New Results on Searches for New Physics beyond the Standard Model in the D0 Experiment

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Abstract—The latest results obtained from searches for particles and phenomena beyond the Standard Model (new physics) in the D0 experiment at the Tevatron [Fermi National Accelerator Laboratory (FNAL), USA] on the basis of a statistical sample corresponding to an accumulated luminosity of 1 to 3 fb^{-1} in 2008 are considered.

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1. INTRODUCTION

Many years of investigations have proven that the Standard Model [1] is viable, satisfactorily describing observed processes and phenomena in particle physics. Yet, it is not free from significant flaws, which furnish motivations to seek Standard Model extensions such that they provide answers to questions existing within the Standard Model. Problems that call for an explanation include the hierarchy problem, the dark-matter phenomenon, and the unification of gauge constants.

Before the Large Hadron Collider (LHC, CERN, Switzerland) will have been completely commissioned, the Tevatron accelerator at the Fermi National Accelerator Laboratory (FNAL, USA) rated at the c.m. colliding-beam energy of 1.96 TeV remains the most appropriate testing ground for new-physics searches. Along these lines, a vast range of studies, including searches for supersymmetric partners of quarks, gluons, and gauge and Higgs bosons and searches for leptoquarks, additional spatial dimensions and effects associated with them, new heavy gauge bosons, and excited lepton states, is being performed in the D0 experiment at the Tevatron. In the present study, we give a survey of the latest results obtained on the basis of a statistical sample that corresponds to the accumulated luminosity of about 1 to 3 fb^{-1} [2].

2. SUPERSYMMETRY

Supersymmetry (SUSY) theory postulates the presence of symmetry between boson and fermion states and predicts the existence of supersymmetric partners for Standard Model particles. The supersymmetric partners differ only in spin values (bosons correspond to fermions, and vice versa). In the theory, one introduces, the concept of R parity, which is a multiplicative quantum number equal to $+1$ for Standard Model particles and to -1 for their supersymmetric partners. In minimal supersymmetric extensions of the Standard Model (Minimal Supersymmetric Standard Model or MSSM), one postulates R-parity conservation (but there are supersymmetry models in which there is no R-parity conservation), and this leads two important consequences: only double production of supersymmetric particles is possible, and the lightest supersymmetric particle must be stable (naturally providing a solution to the dark-matter problem). To date, no experimental corroboration of the existence of supersymmetric particles has been found. This suggests their high masses and, hence, a large mass difference between Standard Model particles and their supersymmetric partners. This in turn means that supersymmetry is a broken symmetry. Several mechanisms of supersymmetry breaking have been proposed. Of these, that which is the most interesting to us is provided by the model of minimal supergravity (mSUGRA). In this model, supersymmetry breaking is induced to interaction with gravity and is characterized by five basic parameters: m_0 and $m_{1/2}$, which are universal masses for the scalar and gauge superpartners on the Grand Unification scale; A_0, which is a a universal trilinear coupling constant on the Grand Unification scale; $\tan\beta$, which is the ratio of Higgs fields in the vacuum; and $\text{sign}(\mu)$, which is the sign of the higgsino mass parameter.

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Numbers of events observed in the data for all of the topologies considered here and after the application of all selections and cuts and number of events expected from Standard Model backgrounds

Topology	Data	Background
"Dijet"	11	$11.1 \pm 1.2\,(\text{stat.})^{+2.9}_{-2.3}\,(\text{Syst.})$
"Three jets"	9	$10.7 \pm 0.9\,(\text{stat.})^{+3.1}_{-2.1}\,(\text{syst.})$
"Gluino"	20	$17.7 \pm 1.1\,(\text{stat.})^{+5.5}_{-3.3}\,(\text{syst.})$

2.1. Searches for Supersymmetric Partners of Quarks and Gluons

In models based on supersymmetry, the decays of supersymmetric partners of quarks (squarks) and gluons (gluinos) lead to the formation of ordinary particles and the lightest supersymmetric particles (the lightest supersymmetric particle, or LSP, is stable) in the final state. In the mSUGRA model, the latter are the lightest of the neutralinos ($\tilde{\chi}_1^0$), which are the supersymmetric partners of neutral gauge and Higgs bosons. The lightest supersymmetric particle interacts with matter only via weak interaction, escaping detection in a detector and contributing to the missing energy.

It is natural to assume that the double production of squarks and gluinos is dominant at hadron colliders; if the squark mass is smaller than the gluino mass (small values of the parameter m_0), then the prevalent process is the double production of squarks, which subsequently decay to an ordinary quark and the lightest supersymmetric particle ($\tilde{q} \to q\tilde{\chi}_1^0$), thereby forming a final state that involves two acoplanar jets and a large missing transverse energy (so-called dijet topology). If the gluino mass is lower than the squark mass (large values of the parameter m_0), then the double production of gluinos will be dominant; subsequently, these gluinos will decay through the channel $\tilde{g} \to q\bar{q}\tilde{\chi}_1^0$, whereby there arise final states featuring four or more jets and a large missing transverse energy (gluino topology). But if the squark and gluino masses are on the same order of magnitude, a considerable contribution of the double production of squarks and gluinos is possible, in which case the resulting final state features three or more jets and a large missing transverse energy (three-jet topology).

In the D0 experiment, the search for squarks and gluinos was performed within all three of the aforementioned topologies on the basis of a statistical sample that corresponds to the accumulated luminosity of 2.1 fb^{-1} [3]. Processes involving W and Z bosons, as well as processes leading to t-quark production and decay, $Z \to \nu\bar{\nu} + jets$ and $W \to l\nu + jets$, $t\bar{t}$, $WW/WZ/ZZ$, and processes of single t-quark production, are dominant background processes here.

The ALPGEN [4] and PYTHIA [5] generators supplemented with the CTEQ6L1 set of structure functions [6] were used to simulate background processes, and the CompHEP code [7] was harnessed to simulate processes involving single t-quark production.

The results of an analysis of all three topologies being considered are listed in the table, where the numbers of events that passed all selections and cuts [3] ("Data" column) are given along with the expected (from a simulation) numbers of events from Standard Model backgrounds.

From the table, it follows that the numbers of events in observed data complies well with the Standard Model predictions; therefore, we can conclude that the statistical data sample presented here do not show any piece of evidence for the double production of squarks and gluinos in the topologies being considered. Upper limits on the cross sections for the production of squarks and gluinos were calculated (with the parameters of the mSUGRA model that were chosen to be $A_0 = 0$, $\tan\beta = 3$, and $\text{sign}(\mu) < 0$) for all three topologies considered here, and the following lower limits on their masses were deduced at a 95% confidence level:

$$m_{\tilde{q}} > 379\ \text{GeV}/c^2,\ \ (\text{"dijet"},\ m_0 = 25\ \text{GeV}/c^2); \tag{1}$$

$$m_{\tilde{g}} > 308\ \text{GeV}/c^2,\ \ (\text{"gluino"},\ m_0 = 500\ \text{GeV}/c^2).$$

The limits obtained for these masses in the CDF experiment on the basis of the statistical sample that corresponds to the accumulated luminosity of 2.0 fb^{-1} and for a somewhat different choice of values for the parameters of the mSUGRA model ($A_0 = 0$, $\tan\beta = 5$, and $\text{sign}(\mu) < 0$) [8] are 392 and 280 GeV/c^2, respectively.

In the plane spanned by the squark and gluino masses, Fig. 1 shows the regions excluded by a data analysis along with the results obtained earlier in several experiments.

2.2. Searches for Supersymmetric Partners of the t Quark

The result obtained from searches for supersymmetric partners of the t quark in the channel $\tilde{t}\bar{\tilde{t}} \to b\bar{b}e^{\pm}\mu^{\mp}\tilde{\nu}\bar{\tilde{\nu}}$ on the basis of a statistical sample that corresponds to the accumulated luminosity of 1.1 fb^{-1} was presented in 2008 [9]. The underlying assumptions there were that the supersymmetric partner of the t quark decayed through the channel $\tilde{t} \to bl\tilde{\nu}$ and that the sneutrino $\tilde{\nu}$ appeared to

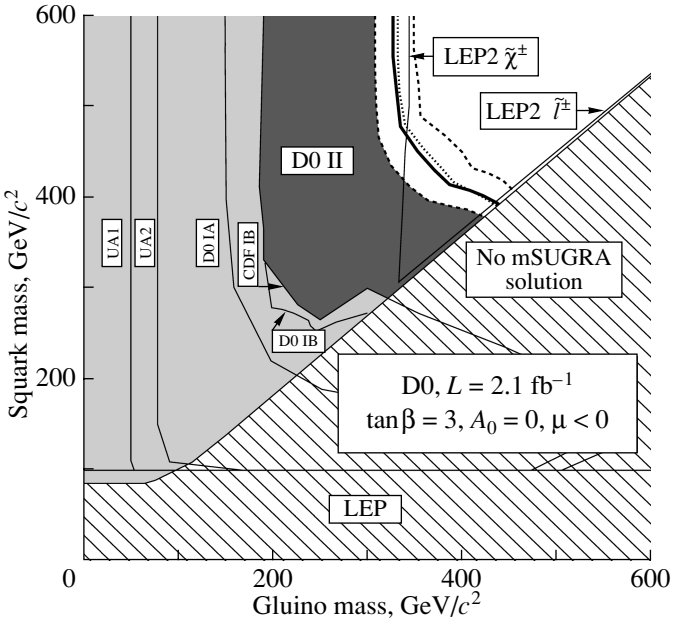

Fig. 1. Region spanned by the squark mass and the gluino mass and excluded on the basis of a data analysis. The expected upper limit (in the absence of a signal) is represented by the dotted curve. The results of earlier experiments are given for the sake of comparison.

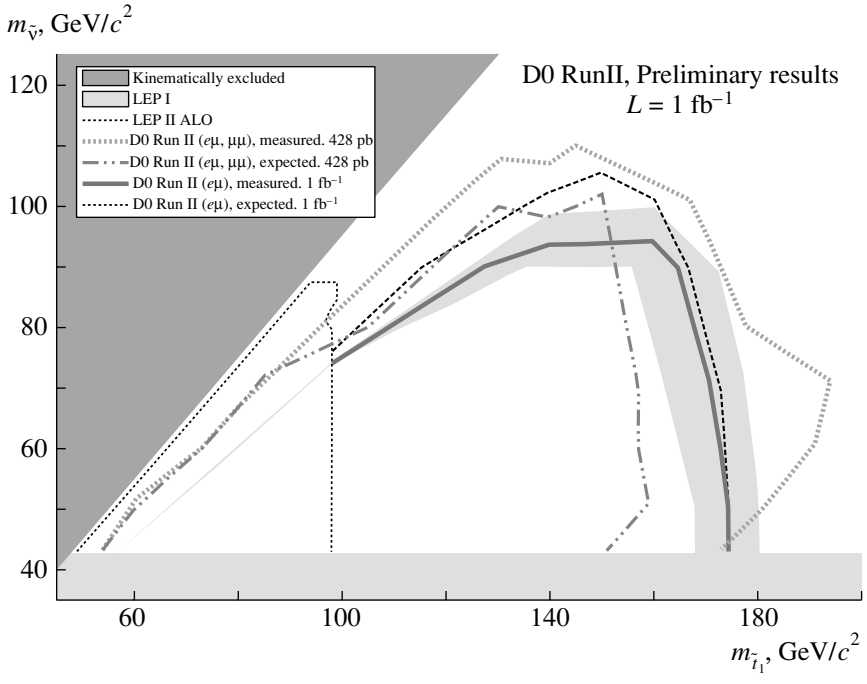

Fig. 2. Region excluded in the $(m_{\tilde{t}}, m_{\tilde{\nu}})$ mass plane on the basis of a data analysis along with the results of earlier experiments.

be the lightest supersymmetric particle. Thus, two oppositely charged leptons, two jets formed by b quarks, and a large missing energy carried away by the lightest supersymmetric particle are produced in the final state.

Processes leading to the production of isolated pairs of electrons and muons, $Z/\gamma^* \to \tau^+\tau^-$, WW, WZ, ZZ, and $t\bar{t}$, are dominant background processes here. The PYTHIA generator [5] was used to estimate the contribution of these backgrounds. Events in which electrons, muons, or jets were misidentified or in which the missing energy was measured

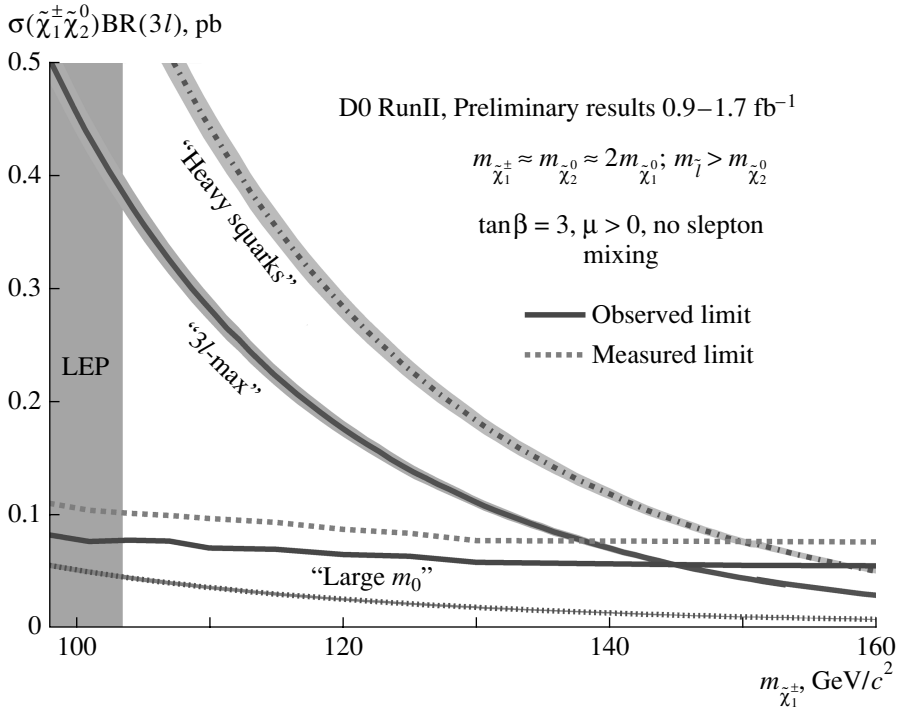

Fig. 3. Upper limit on the quantity $\sigma(\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0)\mathrm{BR}(3l)$ versus the $\tilde{\chi}_1^{\pm}$ mass and comparison with the values expected for three scenarios of the mSUGRA model (see main body of the text).

incorrectly were yet another background source. The background from such processes was estimated directly on the basis of data.

After the application of all selections and cuts to data [9], there remained 61 events, while the estimation of the background from Standard Model processes yielded 64 ± 4(stat.) events. Thus, we can conclude that no evidence in favor of the existence of the supersymmetric partner of the t quark was discovered within the statistical sample under study and within the topology being considered. Limits on the $\tilde{t}$ mass versus the $\tilde{\nu}$ mass were obtained at a 95% C.L., and the results are presented in Fig. 2. At large values of the mass difference $m_{\tilde{t}} - m_{\tilde{\nu}}$, the resulting constraint on the mass of the lightest supersymmetric partner of the t quark proved to be (at a 95% C.L.) $m_{\tilde{t}} > 175$ GeV$/c^2$.

2.3. Searches of Supersymmetric Partners of Gauge Bosons

Supersymmetric partners of gauge bosons were sought in channels featuring three final-state leptons and a large missing energy. The double production of charged ($\tilde{\chi}_1^{\pm}$) and neutral ($\tilde{\chi}_2^0$) superpartners, which subsequently decay to leptons and the lightest supersymmetric particle through intermediate gauge bosons and sleptons ($p\bar{p} \to \tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to lll\nu\tilde{\chi}_1^0\tilde{\chi}_1^0$), are the most probable processes involving supersymmetric particles and leading to the topology in question at hadron colliders. In the D0 experiment, particle-type identification was required for only two leptons in order to improve the detection efficiency for such processes—that is, final states featuring $ee, \mu\mu, e\mu$ + an isolated track in the neutral tracker system and a large missing energy were considered [10, 11].

Of particular interest is the case where the intermediate-slepton mass is slightly less than the $\tilde{\chi}_2^0$ mass. The transverse momentum of the third lepton may then be quite small, and so will accordingly be the detection efficiency for such a lepton. In this case, topology featuring two likely charged leptons and a large missing energy is used in searches for supersymmetric particles [12].

A new combined result for all of the topologies considered above was obtained in 2008 [10]. The total statistical sample corresponded to the accumulated luminosity of 1.7 fb^{-1}. For three scenarios of the mSUGRA model, Fig. 3 displays the resulting upper limit on the cross section for the production of suparsymmetric particles versus the $\tilde{\chi}_1^{\pm}$ mass. Within the large-m_0 scenario, where sleptons have a rather high mass, W/Z proves to be dominant, causing a relatively low probability of decay to three leptons. On the contrary, the $3l$-max scenario corresponds to the assumption of relatively light sleptons ($m_{\tilde{l}}$ is only

slightly less than $m_{\tilde{\chi}_2^0}$). In this case, the probability of decay to three leptons is maximal. Within the heavy-squark scenario, which is the last of the three ones considered here, the cross section for the production of $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ pairs is maximal.

A new lower limit on the $\tilde{\chi}_1^{\pm}$ mass was obtained within the $3l$-max scenario: $m_{\tilde{\chi}_1^{\pm}} > 145$ GeV$/c^2$.

3. SEARCHES FOR LEPTOQUARKS

The existence of leptoquarks, which are scalar and vector bosons having a fractional electric charge (an integral multiple of 1/3), carrying both lepton and quark quantum numbers, and decaying to a lepton and a quark are predicted in many extensions of the Standard Model, such as Grand Unified Theories (GUT), technicolor, and various theories admitting a composite structure of quarks. Concurrently, one assumes that leptoquarks may decay only to leptons and leptoquarks of the corresponding generations; therefore, one discriminates between leptoquarks of the first, second, and third generations. Double-production processes are a dominant mechanism that leads to the production of leptoquarks at hadron colliders. In this case, the cross section for the production of a leptoquark pair depends on the leptoquark mass, but it is independent of leptoquark coupling to the corresponding lepton and quark. If we denote by $\beta = \mathrm{BR}(LQ \to lq)$ the probability of the decay $LQ \to lq$, then $\mathrm{BR}(LQ \to \nu q) = 1 - \beta$ and $\mathrm{BR}(LQ\bar{LQ} \to l\nu qq) = 2\beta(1-\beta)$.

In 2008, the D0 Collaboration presented the results of searches for leptoquarks of all three generations.

3.1. Searches for First-Generation Scalar and Vector Leptoquarks

In the D0 experiment, the double production of first-generation scalar and vector leptoquarks in the process $p\bar{p} \to LQ_1\bar{LQ}_1 \to eeqq$ was sought on the basis of a statistical sample that corresponds to the accumulated luminosity of 1.02 fb^{-1} [13]. In that case, $\beta = 1$.

The presence in the final state of two high-energy electrons and two jets of high transverse energy is a signature for seeking the double production of leptoquarks. The processes $Z + jets \to e^+e^- + jets$ and $Z + jets \to \tau^+\tau^- + jets$, $t\bar{t}$ followed by decay through the dilepton channel, $WW, ZZ, WZ + jets$ processes, and background from QCD processes involving jet formation are dominant background sources here. In estimating the contribution of the majority of the background processes, use was made of a simulation on the basis of the PYTHIA [5] and ALPGEN [4] codes; the contribution of the background from QCD processes was assessed with the aid of experimental data. Processes involving leptoquarks were simulated by means of the PYTHIA [5] and CompHEP [7] codes, VM-type leptoquarks ($T_3 = -1/2$, $Q_{em} = +1/3$, and the $LQ{-}q{-}l$ coupling constant was $\lambda_{\text{eff}} = e$) being considered in the case of vector leptoquarks. In this model, the cross section for the double production of leptoquarks depends on the leptoquark mass and on the so-called anomalous coupling constants k_G and λ_G. Three sets of values were considered for these coupling constants: $k_G = 1$ and $\lambda_G = 0$ (minimum coupling constants, MC), $k_G = 0$ and $\lambda_G = 0$ (Yang–Mills coupling constants, YM), and $k_G = -1$ and $\lambda_G = -1$ (minus–minus coupling constants, MM) [14].

No evidence in favor of the double production of first-generation leptoquarks in the channel $p\bar{p} \to LQ_1\bar{LQ}_1 \to eeqq$ was found upon the application of all triggering conditions, selections, and cuts [13]. An upper limit on the cross section for the double production of second-generation leptoquarks was determined versus the leptoquark mass; the results are shown in Fig. 4 both for scalar and for vector leptoquarks for all three sets of values for the anomalous coupling constants. The corresponding lower limit on the mass of the first-generation scalar leptoquark was 292 GeV$/c^2$ ($\beta = 1$, at a 95% C.L.); the lower limit on the vector-leptoquark mass at anomalous-coupling-constant values from the above three sets was 350 GeV$/c^2$ (MC), 410 GeV$/c^2$ (YM), and 458 GeV$/c^2$ (MM).

3.2. Searches for Second-Generation Scalar Leptoquarks

By using a statistical sample that corresponds to the accumulated luminosity of 1.0 fb^{-1}, the double production of second-generation scalar leptoquarks was sought in the processes $p\bar{p} \to LQ_2\bar{LQ}_2 \to \mu\mu qq$ and $p\bar{p} \to LQ_2\bar{LQ}_2 \to \mu\nu qq$ (at $\beta = 1$ and 0.5, respectively) [15]. The choice of $\beta = 0.5$ maximizes the corresponding decay probability, $\mathrm{BR}(LQ_2\bar{LQ}_2 \to \mu\nu qq) = 0.5$.

Here, $W + jets$, $Z + jets$, and $t\bar{t}$ processes and QCD processes leading to jet production are dominant background sources. A neuron network on the basis of the kNN algorithm (k-nearest-neighbors algorithm) was used to separate processes presumably involving leptoquark production from background processes.

The respective analysis did not reveal any significant deviations from Standard Model predictions.

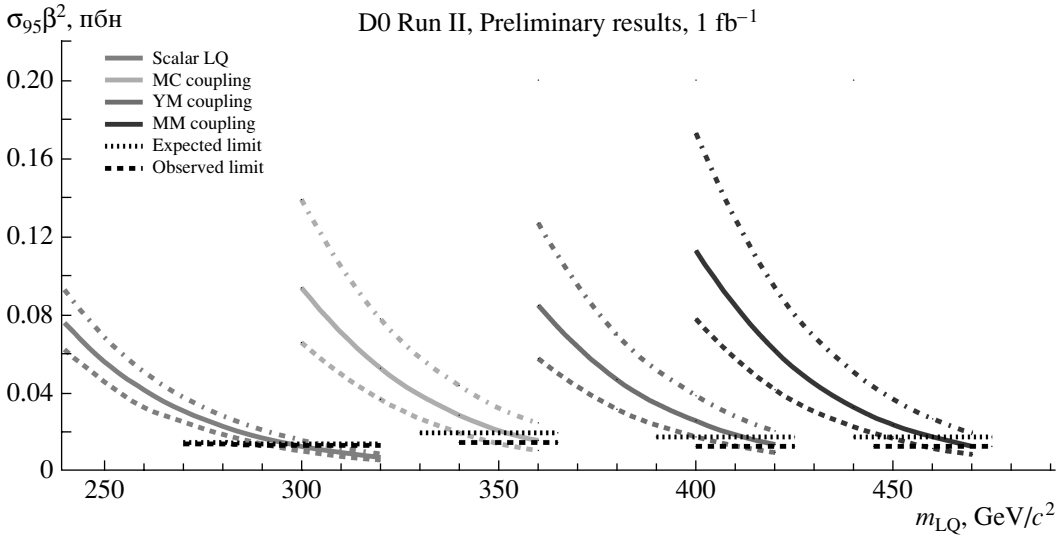

Fig. 4. Upper limit on the cross section for the double production of first-generation leptoquarks (scalar and vector ones for three various values of "anomalous" coupling constants) versus the leptoquark mass along with the cross-section values expected in the leading order (LO) for various values of the renormalization scale ($2m_{\mathrm{LQ}}$, m_{LQ}, $m_{\mathrm{LQ}}/2$).

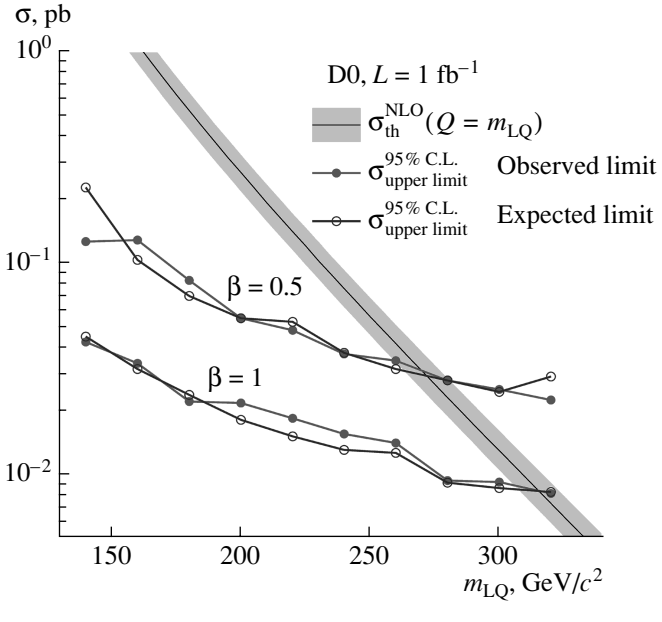

Fig. 5. Upper limit on the cross section for the double production of second-generation scalar leptoquarks (at a 95% C.L.) versus the leptoquark mass and β along with theoretical predictions in the next-to-leading order (NLO).

An upper limit on the cross section for the double production of second-generation leptoquarks was determined as a function of the leptoquark mass; the results are shown in Fig. 5 for the two channels being considered. The respective lower limit on the mass of the second-generation scalar leptoquark proved to be 270 GeV/c^2 ($\beta = 0.5$, at a 95% C.L.) or 316 GeV/c^2 ($\beta = 1$). The previous result obtained in the the CDF experiment for the lower limit on the mass of the second-generation scalar leptoquark was 208 GeV/c^2 (combined statistics for the $\mu\mu qq$, $\mu\nu qq$, and $\nu\nu qq$ channels) [16].

3.3. Searches for Third-Generation Scalar Leptoquarks

Third-generation leptoquarks decaying to a tau lepton and a b quark were considered [17]. In this analysis, it was required that one of the tau leptons decay through the channel $\tau \to \mu\nu_\mu\nu_\tau$ and that the

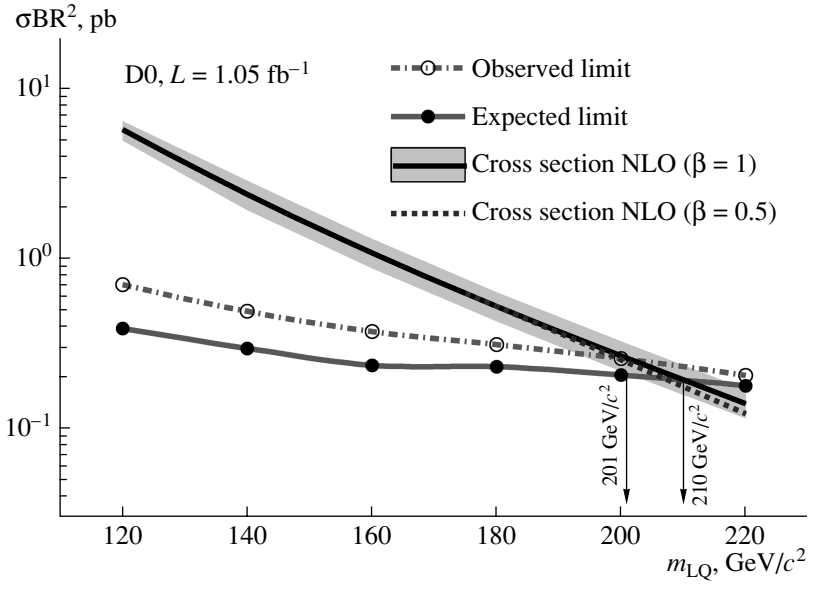

Fig. 6. Upper limit on the cross section for the double production of second-generation scalar leptoquarks (at a 95% C.L.) versus the leptoquark mass along with theoretical predictions in the next-to-leading order (NLO). The dotted curve corresponds to taking into account the decay $LQ_3 \to \nu_\tau t$ (at $\beta = 0.5$ and $m_t = 175$ GeV/c^2).

other decay through the hadronic channel. Thus, the final state would feature two b-quark jets, μ, τ, and a large missing energy. The total statistical sample of events used in the analysis under discussion corresponded to the accumulated luminosity of 1.05 fm^{-1}.

A dominant contribution to the background comes from $W/Z + jets$, $t\bar{t}$, WW, WZ, and ZZ Standard Model processes and various QCD processes leading to jet formation. They were simulated with the aid of ALPGEN [4] and PYTHIA [5] generators, and a simulation of tau-lepton polarization and decays was performed by means of the TAUOLA code [18]. The background from QCD processes was estimated directly on the basis of experimental data.

After the application of all selections and cuts [17], one event was selected, the expected background from Standard Model processes being 4.8 ± 1.0(stat.) events. Figure 6 shows the respective upper limit on the cross section for the production of third-generation leptoquarks versus their mass. The lower limit on the mass of this leptoquark proved to be 210 GeV/c^2 ($\beta = 1$, at a 95% C.L.). The previous result for this channel was 99 GeV/c^2 [19, 20].

3.4. Searches for Scalar Leptoquarks and T*-Odd Quarks in Topologies Involving Acoplanar Jets and a Large Missing Energy*

Interest in topologies featuring acoplanar jets and a large missing energy is motivated by the possibility of seeking, within them, both leptoquarks decaying to a neutrino and quark ($\beta = 0$) and T-odd quarks, which are introduced in the Little Higgs T-parity (LHT) model proposing, in just the same way as supersymmetry, a solution to the hierarchy and dark-matter problems [21]. In this model, one introduces the concept of T parity (which is some kind of an analog of R parity in supersymmetric models) and puts in correspondence so-called T-odd particles to Standard Model particles, which are naturally T-even. Six new T-odd quarks correspond to the left-handed quarks of the Standard Model. The lightest T-odd particle, which is sometimes referred to as a heavy photon ($\tilde{A}_H$), is weakly interacting and stable, providing a natural solution to the dark-matter problem. In contrast to what we have in supersymmetric models, T-odd particles have the same spin as their Standard Model partners; moreover, some states of the Standard Model—for example, right-handed quarks and gluons do not have T-odd partners in the LHT model. In the majority of cases, T-odd quarks decay through the channel $\tilde{Q} \to q\tilde{A}_H$, in which case $\tilde{A}_H$ escapes detection, contributing to the missing energy.

In the D0 experiment, searches for scalar leptoquarks and T-odd quarks within the topology being considered were performed on the basis of a statistical sample that corresponded to the accumulated luminosity of 2.5 fb^{-1} [22]. The process $Z \to \nu\bar{\nu} + jets$ is a dominant Standard Model background process here. Processes like $W \to l\nu + jets$ also contribute to the background in the case where the product lep-

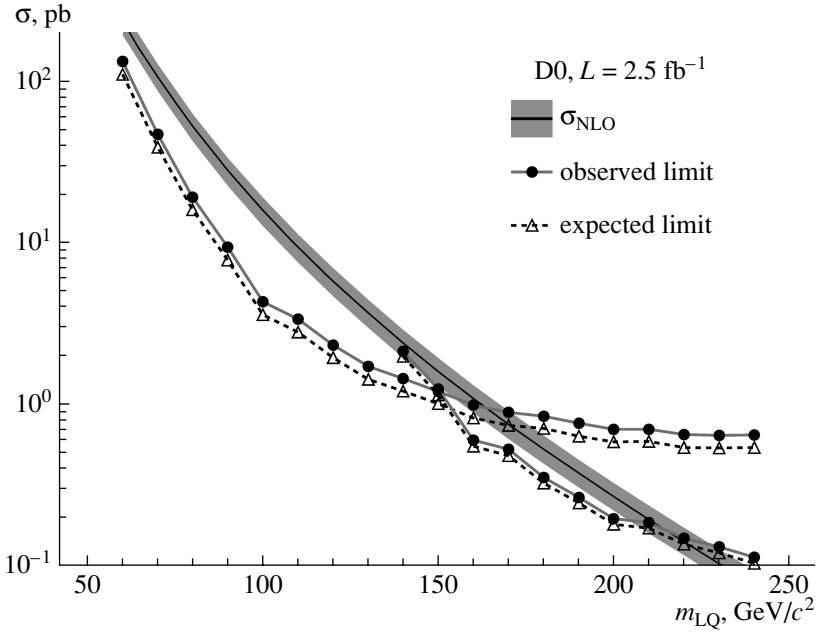

Fig. 7. Upper limit on the cross section for leptoquark production ($\beta = 0$) as a function of the leptoquark mass (at a 95% C.L.) for two different selection criteria optimized for $m_{\mathrm{LQ}} = 140$ and 200 GeV/c^2. Also shown in this figure is the theoretical prediction obtained for this cross section in the next-to-leading order (NLO).

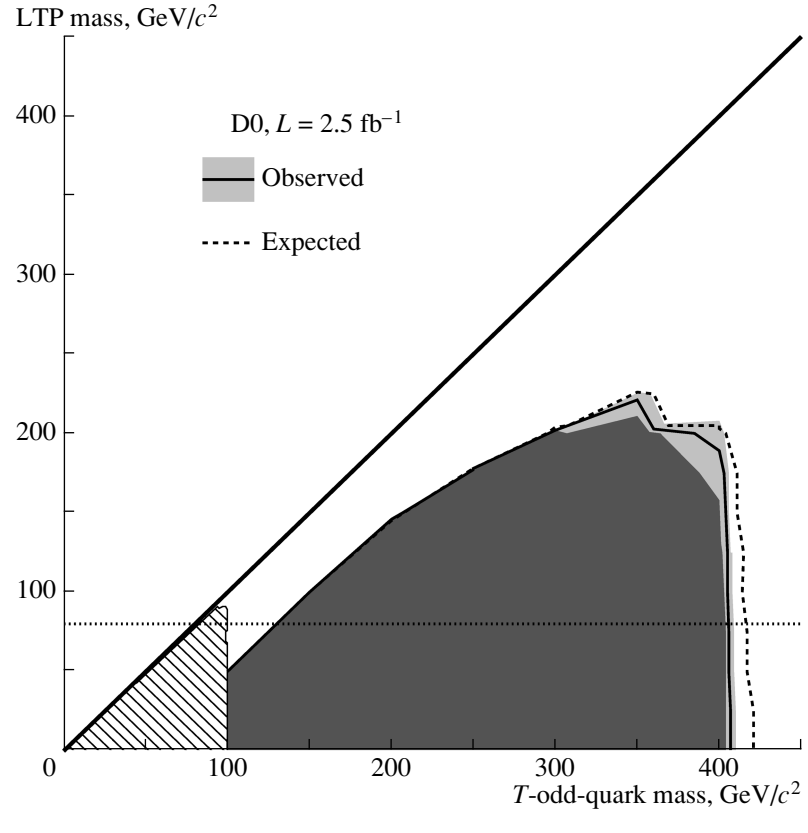

Fig. 8. Region excluded in the $(\tilde{Q}, \tilde{A}_H)$ mass plane on the basis of a data analysis. The shaded region corresponds to the results obtained at LEP. The region below the horizontal dotted straight line was excluded owing to precision measurements of Standard Model parameters.

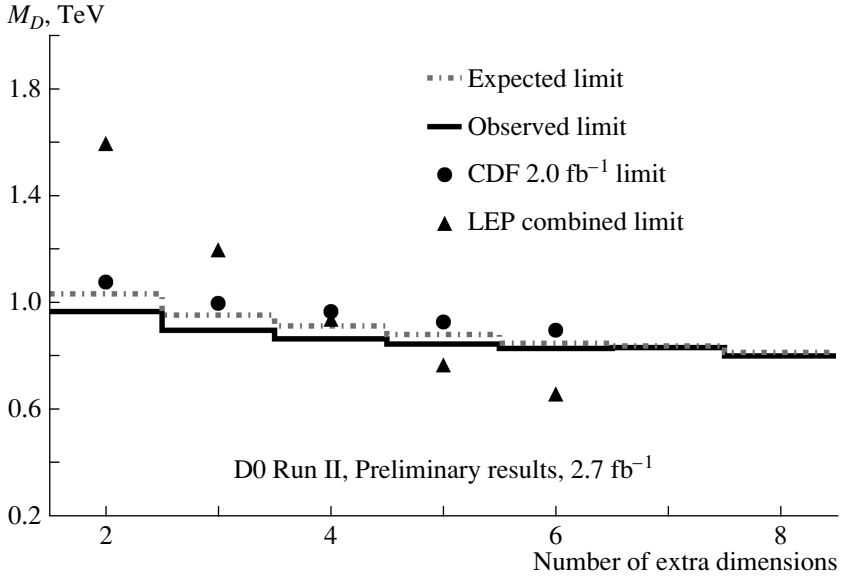

Fig. 9. Lower limits on the fundamental Planck scale M_D versus the number of extra dimensions (at a 95% C.L.) along with the results of previous experiments.

ton has escaped detection or identification. Moreover, QCD processes leading to the production of several jets can also make a contribution to the background if the energy of one or more jets was inappropriately measured, which may lead to an erroneously large missing energy.

The respective data analysis did not reveal any significant deviations from Standard Model predictions. An upper limit as a function of the leptoquark mass was set on the cross section for scalar-leptoquark production, and the results are presented in Fig. 7. The respective lower limit on the leptoquark mass proved to be 205 GeV/c^2 ($\beta = 0$, at a 95% C.L.). The previous result obtained in the D0 experiment for $\beta = 0$ was 136 GeV/c^2 [23]. In the ($\tilde{Q}$, $\tilde{A}_H$) mass plane, the region excluded from the consideration was determined for T-odd quarks owing to the relevant data analysis (see Fig. 8). For a large mass difference between $\tilde{Q}$ and $\tilde{A}_H$, the lower limit on the mass of the T-odd quark was 404 GeV/c^2.

4. SEARCHES FOR EXTRA SPATIAL DIMENSIONS

In addition to supersymmetric models and the Little Higgs model, one can try to solve the hierarchy problem by invoking models that involve extra spatial dimensions [24]. Upon the introduction of n extra dimensions, the Planck scale in four-dimensional space is given by $M_{\rm Pl}^2 = 8\pi M_D^{n+2} R^n$, where M_D is the fundamental Planck scale in $(4+n)$ space and R is the radius of compactification of extra spatial dimensions in units of the Planck length. Thus, we see that, if R is much larger than the Planck length and if n is quite large, we will have a relatively small value of M_D. In models featuring extra spatial dimensions, the gravitational field appears in the form a set of discrete energy states referred to as Kaluza–Klein states. Kaluza–Klein gravitons ($G_{\rm KK}$) are massive, noninteracting, and stable particles, which can be discovered by a large missing energy in an event.

In the D0 experiment, extra spatial dimensions were sought in the process $q\bar{q} \to \gamma G_{\rm KK}$ on the basis of a statistical sample that corresponded to an accumulated luminosity of 2.7 fb^{-1} [25]. The presence of a high-energy photon and a large missing energy in an event is accordingly a signature for these searches. The process $Z + \gamma \to \nu\bar{\nu} + \gamma$ is the only Standard Model background process that has this signature. Moreover, a nontrivial contribution to the background comes from the process $W \to e\nu$ if the product electron is misidentified as a photon, the $W + \gamma$ process in which the lepton from the decay of the W boson was lost, or $W/Z + jets$ processes in which a jet was misidentified as a photon.

An analysis along these lines made it possible to select 51 events, the background level being 49.9 ± 4.1(stat.) events; one can readily see that the result in question complies well with the Standard Model. Lower limits on M_D were determined for $n = 2$–8, and the results are presented in Fig. 9 along the results of earlier measurements.

5. SEARCHES FOR CHARGED LONG-LIVED PARTICLES

The existence of massive charged particles is predicted in several extensions of the Standard Model. For example, the lightest superpartner of the tau lepton ($\tilde{\tau}_1$) or the lightest chargino are such particles in some supersymmetry models.

In the D0 experiment, the double production of such massive long-lived (in the sense that the respective lifetime is sufficiently long for the escape from the detector to be possible) particles were sought on the basis of a statistical sample that corresponded to the accumulated luminosity of 1.1 fb^{-1} [26]. In addition, it is necessary that such particles be detected in the external muon system of the D0 detector, but, in relation to muons, they must have a much lower speed and, accordingly, a much longer time of flight. The decay $Z/\gamma^* \to \mu^+\mu^-$ is a dominant background process here if the muon time of flight was measured incorrectly.

Ultimately, the data analysis revealed no evidence in favor of the production of charged long-lived particles. Upper limits on the cross section for the double production of such particles were obtained versus their mass. Lower limits on the mass of such particles from the analysis in question were 206 GeV/c^2 in the case of the gauginos (supersymmetric partners of gauge bosons) and 171 GeV/c^2 in the case of higgsinos (supersymmetric partners of Higgs bosons). The previous limit obtained at LEP for the mass of long-lived charginos was 103.5 GeV/c^2.

6. CONCLUSIONS

Despite all of the problems inherent in the Standard Model, it works astonishingly well, and the latest results obtained in experiments at the Tevatron have only confirmed this. So far, no data that would be indicative of the existence of new physics beyond the Standard Model have been obtained either in the D0 or in the CDF experiment, even though the searches in question have covered a very broad range of lines of research (only some of them have been listed in the present article). It should be noted, however, that the results considered above were obtained on the basis of a statistical sample that corresponded to an accumulated luminosity of about 1 to 3 fb^{-1}, but, to date, a statistical sample that corresponds to an integrated luminosity in excess of 5 fb^{-1} has been accumulated in the experiments at the Tevatron; moreover, it is planned to accumulate a statistical sample that corresponds to 8 or even 10 fb^{-1} by the end of accelerator operation. It is quite feasible that a two- to threefold increase in the statistical sample would lead to the discovery of new-physics effects even at the Tevatron. Moreover, the commissioning of the Large Hadron Collider would greatly improve the potential for such researches.

Much more detailed information about the work already performed and that under way in searches for new physics in the D0 and CDF experiments can be found on the corresponding web sites of the two experiments [28, 29].

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