Search for New Phenomena at DØ

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Results are reported for three searches for new phenomena beyond the standard model. The particles searched for are SUSY gauginos in trilepton final states, first and second generation leptoquarks and a "bosonic" Higgs which decays to two photons. No evidence of new phenomena is found in any of the searches for a data set representing from 9 to 13 pb^{-1} recorded during the 1992-93 Tevatron running period.

INTRODUCTION

Several topics beyond the standard model are being investigated at DØ. First to be discussed in this report is a search for SUSY gauginos decaying through trilepton signatures. Then, results from a search for first and second generation leptoquarks will be given. Finally, results will be shown from a search for a specific Higgs called a "bosonic" Higgs which would decay into two photons. All of the results reported were conducted with data taken during the 1992-1993 Tevatron running period and represents around 12 pb^{-1} of integrated luminosity.

SUSY GAUGINOS

Many new particle states are predicted as part of the Minimal Supersymmetric Standard Model. These include Supersymmetric partners of quarks (squarks), leptons (sleptons), and of the gauge and Higgs bosons (gauginos). There are two Higgs doublets, the ratio of their Vacuum Expectation Values is called $\tan(\beta)$. There is a quantity called R-parity which is +1 for normal standard model particles and -1 for SUSY states. If R-parity is conserved then SUSY particles can only be created in pairs and the lightest SUSY particle, the $\tilde{Z}_1$ (sometimes referred to as the $\tilde{\chi_1}^0$), must be stable and unobservable. The next lowest mass state gauginos are predicted to be a chargino $\tilde{W}_1$ (or $\tilde{\chi_1}^+$) and a neutralino $\tilde{Z}_2$ (or $\tilde{\chi_2}^0$).

One possible favorable gaugino production method at the Tevatron is through an s channel off-shell W which produces a chargino-neutralino pair (1) shown in Figure 1. These in turn decay to produce the following states:

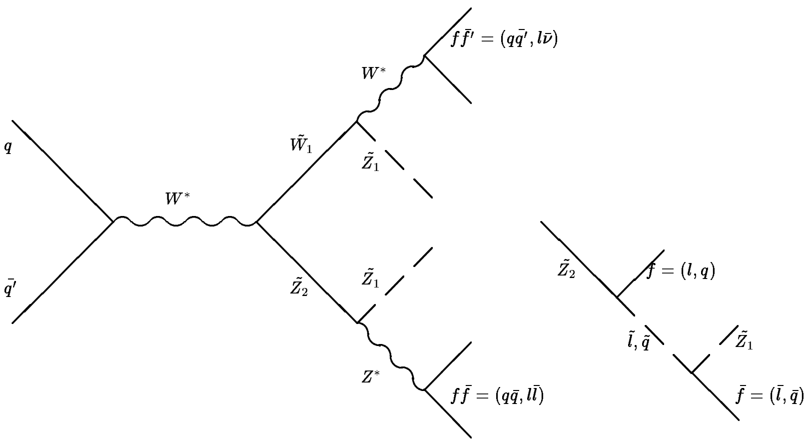

FIG. 1. Feynman diagrams showing the $\tilde{W}_1\tilde{Z}_2$production and decay.

- 4 jets + $\not\!\!E_T$
- 1 lepton + 2 jets + $\not\!\!E_T$
- 2 Leptons + 2 jets + $\not\!\!E_T$
- 3 leptons + $\not\!\!E_T$,

where $\not\!\!E_T$ is the transverse energy imbalance of the event. Of particular interest is the tri-lepton final state which is expected to have very low backgrounds. The $p_T$distributions of the three leptons have been studied using Monte Carlo simulation (2), and show that the lowest $p_T$lepton has a very soft spectrum and requires a low cut on p_T.

TABLE 1. SUSY Trilepton triggers

Trigger requirements
μ with $p_T >$ 15 GeV.
2μ with $p_T >$ 3 GeV.
$\mu + e$ with $p_T >$ (5, 7) GeV.
e with $p_T >$ 20 GeV.
$2e's$ with $p_T >$ 10 GeV.

The search at DØ has been conducted with 12.2 pb^{-1} from the 1992-1993 data taking period (3). The triggers used to collect this sample were based on one high $p_T$lepton or two low $p_T$leptons. The list of triggers employed for the trilepton data accumulation are shown in Table 1. Offline filtering further tightens the cuts imposed by the triggers. There are four channels which are analyzed separately: eee,$ee\mu$,$e\mu\mu$ and $\mu\mu\mu$. Table 2 shows the analysis

TABLE 2. Wino Zino analysis summary

Cut description	Number of events passing the cut			
	eee	$ee\mu$	$e\mu\mu$	$\mu\mu\mu$
Filter Sample	17	53	243	2489
3 clean leptons	5	1	9	23
Missing $E_t > 10$ GeV	0	0	9	23
$\geq$ 1 forward e	0	0	9	23
$m_{/mu/mu} >$ 5GeV	0	0	6	4
$\Delta\phi_{\mu\mu} < 165°$, $\Delta\theta_{\mu\mu} < 160°$	0	0	0	0
Expected Background	0.8	0.2	0.3	0.2
Integrated Luminosity (pb^{-1})	12.2	12.1	12.1	9.0

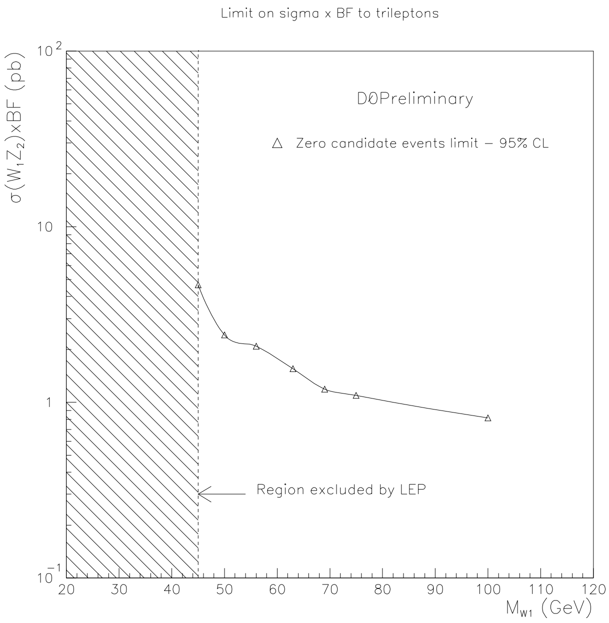

FIG. 2. The 95% CL on cross section times branching fraction into any trilepton plus $\not{E}_T$ final state, as a function of $M_{\tilde{W}_1}$.

steps for each channel. No candidates remain in any channel after all cuts are made. The backgrounds include Drell-Yan and $Z \rightarrow l\bar{l} + \gamma$, Drell-Yan and $Z \rightarrow l\bar{l} + jet$, $W + 2$ jets, $WZ \rightarrow 3$ leptons, $b\bar{b}$, and QCD 3 jet events. Upper limits on the total backgrounds are given in Table 2.

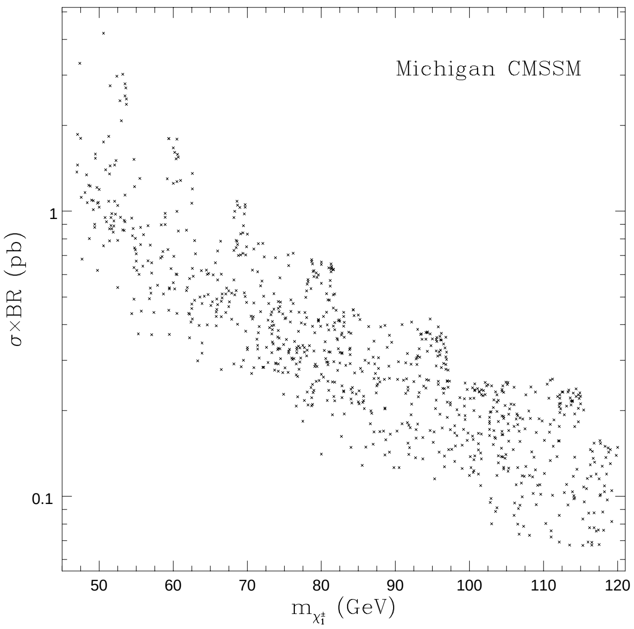

FIG. 3. The space of allowed solutions in the Constrained Minimal Supersymmetric Standard Model, plotted as $\sigma(\tilde{W}_1\tilde{Z}_2) \times BR(3l)$ vs $M_{\tilde{W}_1}$.

The cross section limits for 95% confidence level (CL) are shown in Figure 2. With further improvements in cut efficiencies these limits should be lowered by 30% or more. With the additional data from the run 1b data set, more than 50 pb^{-1} will be added to the statistics. This will greatly improve our reach into the allowed parameter space of such models as, for example, the so-called "Constrained Minimal Supersymmetric Standard Model" (4). Figure 3 shows the space of solutions allowed within the CMSSM, on a plot of $\sigma \times BR(3l)$ vs $M_{\tilde{W}_1}$. We observe that the limit curve is starting to enter the interesting regions predicted by this model.

LEPTOQUARKS

Leptoquarks (LQ) are exotic particles with both color and lepton quantum numbers. They mediate an interaction between leptons and quarks. The coupling strength for LQ masses reachable at the Tevatron is expected to be about $0.1x\alpha$. The decay length for the LQ are expected to be short so they

TABLE 3. Leptoquark dimuon analysis summary

Cut Description	Events passing
Filter Sample	665
Two μ with $p_T>$ 25GeV	173
For both μ's, $\|\eta\| < 1.7$ and at least one μ with $\|\eta\| < 1.0$	93
Muon quality	31
Muon isolation	15
Two jets with $E_t > 25$ GeV	0
Expected background	1.8 $\pm$ 0.7

TABLE 4. Leptoquark single Muon analysis summary

Cut description	Events passing
Filter sample	2912
Detector cleanup	2097
One μ with $p_T> 20GeV$	1806
$\|\eta_\mu\| > 25$ GeV	1347
Muon quality	403
$\not\!\!E_T > 25$ GeV	295
Muon Isolation	127
$\|\pi - \Delta\Phi_{\mu,\not\!\!E_T}\| > 0.2$ rad	69
Two jets with $E_t > 25$ GeV	18
Transverse mass of $(\mu + \not\!\!E_T) > 95$ GeV	0
Expected background	2.4 $\pm$ 1.0

should be easily observed in the detector. The first generation leptoquarks (LQ1) are expected by definition to couple only to electrons, electron neutrinos, up and down quarks. The second generation leptoquarks (LQ2) couple only to muons, muon neutrinos, charm and strange quarks. The generational dependence on the coupling is required to prevent violation of the bounds on rare decays such as $K^+ \to e^+\nu$. The HERA mass limit for scalar LQ1 is 240 GeV for a leptoquark coupling equal to the electroweak coupling α, and drops to LEP limit of 45 GeV at a coupling of $0.05x\alpha$.

Leptoquark production is dominated by pair production through gluon-gluon fusion and $q\bar{q}$ annihilation. We assume that the leptoquark decays to lepton plus quark with a branching fraction of β, and to neutrino plus quark with a branching fraction of $(1-\beta)$. The signatures will be:

- 2 jets + l^+ + l^-
- 2 jets + $l^\pm$ + $\not\!\!E_T$
- 2 jets + $\not\!\!E_T$.

We have conducted searches in the first two channels for first and second generation leptoquarks. The results for the first generation search have been published (5). The excluded region for the first generation LQ is shown in

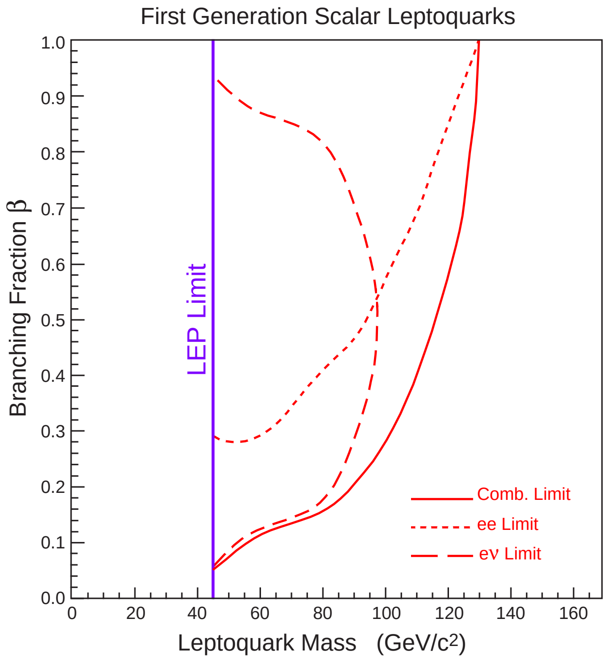

FIG. 4. The 95% CL First generation Leptoquark Mass excluded region vs. branching fraction.

Figure 4 and the limits are $M_{LQ1} > 130$ GeV for $\beta = 1.0$, and $M_{LQ1} > 116$ GeV for $\beta = 0.5$.

The second generation search is based on 12.7 ± 0.67 pb^{-1} of data from the 1992-1993 running period (6,7). The trigger, based on muons plus jets, requires at least one μ with $p_T > 8$ GeV and one jet with $E_t > 15$ GeV. Cuts are made to reduce backgrounds from W and Z bosons plus jets, $b\bar{b}$ production and cosmic rays. The data selection cuts for the dimuon channel are shown in Table 3. The largest background is from $Z \rightarrow \mu\mu$ which is suppressed by requiring there to be two jets associated with the event. No candidates remain after all cuts are imposed, with an expected background of 1.8 ± 0.7 events. The analysis for the single muon channel is shown in Table 4. The largest background is from $W \rightarrow e\nu$ which is reduced with the transverse mass cut. No events are observed with an expected background of 2.4 ± 1.0 events.

The efficiencies for the analyses range up to 5% for the single μ and up to 9% for the $\mu\mu$ channels for a 200 GeV LQ2. These efficiencies are based on kinematic acceptance determined with ISAJET plus a GEANT simulation of the DØ detector ; the muon quality efficiencies are determined from data. Trigger efficiencies are determined from data and a simulation of the effects of the DØ trigger on leptoquark Monte Carlo events. We interpret a null search

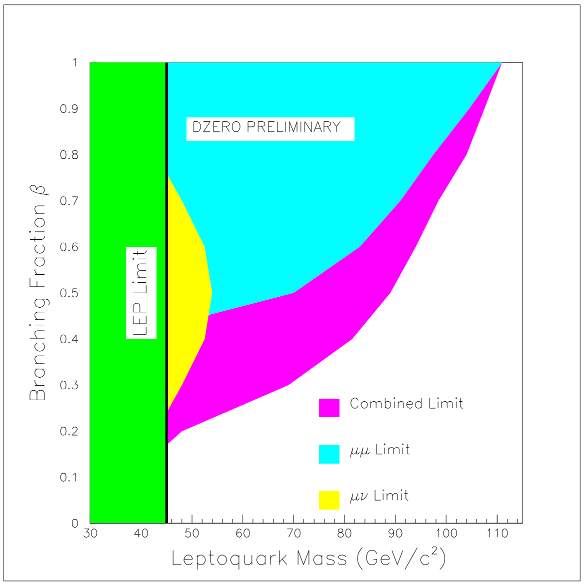

FIG. 5. The 95% CL Second generation Leptoquark Mass excluded region vs.branching fraction.

as a limit on $\sigma\beta^2$. Using the cross section calculations obtained using ISAJET with Morfin and Tung leading order pdf for pair produced scalar leptoquarks, we determine a β dependent limit on the LQ mass. The excluded region is shown in Figure 5. The 95%CL mass limits are $M_{LQ2} > 111$ GeV for $\beta = 1.0$, and $M_{LQ2} > 89$ GeV for $\beta = 0.5$. Including the run 1b data we expect to be able to increase the LQ1 and LQ2 mass limits significantly.

"BOSONIC" HIGGS

In multi-Higgs-doublet models, it is possible for the Higgs which gives mass to fermions to be distinct from that which couples to bosons and which breaks EW symmetry. The latter can then have a very small coupling to fermions and decay predominantly to 2 photons for masses below about 100 GeV, or to WW* for higher masses (8).

DØ has searched for such a "bosonic Higgs" in the associated production channel where the Higgs is produced together with a W or Z which decays to jets. We require two photons above 20 GeV, passing standard DØ photon cuts and with $|\eta| < 2.5$, and two jets above 15 GeV with an invariant mass between 65 and 105 GeV. No events are observed with a diphoton invariant mass above 60 GeV in a 1992-93 data sample with an integrated luminosity

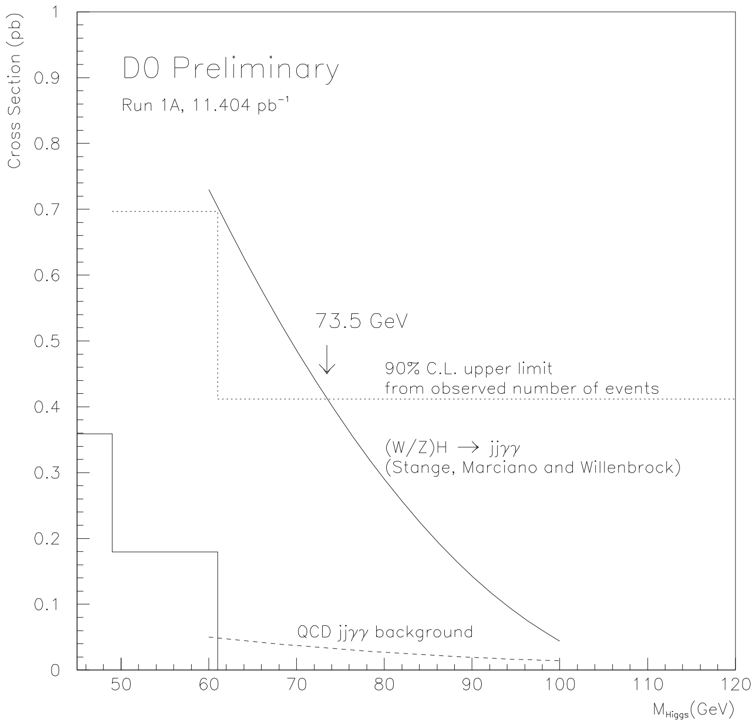

FIG. 6. Mass limit for the "Bosonic" Higgs to 2 jets plus 2 photons. Shown is the 90% CL upper limit from the observed events (dotted line) with the predicted theoretical cross section (solid curve).

of 11.4 pb^{-1}. The principal background is expected to be from QCD two jet plus two photon events, and QCD multi-jet events with some of the jets faking photons in the calorimeter. Using the theoretical cross section of Ref. (8) we are able to set a preliminary lower limit on a bosonic higgs mass of 73.5 GeV at the 90% CL (see Figure 6). With the much larger statistics from the 1994-95 data, we anticipate being able to extend the reach of this search to about 100 GeV.

CONCLUSION

No positive signals of non-standard model physics have been seen thus far in the gaugino, leptoquark or "bosonic" Higgs searches. What has been presented are preliminary results of analyses performed on 1992-93 data representing about 12 pb^{-1}. Analysis is underway for the approximately 90 pb^{-1} of additional data taken during the 1994-95 running period.

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