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Searches for Supersymmetry and Higgs Particles with DØ

Naba K. Mondal
For the DØ Collaboration

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

Tata Institute of Fundamental Research
Bhabha Road, Mumbai-400005, India

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Naba K Mondal
Representing the DØ collaboration

Tata Institute of Fundamental Research
Homi Bhabha Road, Mumbai, India

We report on searches for the Supersymmetric and the neutral scalar particles with the DØ detector at $\sqrt{s} = 1.8$ TeV. The three searches that we report here are: (1) SUGRA motivated SUSY search, (2) search for Charginos and neutralinos, and (3) search for heavy neutral scalar particle produced in association with W bosons.

1 Introduction

In this paper we present preliminary results on searches made for the production of Supersymmetric particles and also for the production of heavy neutral scalar particles like Higgs boson using the data from the DØ detector at the Tevatron collider, which has just completed a run with integrated luminosity $\sim 100\ pb^{-1}$ at $\sqrt{s} = 1.8$ TeV. The DØ detector has been completely described elsewhere [1]. Briefly, its main components are: a central tracking region, occupied by a vertex detector, a transition radiation detector, a central drift chamber and a forward tracking chamber; uranium-liquid argon calorimeter modules, contained in three cryostats; and wide and small angle muon spectrometers with toroidal magnets, proportional drift tubes and a layer of scintillator in the central region. Jets and electrons are identified and their energies measured by the finely segmented calorimeter, with coverage in $\mid \eta \mid$ out to 4.2. Muons are identified with negligible punchthrough background. Missing transverse energy, $\not{E}_T$, is well measured because of the hermeticity of the calorimeter.

2 SUGRA motivated SUSY Search in the dielectron channel

The Minimal Supersymmetric Standard Model (MSSM), which is a direct supersymmetrization of the Standard Model, has many free parameters, which makes the experimental analyses very difficult. For this reason, in the present analysis, we work within the SUGRA-GUT framework which has only five free parameters: a common SUSY-breaking scalar mass (m_0), a common gaugino mass ($m_{1/2}$), a common value for all trilinear coupling (A_0), the ratio of the vacuum expectation values of the two Higgs fields (tanβ) and the sign of μ, where μ is the Higgsino mass mixing parameter. In the early searches for squarks and gluinos, probing the low mass region, one assumed a one step decay of squarks and gluinos into quark jets and the lightest supersymmetric particle (LSP). For higher mass squarks and gluinos, there are additional decay channels through chargino($\widetilde{W}_{1,2}$) and neutralino ($\widetilde{Z}_{1,2,3,4}$) intermediate states. In addition to hadronic decays, these charginos and higher mass neutralinos can also decay leptonically. The final states in such decays contain leptons in addition to jets and $\not{E}_T$.

Events for this analysis are selected by requiring at least two electrons with $E_T > 15$ GeV within $\mid \eta \mid < 2.5$, two jets with $E_T > 20$ GeV and $\mid \eta \mid <$ 2.5 satisfying jet quality cuts and $\not{E}_T > 25$ GeV. In addition, events in which the invariant mass of the two electrons lies between 79 and 103 GeV are removed as possible Z events unless the $\not{E}_T$ in such events is above 40 GeV. Only 2 events survive all the above cuts.

Standard Model backgrounds were studied using a combination of Monte Carlo (for kinematic efficiencies) and data (for electron identification efficiencies). Measured cross sections were used for all background processes except W boson pair production. The instrumental background due to the misidentification of a jet as an electron was determined from single electron + jets sample. The total estimated number of background events is 3.0 $\pm$ 1.3, compared to two events observed in data. We therefore saw no evidence for the production of dielectron + dijet + $\not{E}_T$events in our data in excess of the Standard Model prediction.

From this result, we obtain an exclusion region in the SUGRA parameter space, by generating signal

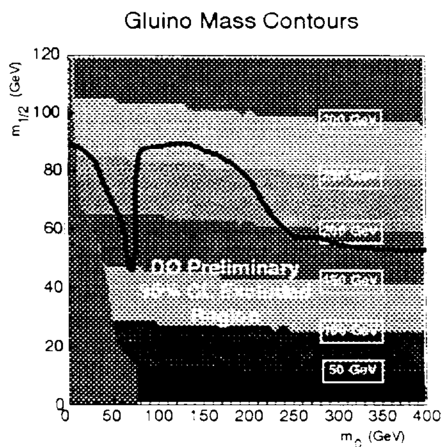

Figure 1: The 95% CL limit in the $m_0 - m_{1/2}$ plane superimposed on contours of constant gluino mass for A_0=0, tan(β)=2 and negative μ

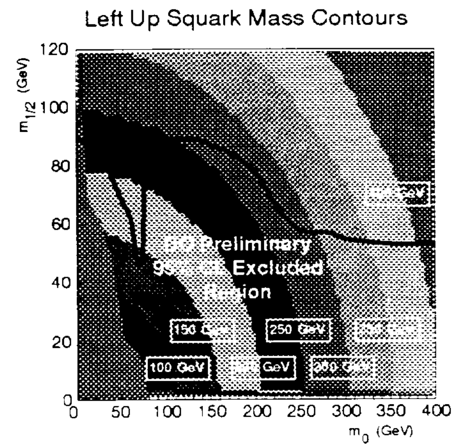

Figure 2: The 95% CL limit in the $m_0 - m_{1/2}$ plane superimposed on contours of constant up squark mass for A_0=0, tan(β)=2 and negative μ

Monte Carlo at various points in the 2-dimensional $m_0 - m_{1/2}$ plane using (ISAJET 7.13)[2]. The three other SUGRA parameters A_0, tan(β), sign(μ) were fixed at 0, 2 and negative respectively and the top mass was assumed to be 180 GeV. All sparticle (gluino, squark, chargino and neutralino) production was included in our simulated samples. The response of the DØ detector was determined using a detailed detector and trigger simulation. We then estimated the signal efficiency at each point. Using the signal efficiencies, background expectations and the two observed events, we have determined the 95% CL upper limit on the SUSY cross section, as a function of m_0 and $m_{1/2}$ using a Bayesian calculation. From these cross section limits and the leading order estimated cross sections, we determine the 95% CL exclusion contours shown in figures 1 and 2. The excluded region is the area below the solid line. Figure 1 shows the exclusion contour superimposed on a plot of gluino mass contours; Figure 2 shows the same exclusion contour superimposed on the mass contour for the left up squark. The "dip" in the exclusion contour around m_0 = 70 GeV is due to the fact that in this region $\tilde{\nu}$ is lighter than $\widetilde{Z}_2$ and the decay $\widetilde{Z}_2 \rightarrow \tilde{\nu}\nu$ replaces $\widetilde{Z}_2 \rightarrow ee\widetilde{Z}_1$ as the dominant decay mode.

3 Search for charginos and neutralinos in the trilepton channel

An established technique of searching for SUSY at Tevatron collider is to look for trileptonic final states from decays of the lightest chargino, $\widetilde{W}_1$, and second lightest neutralino, $\widetilde{Z}_2$, produced in association.

For this analysis, we have looked for the following four trileptonic final states: eee, $ee\mu$, $e\mu\mu$, $\mu\mu\mu$.

Various combinations of single lepton (e or μ) and dilepton triggers were used for selecting these final states. These triggers included: a single muon with p_T^μ > 15 GeV/c; two muons with p_T^μ > 3 GeV/c; one muon with p_T^μ > 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, $\not\!\!E_T$, > 15 GeV; and two electromagnetic clusters with E_T^{e1} > 12 GeV, E_T^{e2} > 7 GeV, and $\not\!\!E_T$> 7 GeV.

In addition, to reduce trigger bias, during offline analysis the first or first two leading leptons (depending on trigger) are required to have their p_T at least 2 GeV above trigger threshold. For the channels involving muons, we rejected back to back muons within 0.1 rad to reduce cosmic ray background and also rejected events where the $\not\!\!E_T$ is either back to back to the leading muon or parallel to any muon within 0.1 rad. The last one is to reduce the effect of mismeasured muon momentum. We further required that any lepton in the event must have $E_T^e > 5$ GeV or $P_T^\mu > 5$ GeV/c. In addition, electrons and muons in these events were required to pass various quality cuts. Finally, additional decay mode specific cuts were applied to reduce the background further. For the *eee* channel, we rejected events having an electron pair with invariant mass between 81 and 101 GeV/c^2, or having $\not{E}_T < 15$ GeV, or having the first two leading electrons back to back within 0.2 rad. In the $e\mu\mu$ channel, we rejected events having two leading muons within 0.2 rad to reject J/ψ. For the $\mu\mu\mu$ channel we required $\not{E}_T > 10$ GeV and rejected events with dimuon invariant mass less than 5 GeV/c^2. After applying these cuts we found no events in any of the four channels.

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 total background for all the four processes combined is 1.34 ± 0.37.

To analyze the $\widetilde{W}_1$ - $\widetilde{Z}_2$ signal characteristics, we generated Monte Carlo events for each channel and for various $\widetilde{W}_1$ masses, ranging from 45 to 96 GeV/c^2 using ISAJET 7.13. These MC events follow the mass relation common to many SUGRA inspired SUSY models: $M_{\widetilde{W}_1} \approx M_{\widetilde{Z}_2} \approx 2M_{\widetilde{Z}_1}$.

Using this, we present a 95 % CL upper limit on the cross section (for producing $\widetilde{W}_1$ - $\widetilde{Z}_2$ pairs) times branching fraction into any one of the trileptonic final states. Figure 3 shows the resulting limit (labelled Run 1B). Also shown in the same figure are our previously published result [3] (labelled Run 1A) and the limit based on combined (labelled Run 1A + 1B) data.

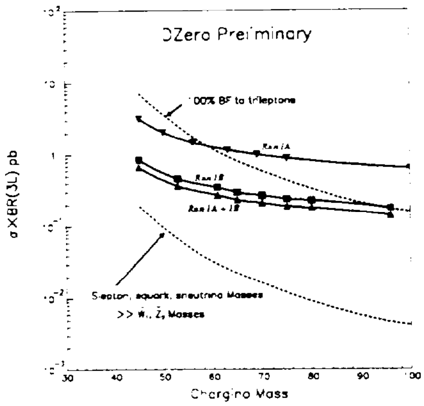

Figure 3: The 95% CL limit on $\sigma\ \times$ branching fraction to a trileptonic channel vs lightest chargino mass. Two dotted lines cover the expected range of $\sigma\times$BR($3l$) from various models.

4 Search for Neutral Scalar produced in association with W boson

We have also looked for the production of a heavy scalar particle in association with W through the process $p\bar{p} \rightarrow W + X$. This process is a feature of many models including the standard model and SUSY Higgs and of various technicolor model. Although the limits on the number of allowed signal events presented in this analysis are model independent, we derive cross section limits using acceptances derived for the case in which X has the spin and decay properties of a neutral Higgs boson H^0 decaying exclusively to $b\bar{b}$. We use events in which the W decays via $W \rightarrow l\overline{\nu_l}$, $l = e,\mu$ and the X decays via $X \rightarrow b\bar{b}$, where we identify b jets through the soft muon tag. The final states of such events will consist of either a high p_T electron or muon, missing transverse energy and at least two jets. The following cuts are then applied offline to select the signal. For the electron channel: (1) one isolated e with $p_T \geq 25$ GeV and $|\ \eta\ | \leq 2.5$; (2) $\not{E}_T \geq 25$ GeV; and (3) two jets with $|\ \eta\ | \leq 2.0$ and $p_T \geq 15$ GeV. For the muon channel: (1) one isolated muon with with $p_T \geq 20$ GeV and $|\ \eta\ | \leq 1.7$; (2) $\not{E}_T \geq 20$ GeV; (3) two jets with $|\ \eta\ | \leq 2.0$ and $p_T \geq 15$ GeV; and (4) $P_T^W \geq 20$ GeV. We have used the complete DØ 1992-1995 data sample of 100 pb^{-1} and the number of candidate events that pass all our cuts are 12 in the electron channel and 15 in the muon channel.

The backgrounds relevant to this search are (a) W + jets events in which the jets arise from gluon radiation, (b) multi-jet events in which fluctuations give rise to misidentification of jet systems as leptons, and (c) $p\bar{p} \rightarrow t\bar{t}$ events. Total number of background events expected from all these sources are 15.1 ± 2.0 for the electron channel and 10.4 ± 1.4 for the muon channel. Combining the muon and electron channels we have observed 27 events in good agreement with the expected background of 25.5 ± 3.3. Based on this null result we set limits on $p\bar{p} \rightarrow W + H^0$ cross section using two methods. In the first method, cross section limits as a function of H^0 mass was derived by simply

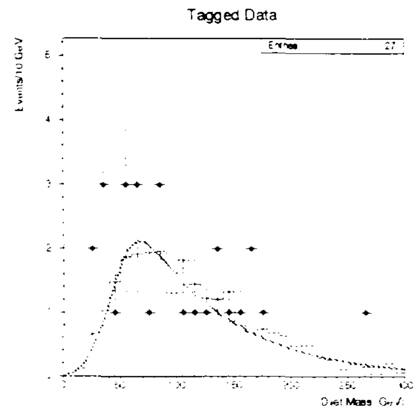

Figure 4: Dijet mass spectrum for data shown as points. The histogram is the background prediction and the curve is a fit to the background

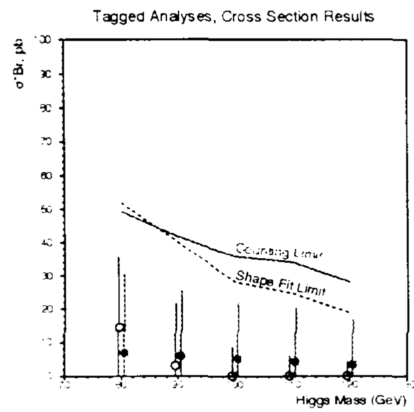

Figure 5: 95% CL limits on σ*Br from the counting analysis (solid line) as well as shape fit (dashed line) are shown. The open circles are the central value for the shape fit result and the solid circles are the central value for the counting analysis.

computing the cross section using the following relation.

$$\sigma = \frac{N_0 - B}{AL * Br(W \to l\overline{\nu_l})}$$

Here N_0 is the number of events observed in the data, B the predicted background, A the detector acceptance and L is the total luminosity. The resulting cross section limits range from 49 pb to 28 pb for H^0 masses from 80 GeV to 120 GeV respectively.

In the second technique, we fitted the observed dijet mass spectrum to a combination of signal and background. The two jets used to form the dijet mass are the tagged jet and the highest E_T untagged jet. The resulting spectrum is shown in figure 4 for the data, the predicted background and a fit to the background determined from the data itself. The signal shape was determined from Monte Carlo. These background and signal shapes was used as the input spectra for a single-parameter binned maximum likelihood fit to extract the fraction of WH^0 signal in the data. After estimating the number of signal events as function of Higgs mass, we estimated the 95 % CL cross section limits on the production cross section using the same technique as in the case of the counting method. The 95% CL cross section limits range from 52 pb to 19 pb for H^0 masses from 80 GeV to 120 GeV. Figure 5 shows the cross section times branching fraction limits obtained from the counting as well as shape fit analysis.

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