Search for Supersymmetry in the Trilepton Channel $q\bar{q} \rightarrow \widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0 \rightarrow 3\ell + \not{E}_T$ with the DØ Detector at TeVatron Run II

M. Binder, O. Biebel, T. Christiansen, F. Fiedler, J. Elmsheuser, T. Nunnemann, D. Schaile, and R. Ströhmer

In the mSUGRA unified model, the sleptons ($\tilde{\ell}$), the lighter charginos ($\tilde{\chi}_1^{\pm}$) and the lighter neutralinos ($\tilde{\chi}_1^0, \tilde{\chi}_2^0$) are typically less massive than gluinos and squarks. Therefore, the signal with three leptons and missing transverse energy ($3\ell + \not{E}_T$) in the final state, from associated production and decays of $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ is one of the most promising channels for supersymmetric (SUSY) particle searches at the TeVatron.

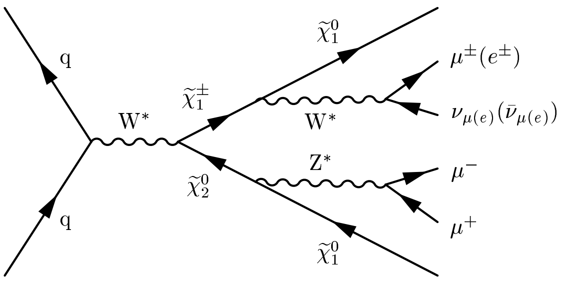

Fig. 1: Feynman diagram of the $3\ell + \not{E}_T$ signal for the $\mu^+\mu^-\mu^{\pm}(\mu^+\mu^-e^{\pm}) + \not{E}_T$ final state.

In most of the mSUGRA parameter space, the gaugino masses are related to the gaugino mass parameter $m_{1/2}$ by $m_{\tilde{\chi}_1^0} \sim 0.4\ m_{1/2}$ and $m_{\tilde{\chi}_1^{\pm}} \sim m_{\tilde{\chi}_2^0} \sim 0.8\ m_{1/2}$, considering universal boundary conditions at the GUT scale with a common gaugino mass $m_{1/2}$ and a common scalar mass m_0. The most sensitive mSUGRA parameter space for the $3\ell + \not{E}_T$ signal at the TeVatron is $m_{1/2} < 250$ GeV, $m_0 < 200$ GeV and $\tan\beta < 10$. The associated boundaries are for the neutralino masses $m_{\tilde{\chi}_i^0} < 200$ GeV and (indirectly) for the gluino mass $m_{\tilde{g}} < 600$ GeV. [1]

The major source of this signal is associated production of $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ both decaying to leptons. In this analysis only the decay of the Z^* boson via muons and the semileptonic decay of the W^* boson to a muon or an electron and their associated neutrinos, are investigated (Figure 1).

Muons are detected with the muon system of the DØ detector and matched to tracks identified with the inner detector. The muon detector itself consists of scintillator counters and drift tubes, with effectively complete coverage out to $|\eta| \leq 2$, η being the pseudo-rapidity $\eta = -ln(\tan\frac{\theta}{2})$. The detector is split at $|\eta| = 1$ into a central and forward system. Layers of Pixel scintillator counters within the same $\eta-$region have ϕ-segmentation of 4.5 degrees. The muon detector has a poor detector redundancy in the downward direction in the central region. New scintillator counters were installed recently to improve the coverage of this region. [2,3]

The Standard Model (SM) background to the signal $q\bar{q} \rightarrow \widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0 \rightarrow \mu^+\mu^-\mu^{\pm}(\mu^+\mu^-e^{\pm}) + \not{E}_T$ can be greatly reduced with a simple cut-based preselection. The dominant SM backgrounds are: (i) directly produced trilepton events ($W^{\pm}Z$, ZZ, $t\bar{t}$, $W^{\pm}\gamma$) and (ii) dilepton events with an additional 'fake isolated' lepton: a 'true' muon or electron from background processes usually generating *non-isolated* leptons, e.g. leptons from semileptonic decays of b,c ($Wb\bar{b}$, $Zb\bar{b}$), or photons from π^0 decays, which might be wrongly identified as electrons. A careful study of the selected muons and electrons must be performed: trigger studies, isolation cuts and efficiencies.

To define the muon efficiency for isolation cuts two samples are required: events with two opposite sign muons and invariant mass of $M(Z)$ or $M(J/\Psi)$ are used as the isolated muon sample, events with two like sign muons are used as the 'fake isolated' muon sample, assuming those muons are generated from $b\bar{b}$ events. The sum of the energy $E(R_x)$ in the calorimeter cells within a hollow cone in R_x surrounding the muon is used to discriminate between both samples:

$$E_H(R_a, R_i) = \sum_{R_x > R_i}^{R_x < R_a} E(R_x)$$

The optimal size of the hollow cone is $0.4 > R_x > 0.1$. For both samples the efficiency that a muon is identified as isolated is determined as a function of the energy cut: ε_s for the isolated muon sample and ε_f for the 'fake isolated' muon sample. The supersymmetric signal has three isolated muons in the final state each contributing with ε_s. Assuming that the predominant background has one 'fake isolated' muon (combined efficiency $\epsilon_s^2\epsilon_f$), the optimal isolation cut for $E_H(0.4, 0.1)$ is the maximum of the ratio $\epsilon_s^2/\sqrt{\epsilon_f}$ sh

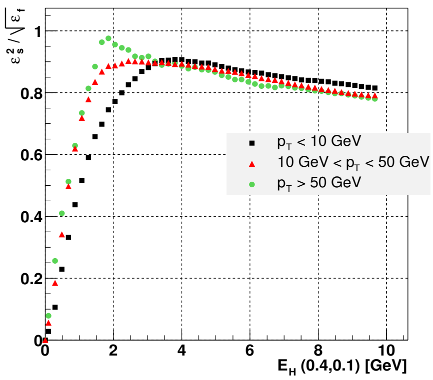

Fig. 2: $\varepsilon_s^2/\sqrt{\varepsilon_f}$ for different p_T of the muon within a hollow cone $E_H(0.4, 0.1)$ around the muon.

The isolation depends on the p_T of the muon. For p_T <10 GeV/c, the optimal isolation cut is $E_H(0.4, 0.1) <$ 3.6 GeV/c. Muons with 10 GeV/c $< p_T <$ 50 GeV/c require an isolation cut of $E_H(0.4, 0.1) < 2.5$ GeV/c and for muons with $p_T > 50$ GeV/c the isolation cut is $E_H(0.4, 0.1) < 1.9$ GeV. Similar studies for different variables will improve the reduction of the SM background.

References

[1] V. Barger, C.E.M. Wagner *et al.*, hep-ph/0003154
[2] DØ Collaboration, B. Baldwin *et al.*, DØ note 3365
[3] DØ Collaboration, G. Alexeev *et al.*, DØ note 3366