SEARCH FOR NEW PHENOMENA AT THE DØ EXPERIMENT

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Searches for New Physics beyond the Standard Model have been performed with the DØ detector at the Tevatron $p\bar{p}$ collider (Fermi National Accelerator Laboratory) at $\sqrt{s} = 1.96$ TeV. Using a Run II data set of ~ 350 pb^{-1}, various analyses have covered a multitude of signatures, reaching sensitivity in parameter regions well beyond existing limits. No significant deviation from the Standard Model has been observed while searching for supersymmetry, leptoquarks and neutral long-lived particles.

1. Introduction

The Standard Model describes successfully all phenomena observed in collision experiments at current energy scales. However there are various indications that it is only an effective low-energy theory of a more fundamental theory: the hierarchy between the electroweak scale and the Planck scale, the evolution of the coupling constants and the pending integration of gravity.

In the following, a brief overview of recent results from DØ in Run II is given.[1] All reported cross section limits are derived at 95% C.L. A detailed description of the DØ detector can be found elsewhere.[2]

2. Search for Associated Chargino/Neutralino Production

Due to the small background from Standard Model processes, the associated production of chargino/neutralino with subsequent decay into three charged leptons is a promising channel for SUSY discovery at the Tevatron. Assuming R-parity, the lightest neutralino is stable and escapes detection, leading to large $\not\!\!E_T$. Using 320 pb^{-1}, four different selections are defined:

$ee\ell$, $\mu\mu\ell$, $e\mu\ell$ and like-sign $\mu\mu$. To maximize the signal yield, the third lepton is identified as an isolated track. The optimization of the selection is based on mSUGRA signals with low slepton masses and low chargino and neutralino masses at $\tan\beta = 3$. Combining all four analyses, the expected Standard Model background sums up to 2.93±0.54(stat)±0.64(sys) events, while 3 events remain in data. An upper limit on $\sigma \times \mathrm{BR}(3\ell)$ is extracted and compared with three different benchmark scenarios. The resulting chargino mass limit (see Figure 1 (left)) extends the LEP limits of 103 GeV for SUSY scenarios with enhanced leptonic branching ratios (3l-max).

3. Search for Squarks and Gluinos in Jets and $\not\!\!E_T$ Topology

The most copiously produced supersymmetric particles in hadron collisions should be – if sufficiently light – squarks ($\tilde{q}$) and gluinos ($\tilde{g}$). Assuming R-parity, the particles are produced in pairs and the event topology consists of multijet events with significant $\not\!\!E_T$ stemming from the LSP. The search uses 310 pb^{-1} of data, and the selection criteria are optimized in three benchmark scenarios using the scalar sum of all jets (H_T) and $\not\!\!E_T$ to minimize the expected upper limit on the cross section. In the mass region $m_{\tilde{g}} > m_{\tilde{q}}$, di-jet events are selected with $H_T > 250$ GeV and $\not\!\!E_T > 175$ GeV. Three jet events with $H_T > 325$ GeV and $\not\!\!E_T > 100$ GeV cover the mass region $m_{\tilde{g}} \sim m_{\tilde{q}}$, while four jet events with $H_T > 250$ GeV and $\not\!\!E_T > 75$ GeV cover $m_{\tilde{g}} < m_{\tilde{q}}$. Limits are set for an mSUGRA model with $\tan\beta = 3$, $A_0 = 0$ and $\mu < 0$ and are shown in Figure 1 (right).

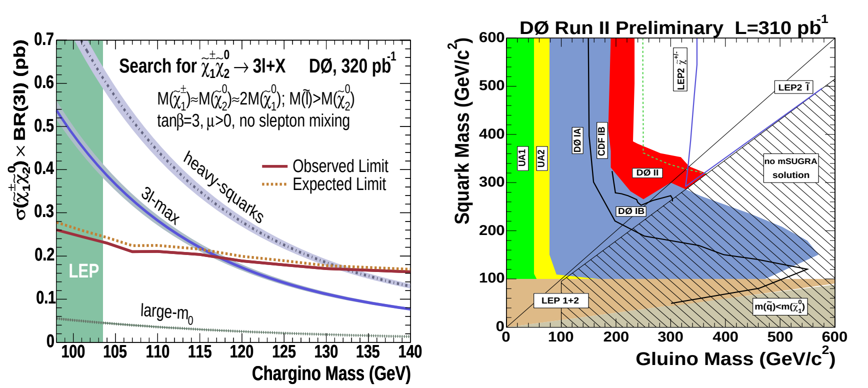

Figure 1. *Left:* Resulting limit on $\sigma \times \mathrm{BR}(3\ell)$ as a function of the chargino mass from the search for associated production of chargino/neutralino. *Right:* Excluded region in the $(m_{\tilde{g}}, m_{\tilde{q}})$-plane from the search for squarks and gluinos.

4. Search for Direct Production of Scalar Top and Bottom Quarks

Large Higgs Yukawa couplings to the third quark generation induce a strong mixing between the supersymmetric partners of the two chirality states of the top and bottom quark, resulting in two different physical states: $\tilde{t}_1$ ($\tilde{b}_1$) and $\tilde{t}_2$ ($\tilde{b}_2$). Therefore the lightest scalar top quark ($\tilde{t}_1$) might be the lightest squark. At large values of $\tan\beta$, a light $\tilde{b}_1$ is also expected.

A combination of two analyses which search for the scalar top in the $e^{\pm}\mu^{\mp}b\bar{b}+\not{E}_T$ ($e\mu$ selection) and $\mu^+\mu^-b\bar{b}+\not{E}_T$ ($\mu\mu$ selection) final states from the $\tilde{t}_1$ pair production is performed using 339 pb^{-1} ($\mu\mu$), resp. 350 pb^{-1} ($e\mu$). This result supersedes the result shown at the conference. The excluded region in the $(m_{\tilde{t}}, m_{\tilde{\nu}})$-plane is shown in Figure 2 (left). Using 310 pb^{-1}, the sbottom pair production with subsequent decays $\tilde{b} \to b\tilde{\chi}_1^0$ is examined. The resulting exclusion regions in the $(m_{\tilde{b}}, m_{\tilde{\chi}^0})$ are shown in Figure 2 (right).

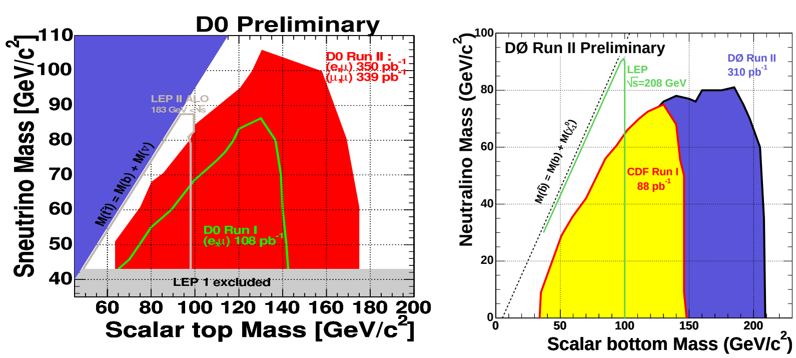

Figure 2. Excluded region in the $(m_{\tilde{t}}, m_{\tilde{\nu}})$-plane *(left)* and the $(m_{\tilde{b}}, m_{\tilde{\chi}^0})$-plane *(right)*.

5. Search for Charged Massive Stable Particles (CMSP)

Limits from cosmology on new particles that are absolutely stable are quite strict. However, these restrictions do not apply to particles that decay outside the detector region. The detector signal of such a CMSP resembles a muon signal. Using timing information from the muon system, the relatively slow moving CMSPs can be distinguished from real muons. DØ has performed a search for the pair production of CMSPs using 390 pb^{-1}. In models with anomaly-mediated supersymmetry breaking, the lifetime of the lightest chargino can be long enough to escape the detector if the mass difference between the lightest chargino and the lightest neutralino is small. In the present analysis, mass limits for a higgsino-like chargino and a gaugino-like chargino can be set at 145 GeV and 175 GeV.

6. Search for Neutral Long-Lived Particles (NLLP)

DØ has searched for the pair production of NLLPs using 383 pb^{-1}. The NLLP is assumed to have a mass as low as several GeV and a decay length in the order of a few centimeters, before decaying to two muons and a neutrino. As a theoretical model, the MSSM with R-parity violating decays of neutralinos is used, where the RPV couplings are expected to be small resulting in long lifetimes. Studies of the decay $K_s^0 \to \pi^+\pi^-$ are performed to demonstrate the ability to reconstruct long-lived particles up to a radius of 20 cm with reasonable efficiency. The DØ result is compared to the NuTeV result (Figure 3), and it improves on the NuTeV limit by several orders of magnitude at long lifetimes and adds coverage at lower lifetimes.

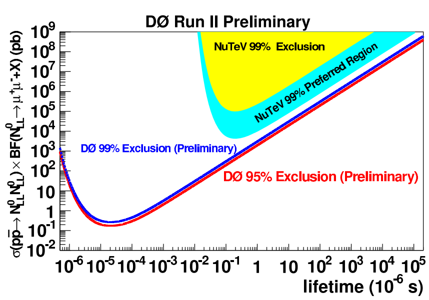

Figure 3. Limit on $\sigma \times \mathrm{BR}$ for pair-production of NLLPs as a function of lifetime. The NuTeV exclusion has been converted to a $p\bar{p}$ cross section at $\sqrt{s} = 1.96$ TeV.

7. Search for First and Second Generation Leptoquarks

At the Tevatron, leptoquarks would be produced in pairs through $q\bar{q}$ annihilation and gluon fusion. A search for first generation leptoquarks in the $ejej$ and the $ej\nu j$ channels based on 252 pb^{-1} shows no excess of data over Standard Model background. The limits on the cross sections are translated into lower mass limits on LQ_1 as a function of the branching ratio into eq (see Figure 4 (left)). Using data corresponding to an integrated luminosity of 294 pb^{-1}, DØ has searched for second generation leptoquarks. Assuming a branching ratio of $\mathrm{BR}(LQ_2 \to \mu q) = 1$, the final state consists of two muons and two quarks. Since no excess in data is found, lower limits on $m(LQ_2)$ are determined as a function of the branching ratio into μq. The results of a complementary Run I analysis in the $\mu j \nu j$ channel are combined with the current results, and the exclusion is shown in (Figure 4 (right)). Both LQ_1 and LQ_2 searches result in the most stringent limits on leptoquarks from direct measurements for large branching ratios.

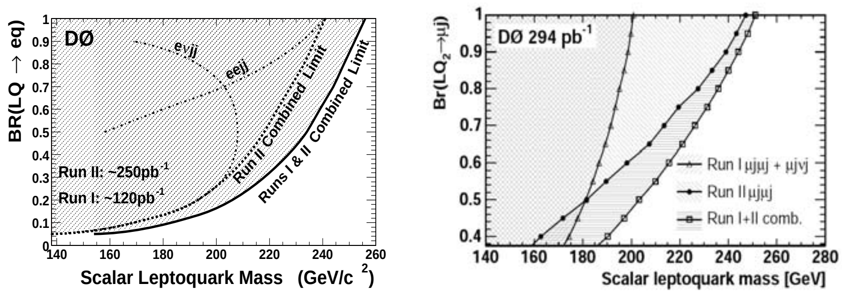

Figure 4. Excluded parameter space for LQ_1 *(left)* and LQ_2 *(right)* searches.

8. Summary

The Run II of the Tevatron collider is progressing well, and DØ is collecting a large amount of high quality data. Within the analyzed data set of 350 pb^{-1}, no deviation from the Standard Model expectation has been found. A number of restrictive upper limits on new physics beyond the Standard Model has been derived, which are the most constraining to date. Currently 1 fb^{-1} of data is being analyzed, which should lead to substantial improvements of the current limits if no deviation is found.

References

1. `http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm`
2. DØ Collaboration, V. Abazov *et al.*, physics/0507191, submitted to Nucl. Instr. Methods in Phys. Res. A (2005).