
$\tan\beta$	2.0	Ratio of the Higgs vacuum expectation values
M_{H^+}	500 GeV	Mass of the charged Higgs
$M_{\tilde{l}}$	200 GeV	Slepton mass
$M_{\tilde{q}}$	1000 GeV	Squark mass
M_t	150 GeV	Top quark mass
$M_{\tilde{g}}$	160-355 GeV	Gluino mass

3.2. *Background*

The largest source of background is due to misidentification of one or more of the leptons, for example in Drell-Yan + jet production where the jet is largely electromagnetic and is misidentified as an electron. Sources of background from misidentification include QCD three jet events, Drell-Yan + b jets, Drell-Yan + jets, Drell-Yan + γ,

Z^0 + jets where $Z^0 \to l\bar{l}$, and $W^\pm$ + 2 jets. Physics backgrounds include $W^\pm Z^0 \to 3$ leptons, $b\bar{b} + \geq 1$ additional b jet, and $b\bar{b} + \geq 1$ c jet. A conservative estimate (using the highest preliminary efficiency) of the number of background events is shown in the table:

	eee	eeμ	e$\mu\mu$	$\mu\mu\mu$
Misidentification	0.43	0.13	0.21	0.05
Physics	0.35	0.08	0.07	0.18
Total	0.78	0.22	0.28	0.23

4. Summary

We are making good progress in a search for $\widetilde{W}_1\widetilde{Z}_2 \to$ tri-leptons using the DØ Detector at the Fermilab Tevatron. The current study is based on an integrated luminosity of 13.8 ± 1.6 pb^{-1} from the 1992-1993 Tevatron run. During the Tevatron run now in progress, we are using triggers optimized for the low p_t leptons in these events and, with an expected integrated luminosity of 50 – 100 pb^{-1}, anticipate inproving the upper limit on $\sigma \times Br$ by a factor of $\approx 3 - 5$.

References

1. See, *e.g.*, H.P. Nilles, *Phys. Rep.* **110** (1984) 1; P. Nath, R. Arnowitt, and A. Chamseddine, *Applied N=1 Supergravity*, ICTP Series in Theoretical Physics, Vol. I, World Scientific (1984); H. Haber and G. Kane, *Phys. Rep.* **117** (1985) 75.
2. T. Medcalf (for the ALEPH Collaboration), in *International Workshop on Supersymmtry and Unification of Fundamental Interactions, Boston, Northeastern Univ, 29 March 1993 – 1 April 1993*, ed. Pran Nath (World Scientific, 1993) R. M. Brown (for the OPAL Collaboration), *ibid.*; B. Zhou (for the L3 Collaboration), *ibid.*
3. R. Arnowitt and P. Nath, *Mod. Phys. Lett.* **A2** (1987) 331; H. Baer and X. Tata, *Phys. Rev.* **D47** (1993) 2739; H. Baer, C. Kao, and X. Tata, *Phys. Rev.* **D48** (1993) 5175.
4. H. Baer, private communication.
5. G. Ross and R. Roberts, *Nucl. Phys.* **B377** 571; R. Arnowitt and P. Nath, *Phys. Rev. Lett.* **69** (1992) 725; S. Kelley *et al.*, *Nucl. Phys.* **B398** (1993) 3.
6. ISAJET V7.06, F. Paige and S. D. Protopopescu, BNL Report No. 38304 (1986); H. Baer, F. Paige, S. D. Protopopescu, and X. Tata, *Simulating Supersymmetry with ISAJET 7.0/ISASUSY 1.0*, FSU-HEP-930329 (1993).
7. S. Abachi *et al.*, *Nucl. Instr. and Meth.* **A338** (1994) 185.