Status of Experimental Searches at Colliders

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This document reports on the current status of the searches for Physics beyond the standard model performed by the high-energy-physics experiments located at the Tevatron and the HERA colliders. The main results from the analyses and their connection with possible extensions of the Standard Model are discussed.

1 Introduction

The standard model (SM) of elementary particles and fundamental interactions, however successful, is incomplete, since it does not explain the origin of electroweak symmetry breaking or the gauge hierarchy problem [1]. In addition some experimental observation are not included in the SM, as the gravitational interaction, the neutrino masses and the non-barionic content of the Universe (Dark Matter). These limitations lead to the need of introducing some additional components to the theory, extending the SM beyond its current structure. This extension is referred as *New Physics* and requires the presence of new particles and/or new interactions which would help to expand our knowledge about Nature by solving the limitations of the SM.

In order to test the possible existence of the New Physics, experiments taking place at the highest available energies are required. For this purpose, analyses performed at the LEP, HERA and Tevatron colliders are the most sensitive to the presence of interactions beyond the SM. The LEP accelerator, colliding e^- and e^+ finished operations in 2000 and therefore the results from the experiments have been extensively covered in the past. This report would not describe directly the analyses of the LEP data, but some of the results are still relevant and will be shown in comparison with the more recent updates from Tevatron and HERA.

The Tevatron accelerator has been during several years the most energetic collider in the world. Currently in operation for the run II, it collides protons and antiprotons at a center-of-mass energy of 1.96 TeV and has provided more than 7 fb^{-1} of data to the two experiments, CDF and DØ. With the current data sample, the analyses are sensitive to previously unexplored regions and being sensitive to very different new physics.

The HERA collider, in which interactions between protons and $e^\pm$ at a center-of-mass energy of 300/318 GeV were studied, finished operations in 2007. During two run periods, it provided 0.5 fb^{-1} of data to the two collider experiments, H1 and ZEUS. Due to the unique initial state at such energies, the searches for new physics and particles performed in this collider are competitive/complementary to LEP and Tevatron.

This report summarizes the status of the searches performed at the collider experiments in these accelerators. Due to space limitation it does not provide a full report on the current status on searches. The interested reader may check the specific references and web-pages of the experiments for that purpose.

2 Searches for supersymmetric particles

A proposed extension of the SM, supersymmetry (SUSY) [2] solves some of the indicated limitations of the SM by introducing a symmetry that relates particles of different spin. In these models, a new multiplicative quantum number, R-parity, is introduced to distinguish SUSY and SM particles, with R-parity = $(-1)^{3(\mathrm{B-L})+2\mathrm{S}}$ where B and L are the baryon and lepton numbers, and S is the spin. In case of R-parity conserving scenarios, SUSY particles are produced in pairs and ultimately decay into the lightest supersymmetric particle (LSP), which constitutes a valid candidate for cold dark matter. If unbroken, SUSY would predict the existence of partners of the SM particles sharing the same properties but the spin. Since no such particles have been observed, SUSY must be a broken symmetry, and more than a hundred new parameters enter the theory even in the minimally supersymmetric extension of the SM (MSSM [3]). The choice of mechanism for the SUSY breaking mediation and of the soft SUSY breaking terms determines the phenomenology and therefore the search strategies at colliders.

The most widely studied SUSY models involve mediation by gravitational interactions. In the minimal model of supergravity (mSUGRA), the vast SUSY parameter space is reduced to only five parameters that determine the low energy phenomenology from the scale of Grand Unification (GUT): the common scalar mass m_0, the common gaugino mass $m_{1/2}$, the common soft trilinear SUSY breaking parameters A_0, the ratio of the Higgs vacuum expectation values at the electroweak scale tanβ, and the sign of the Higgsino mass term sgn(μ). In most of the mSUGRA parameter space, the LSP is the lightest neutralino, sleptons are lighter than squarks, and the relation among gaugino masses is given by: $m_{\tilde{g}}/3 \simeq m_{\tilde{\chi}^{\pm}} \simeq 2m_{\tilde{\chi}_1^0}$. At hadron colliders, standard-SUSY searches based on these models focus on production of electroweak gauginos (chargino and neutralino), and on the search for squarks and gluinos.

In gauge-mediated SUSY breaking models (GMSB), the LSP is the gravitino, $\tilde{G}$, which has very low mass ($\ll$keV). The phenomenology depends on the nature of the next-to-lightest SUSY particle (NLSP), typically the lightest neutralino or the lightest stau, and on its lifetime. GMSB scenarios are defined by six parameters: the effective SUSY breaking scale Λ, the number of messenger fields N, the mass of the messenger field m_M, the gravitino mass factor C_G, tanβ and the sign of μ. In the context of standard GMSB models, coloured SUSY sparticles and first and second generation sleptons are expected to be heavy (>1 TeV), and gaugino pair production dominates.

As a consequence of the electroweak symmetry breaking, higgsinos and electroweak gauginos mix with each other to form four neutral and two charged mass eigenstates (neutralinos and charginos, respectively). For a large fraction of parameter space, these sparticles have low mass and the cross section of the associated production of chargino and neutralino is sizable. If sleptons are sufficiently light, leptonic decays such as $\tilde{\chi}^{\pm} \rightarrow \tilde{l}^{*}\nu \rightarrow l\nu\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0 \rightarrow \tilde{l}^{*}l \rightarrow l^{+}l^{-}\tilde{\chi}_1^0$ are enhanced, leading to very clean final states containing three isolated leptons and missing transverse energy ($\not\!\!E_T$). This signature has a very low expected background in the SM, but can be particularly challenging in regions of parameter space where lepton momenta are soft due to small mass differences of the SUSY particles. As a consequence, CDF and DØ search strategy is to require three charged leptons l ($l = e, \mu$) with minimum transverse momenta as low as possible, or two identified l and one isolated track ($t = e, \mu, \tau$). In the DØ search [6], additional categories of events including one identified μ, one hadronic τ and one isolated track or a

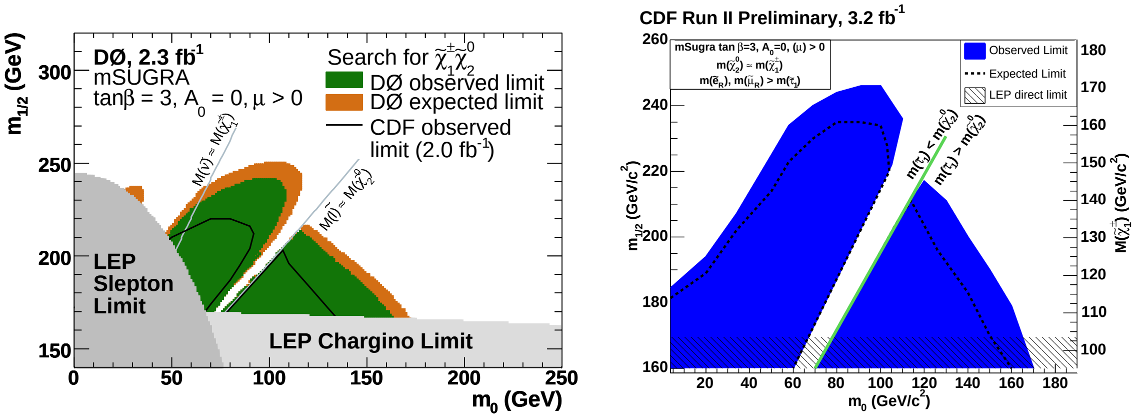

Figure 1: Limits obtained from the trilepton-signature searches performed by the DØ (left) and CDF (right) collaborations. Limits from LEP analyses are also shown.

second hadronic τ are considered, to enhance the sensitivity at large tanβ, where m($\tilde{\tau}$)$\ll$m($\tilde{l}$) and several τs are expected in the final state. The observed data are found to be consistent with SM predictions. In the CDF search [7], based on 3.2 fb^{-1} of data, one trilepton event passes all the stages of the selection, with a background expectation of 1.47$\pm$0.21 events; 6 events are observed in the leptons+track categories, with expectation of 9.38$\pm$1.44 events. Similarly, agreement between data and SM predictions is found for all lepton categories considered by the DØ analysis, based on 2.3 fb^{-1} of data. The results are translated into 95% confidence-level (C.L.) exclusion limits on the product of production cross section and leptonic branching fraction ($\sigma \times BR$). Within minimal supergravity, these limits translate into bounds on m_0 and $m_{1/2}$, for parameter tanβ=3, A_0=0, $\mu > 0$ and they are shown in Figure 1 (left). The gap between the two lobes in the plane corresponds to the parameter space regions where slepton masses are similar to neutralino masses and one of the leptons arising from $\tilde{\chi}_2^0 \to \tilde{l}^* l$ is too soft to be detected. Figure 1 (right) shows CDF upper limits on $\sigma \times BR$ as a function of the chargino mass, for m_0=60 GeV/c^2: chargino masses below 164 GeV/c^2 are excluded for this benchmark configuration.

The CDF collaboration recently reported on a search [8] for gaugino pairs using events with Z bosons, two or more jets and missing transverse energy. In regions of the parameter space where the mass of $\tilde{\chi}_2^0(\tilde{\chi}_1^\pm)$ is larger than the lightest neutralino by at least the mass of the $Z(W)$ boson, chargino-neutralino pairs decay into real W/Z bosons. The analysis, based on an integrated luminosity of 2.7 fb^{-1}, requires two electrons to reconstruct Z boson candidates, while W boson candidates are searched for in the di-jet invariant mass spectrum. The selection on the missing transverse energy is optimized to maximize the expected exclusion limit. Results are found in agreement with SM predictions. The extracted upper limits at 95% C.L. on $\sigma \times BR$ are between 3 and 1 pb as the $\tilde{\chi}_2^0$ mass increases.

The production of squarks ($\tilde{q}$) and gluinos ($\tilde{g}$), superpartners of quarks and gluons and therefore strongly-interacting particles, constitutes one of the most promising channels at the Tevatron. The cascade decay of gluinos and squarks into quarks and gluons will result in a final state consisting of several jets plus missing transverse energy coming from the undetected neutralinos. At low tanβ, depending on the relative masses of squarks and gluinos, different event topologies are expected. If squarks are significantly lighter than gluinos, $\tilde{g}$ production is enhanced. The squark tends to decay according to $\tilde{q} \rightarrow q\tilde{\chi}_1^0$, and a dijet+$\not\!\!E_T$ topology is favored. If gluinos are lighter than squarks, $\tilde{g}\tilde{g}$ process dominates. Gluinos decay via $\tilde{g} \rightarrow q\bar{q}\chi_1^0$, leading to topologies containing a large number of jets (≥ 4) and moderate $\not\!\!E_T$. For $m_{\tilde{g}} \approx m_{\tilde{q}}$, a topology with at least three jets in the final state is expected. As a result, CDF and DØ collaborations have optimized three different analyses, requiring at least 2, 3 or 4 jets in the final state and missing transverse energy. No significant deviation from SM predictions is found by the CDF [9] and DØ [10] searches, carried out using 2 and 2.1 fb^{-1} of data, respectively. The results are translated into 95% C.L. upper limits on the cross section for squark and gluino production in different regions of the squark-gluino mass plane. The CDF search excludes masses up to 392 GeV/c^2 at 95% C.L. in the region where gluino and squark masses are similar and gluino masses up to 280 GeV/c^2 for every squark mass. Similar exclusion limits are found by the DØ collaboration.

If tanβ is large, then there can be a large mass splitting in the scalar bottom sector, yielding a mass to the lightest state ($\tilde{b}$) in the reach of the Tevatron center of mass energy. Assuming R-parity conservation the only particle lighter than the $\tilde{b}$ is the LSP. At Tevatron, two different searches for sbottom are performed depending on its production mechanism. Direct $\tilde{b}$ production with the subsequent sbottom decay to a b-quark and the lightest neutralino ($\tilde{\chi}^0$), leads to the main signature for $\tilde{b}$ detection which includes two b jets and $\not\!\!E_T$. Due to the presence of these b jets in the final state, applying a b tagging algorithm is a mandatory tool to enhance the sensitivity by reducing backgrounds. The B hadrons in jets coming from b quark fragmentation have an average flight path of about 500 μm, yielding secondary vertices relative to the interaction point (primary vertex). The tagging algorithms are optimized to find these sencondary vertices using different approaches in each experiment.

Recent analyses by the CDF [11] and DØ [18] collaborations have exploited the properties of these final states to increase the sensitivity of the search for sbottom and have extended previous limits.

The CDF analysis was performed optimizing the selection of events with cuts on $\not\!\!E_T$ and in the scalar sum of the transverse energy of the jets in a dijet sample with the two jets tagged as coming from a bottom quark. Several optimization were performed in order to increase sensitivity in different regions of the phase space, basically identified with the mass difference between the sbottom and the neutralino. No significant discrepancy was observed between the observed number of events and the expectations from the SM. Plot on the right-side in Figure 2 show the obtained limit in the sbottom-neutralino mass plane. The DØ sbottom search was done as part of the analysis searching for third-generation leptoquarks decaying into bottom+neutrino, which yields a very similar topology (see below). 95% C.L. limit on sbottom mass was extended to $m(\tilde{b}) > 240$ GeV/c^2 for a neutralino mass smaller than 80 GeV/c^2, as shown in the left-side plot in Figure 2.

A parallel approach at Tevatron is to search for the $\tilde{b}$ production through gluino ($\tilde{g}$) decays. Under the assumption that mass of the $\tilde{g}$ is smaller than mass of the $\tilde{q}$, but larger than mass of the lightest $\tilde{b}$, the gluino pair production, $p\bar{p} \rightarrow \tilde{g}\tilde{g}$ is one of the dominant SUSY processes. After production the gluino decays to $\tilde{g} \rightarrow b\tilde{b}$ with the subsequent sbottom decay to a b-quark and $\tilde{\chi}^0$, $\tilde{b} \rightarrow b\tilde{\chi}^0$. Although involving more particles and constraints in the SUSY spectrum, this last approach is stronly motivated by the fact that the gluino pair production cross section is large ($\sigma(g\tilde{g}) \sim 10 \times \sigma(b\tilde{b})$) compared to direct sbottom pair production of similar mass. The analysis by the CDF collaboration [12], requiring large $\not\!\!E_T$ and at least two b-tagged jets finds a very good agreement with the SM predictions and the obtained limit excludes the presence

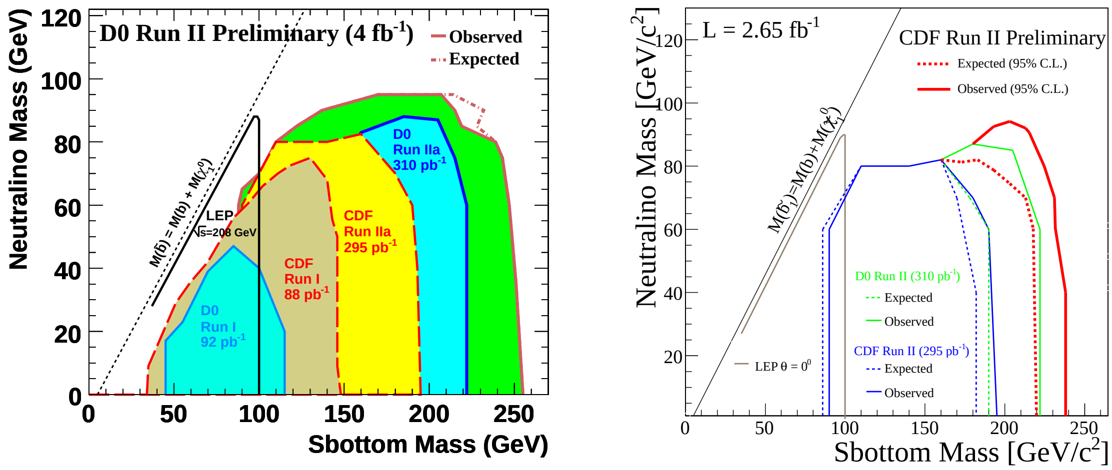

Figure 2: Limits on sbottom pair production at the Tevatron by the DØ (left) and CDF (right) collaborations. Limits from LEP analyses are also shown.

of gluinos with $m(\tilde{g}) < 350$ GeV$/c^2$ at 95% C.L. nearly independent of the $\tilde{b}$ mass.

As in the case of the sbottom, the mass splitting between the two stop quarks states $(\tilde{t}_1, \tilde{t}_2)$ may be large due to the large mass of the top quark. This gives the possibility that the lightest stop state, $\tilde{t}_1$, might be the lightest squark, and even lighter than the top quark.

Three different seaches for $\tilde{t}_1$ particles are performed at Tevatron depending on their decay mode. The first scenario is accessible in the range $m_{\tilde{t}_1} < m_b + m_{\tilde{\chi}^+}$ and $m_{\tilde{t}_1} < m_W + m_b + m_{\tilde{\chi}^0}$. The dominant $\tilde{t}_1$ decay mode in this model is the flavor changing process $\tilde{t}_1 \rightarrow c\tilde{\chi}^0$ which is typically assumed to occur with 100% branching fraction. The $\tilde{t}_1 \rightarrow t\tilde{\chi}^0$ decay is kinematically forbidden over the $\tilde{t}_1$ mass range currently accessible at Tevatron, and the tree level four-body decays $\tilde{t}_1 \rightarrow bff'\tilde{\chi}^0$ may be neglected. In this particular case the experimental signature consists of two c-jets and $\not{E}_T$ from the undetected $\tilde{\chi}^0$ [13]. A recent analysis by CDF [14] exploited the properties of jets originating from charm in order to reduce the background coming from bottom and light jets while enhancing the signal and the sensitivity of the analysis. This was achieved with a Neural-Network based discriminant using the displaced vertex and track properties of the jets tagged as originating from heavy-flavour jets. The use of this discriminant allows to increase the sensititivy of this search far beyond the increase in luminosity.

In the second scenario one assumes that BR$(\tilde{t}_1 \rightarrow bl\tilde{\nu}) = 1$, where $\tilde{\nu}$ is the scalar neutrino (sneutrino). Among possible stop decays, this final state is one of the most attractive from the experimental point of view; in addition to a b quark, it benefits from the presence of a lepton with high transverse momentum with respect to the beam axis. The sneutrino is either the LSP or decays invisibly: $\tilde{\nu} \rightarrow \nu\tilde{\chi}^0$ or $\nu\tilde{G}$ where the lightest neutralino, $\tilde{\chi}^0$, or the gravitino, $\tilde{G}$, is the LSP. The signal topology consists of two isolated leptons, $\not{E}_T$, coming mainly from undetected sneutrinos, and jets [15].

The third scenario happens when $\tilde{t}_1 \rightarrow b\tilde{\chi}^+ \rightarrow b\tilde{\chi}^0 l\nu$ assuming a 100% branching ratio of the stop squark into a b quark and chargino, and allow for the chargino to dileptons through a variety of channels. These stop events produce signatures similar to those of SM top quark

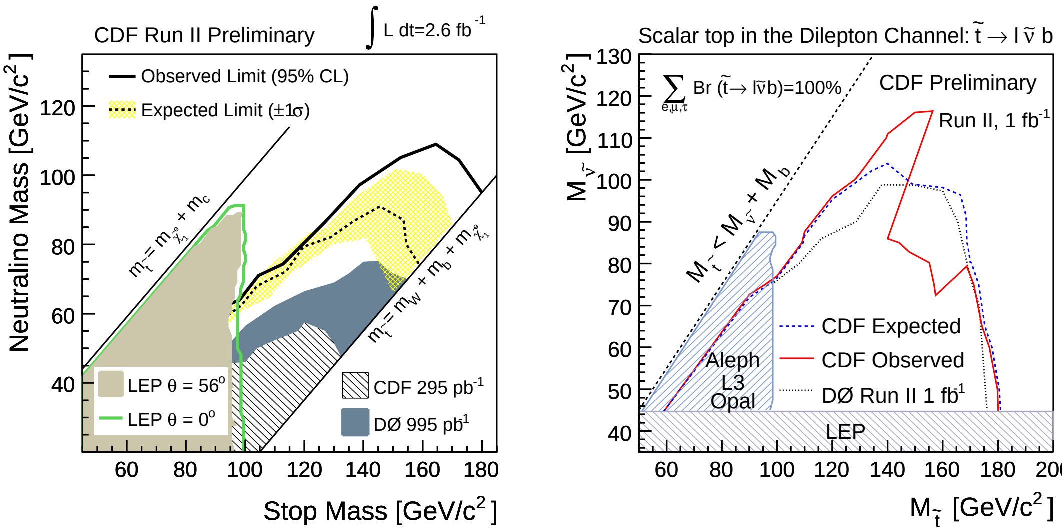

Figure 3: Limits for stop pair production at the Tevatron for the charm+LSP (left) and the lepton+bottom+LSP (right) decays.

decays, and could potentially be hiding in the top samples of the Tevatron data.

No significant deviation from the SM prediction was observed in any of the previous searches, and the results were used to extract exclusion limits for the cross section of the described process. Plots in Figure 3 show the exclusion limits at 95% C.L in the neutralino-stop mass plane for stop decaying into charm+neutralino, the exclusion limits at 95% C.L in the sneutrino-stop mass plane for stop decaying into $bl\tilde{\nu}$. Limits extracted in the third scenario may be found in reference [16].

3 SUSY Searches with photons

Gauge-Mediated Supersymmetry Breaking (GMSB) Models usually allow the neutralino to decay in a photon and a gravitino, which is the LSP as mentioned before. Under these assumptions the production of neutralinos that would eventually decay into gravitino and photon would provide a final state with two photons and $\not{E}_T$ from the escaping gravitinos. CDF has performed the search for this process [17] using the timing of the electromagnetic calorimeter to reject events that are out-of-sync with the interactions, which are mostly related to background such as cosmics. The analysis was performed by electing events containing two photons, large $\not{E}_T$ and having large H_T defined as the scalar sum of transverse energy of all objects.

The sensitivity was increased by using a probabilistic model to assign a significance of the observed $\not{E}_T$ in the event. The model accounts for resolution effects expected for the observed objects and provides a new handle to reject events in which the $\not{E}_T$ is originated by a mismeasured object. This tool also allows to estimate the QCD background from data, as done in this analysis.

With all the tools in hand, and after the final optimization, no events were observed, consistent with a standard model background expectation of 1.4±0.4 events. This results extend the sensitivity to previously unexplored regions and the good agreement in the final selection between data and SM expectation translates into a 95% C.L. limit set to a mass of the neutralino larger than 149 GeV/c^2 for a lifetime smaller than 2 ns. It should be noted that the use of timing to reject background makes this search insensitive to long-lived neutralinos.

4 Searches for leptoquarks

Other possible extensions of the SM suggests the existence of a new kind of particle, generically known as *leptoquarks* having both barion and lepton number different from zero. These particles are scalar or vector bosons which would mediate lepton-quark transitions in the different GUT or compositeness models, among others. At colliders, the searches are optimized for different final states, depending on the generation of the leptoquark, which determines to which families they couple. For this reason, interpretation of the results are commonly done in different parameter planes.

Related to the third generation, DØ has performed a recent search [18] of leptoquarks decaying to bottom and neutrino by requiring bottom tagging of the final jets. The analysis did not find a significant excess in the data that might be attributed to leptoquarks and therefore a limit was set which excludes at the 95% C.L. third generation scalar leptoquarks with masses smaller than 252 GeV/c^2.

Regarding leptoquarks, the experiments at the HERA collider are very competitive since HERA is the most efficient collider to produce leptoquarks that couple to the first generation, since they are produced in resonance. A recent analysis by H1 [19] of the full data sample look for leptoquarks as a resonance in the invariant mass of the final lepton and the leading jet. Good agreement with the SM expectation is observed, as shown in the upper plots in Figure 4 for the electron and positron data samples and for neutral-current (left plots) and charged-current (right plots) interactions. Out of this agreement, 95% C.L. limits were obtained and are shown in the lower plots in Figure 4 compared to the limits obtained at LEP and at Tevatron. The current best limit obtained by the ZEUS collaboration is $m/\lambda > 0.41 \quad 1.88$ TeV/c^2 done in the analysis searching for contact interactions [20].

It should be noted that the limits at HERA goes beyond the actual kinematic limit due to the additional sensitivity achieved by the u channel.

5 Searches for resonances

Some extensions of the SM suggest the existence of new resonances which would eventually decay into known SM particles. In the case that the width is much smaller than the detector resolution related to the corresponding objects, the search may be performed in a model-independent way and just search for the presence of a resonance over the continuous spectrum. CDF [24] and DØ [25] have studied the distribution of the dielectron invariant mass in a clean event selection. The distributions in Figure 5 show the results from the two collaborations, in which no significant discrepancy has been found, although the CDF distribution shows a visible excess around $M(ee) > 240$ GeV/c^2 which is not confirmed by the DØ analysis with a larger dataset.

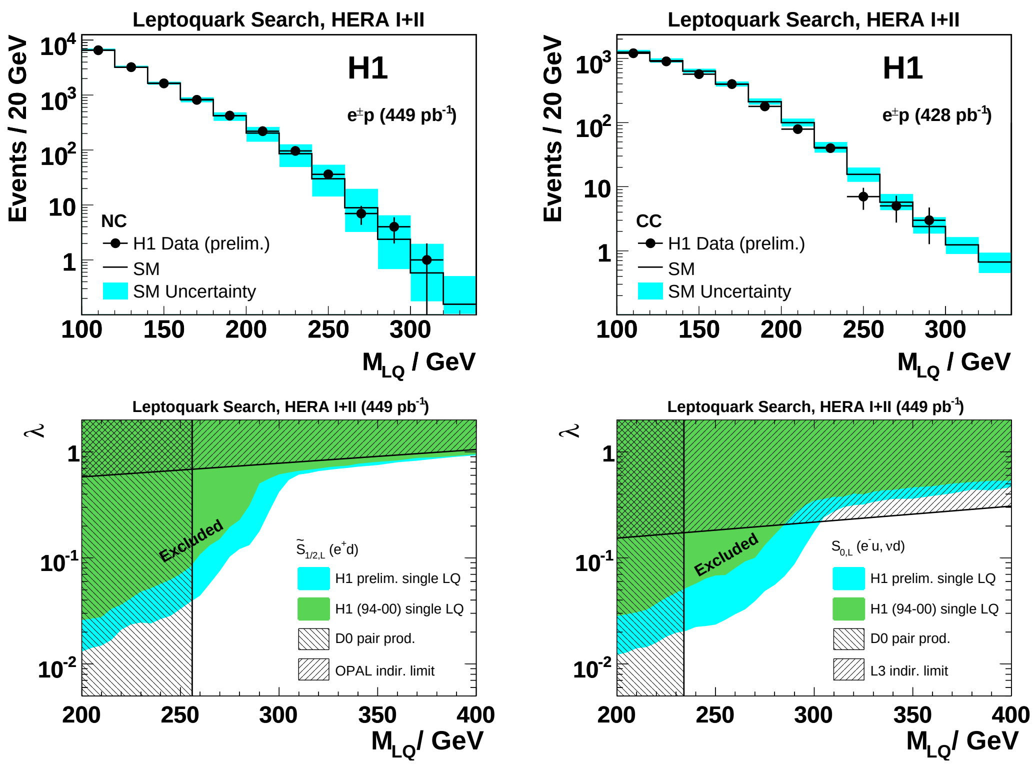

Figure 4: Distribution of the lepton+jet invariant mass and current leptoquark limits by the H1 search. See text for details.

Similar searches are done in the dimuon channel where the resolution commonly gets worse as the mass improves. For this reason, the CDF collaboration has performed the analysis [26] by looking for an excess in the distribution of the $1/m(\mu\mu)$ variable, for which the resolution is constant. In this analysis, done with 2.3 fb^{-1} of data, measurements are in good agreement with the SM predictions and no excess is observed. Limits are set for different models, and especifically a limit on the mass of a SM-like Z' of $m(Z') > 1.03$ TeV$/c^2$ at 95% C.L.

6 Searches for large extra-dimensions

If gravity propagates in 4 + n dimensions (as a difference to the other interactions, confined in 3+1 dimensions), the effective Planck scale could be small (perhaps of the order of $\sim$ 1 TeV and gravity becomes comparable in strength to the electroweak interaction. The typical golden channel for this at Tevatron is the production of a single high-ET photon and $\not{E}_T$ from the undetected graviton, which is typically a Kaluza-Klein mode. Analyses looking for this signature have been performed by CDF [21] and DØ [22] using the Tevatron data. Good agreement with the SM expectations has been observed in both cases and the results were used to set limits on the extradimension scale at the order of 1 TeV. These limits are more stringent than those obtained at LEP for a number of extra dimensions larger than 3.

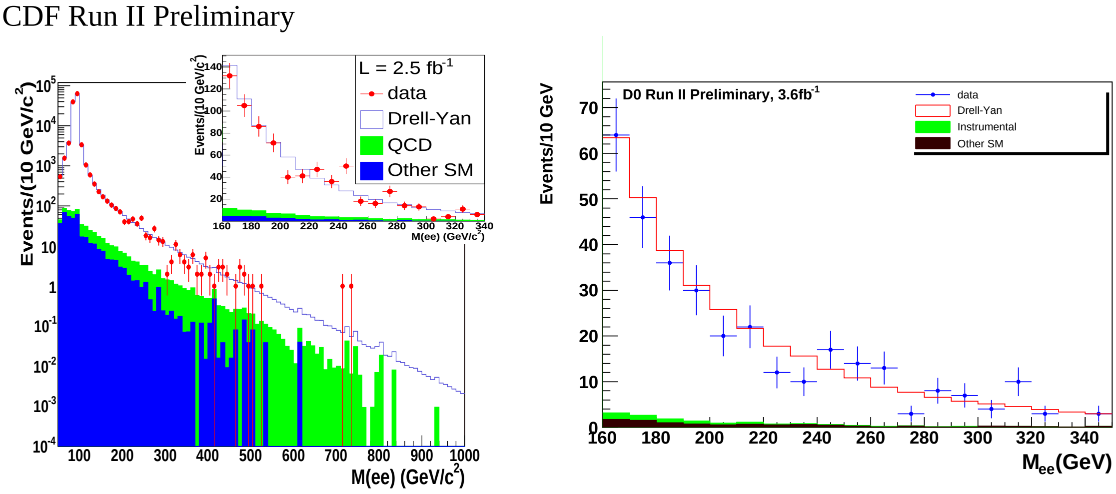

Figure 5: Invariant mass distribution for electron+positron pairs in the resonance search performed by the CDF (left) and DØ (right) Collaborations. See text for details.

At HERA the presence of extra dimensions may be observed as a deviation of the total ep cross section at high energies where gravity effects become comparable to the electroweak interaction. The contribution of the graviton exchange is described in the model as a coupling depending on the effective Planck scale (M_s), which sets the energy scale of the extra dimensions. The study of the high Q^2 distribution the ZEUS Collaboration [20] shows a good agreement with the SM expectations, as shown in Figure 6. A limit of $M_s > 0.94$ TeV at 95% C.L. has been set with the full dataset. Previous limits by H1 based on the Run I dataset the limit of $M_s > 0.48$ (0.72) TeV$/c^2$ [23] for a constructive (destructive) interference between the graviton and the electroweak boson exchange.

7 Multileptons at HERA

In the context of signature-based searches, the experiments are also performing analyses which are intended to look for striking final states for which the SM processes have very small cross section.

For this one of the most interesting signatures is the multilepton production at HERA, in which the HERA sample shows an excess in the positron data. Recently the two collaborations have performed a combined analysis [27] with their full data samples to extract the highest sensitivity to this final state.

In the analysis the data shows an excellent agreement for the electron data. As a function of the sum of the p_T of the leptons, the positron data shows good agreement for small values of that variable, but a clear excess of events for which that sum is larger than 100 GeV$/c^2$. Numbers in Table 1 summarizes the comparison in that region for the two data samples.

Final statistical significance of the excess in the positron data is 2.6σ but it should be remarked that most of the significance is coming from the H1 dataset.

Multi-Leptons at HERA (0.94 fb^{-1})				
$\sum P_T > 100/c^2$ GeV				
Data sample	Data	SM	Pair Production (GRAPE)	NC DIS + QEDC
e$^+$p (0.56 fb^{-1})	7	1.94 ± 0.17	1.52 ± 0.14	0.42 ± 0.07
e$^-$p (0.38 fb^{-1})	0	1.19 ± 0.12	0.90 ± 0.10	0.29 ± 0.05
All (0.94 fb^{-1})	7	3.13 ± 0.26	2.42 ± 0.21	0.71 ± 0.10

Table 1: Number of observed and expected events containing two or more high-p_T isolated leptons in the full HERA data. Events in which the sum of the p_T of the leptons is larger than 100 GeV/c^2 are counted and organize according to the charge of the initial lepton. The grand totals are also listed.

8 Searches of Hidden-Valley signatures

Hidden valley models – some of them including SUSY – introduce a new "hidden" sector, which is very weakly coupled to the SM particles. A recent DØ analysis [28] searches for a new light gauge boson, a dark photon (γ_D), considering a scenario in which SUSY particles are pair-produced and decay into SM particles and the lightest neutralino. The $\tilde{\chi}_1^0$ can decay into the hidden sector state (darkino, $\tilde{X}$) plus either a photon or a dark photon, the latter decaying through its mixing with a photon into fermion pairs. The branching fraction (BR) of $\tilde{\chi}_1^0 \rightarrow \gamma_D \tilde{X}$ is a free parameter of the model. If it is small, decays into γ dominate, and the signature is the same as in GMSB models. Due to the overwhelming SM jet backgrounds, dark photons are searched for in isolated electron or muon pairs. Events are required to contain two spatially close leptons, a photon and $\not\!\!E_T$ arising from the escaping darkinos. No evidence of dark photon signal is found. Limits are set on γ_D production cross section and interpreted as limits on the lightest chargino mass as a function of the dark photon mass and the neutralino branching fraction. Figure 7 shows the exclusion limit set by this analysis. It should be noted that the sensitivity gets worse when the branching ratio of the neutralino decaying to photon and darkino is small dure to the requirement of a photon in the final state. It also gets worse when that branching ratio approaches 100%. In this case this search is in fact less competitive when compared to the standard diphoton+$\not\!\!E_T$ GMSB seach.

In Hidden-Valley models another possible final state is given by the existence of long-lived particles which decay into a bottom-antibottom quark pair. This decay takes place inside the detector volume and further from the beam-axis than it is commonly used to reconstruct B-hadron decays and for that reason this kind of topology might have been missed in previous searches which include displaced vertices and decays. On the other hand this kind of analysis is very challenging since it require a good understanding of the material and the background due to particle-detector interactions (conversions, inelastic interaction with nuclei) or decays in flight of kaons (and others). The results of the search performed by DØ [29] were interpreted in a model in which the Higgs boson decays into the Hidden-Valley particles producing the b-quark pair. No significant discrepancy was observed in the properties of the two secondary vertices when comparing the data to the SM expectations and therefore limits were set that represent the first constraints at a hadron collider on pair-production of neutral long-lived particles decaying in distances of 1.6-2.0 cm.

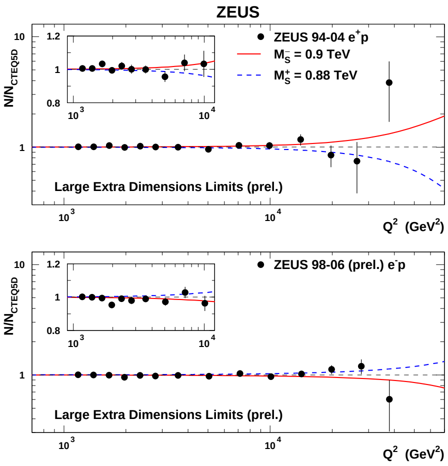

Figure 6: Ratio of the measurements to the SM expectation for the High-Q^2 cross section as measured by the ZEUS Collaboration in the positron (above) and electron (below) data samples.

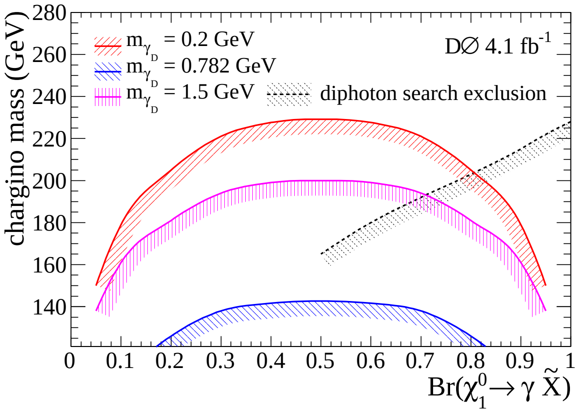

Figure 7: Limit in the chargino mass obtained from the Dark Photon search by the DØ Collaboration. Limit is plotted as a function of the neutralino branching ratio to photon+LSP and compared to the standard GMSB-based diphoton+$\not\!\!E_T$ search.

9 Global searches of New Phenomena

In order to avoid any possible bias from the assumed model and signature, a different strategy has been put in place which looks for discrepancies in all possible final states (and relevant variables). The advantage of this kind of studies is that they are completely independent of the model, and therefore avoid any bias from the assumptions on the structure of the New Physics. On the other hand, the interpretation of any observed discrepancy must be interpreted taking into account the large number of observables (as trial factors) and therefore the significance must be properly corrected.

H1 performed a global analysis of the full dataset studying all the possible final states [30] and found no significant discrepancy with the standard model prediction in the electron and positron data.

Both Tevatron experiments have performed these studies in their datasamples [31]. Although some discrepancies have been found, the related significances is not high enough to claim a deviation that cannot be explained by the SM predictions. Studies of the larger dataset currently being collected will be very helpful to clarify the situation in the distributions that are not correctly described by the predictions.

10 Conclusions

The most recent results on searches for physics beyond the SM at the HERA and Tevatron experiments have been reported. No evidence of New Physics has been found yet in both direct analysis and more inclusive searches. Out of these studies stringent exclusion limits have been extracted in several models.

Further analyses of the HERA and the Tevatron data could reveal hints of New Physics, or place more severe limits on the vast SUSY parameter space as we come into the LHC era.

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