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Searches for New Physics at D0 (non-SUSY)

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Abstract. The D0 experiment at the Fermilab Tevatron collider has already collected more than 4 fb^{-1} of integrated luminosity, allowing for a large number of new phenomena searches. Recent results are presented including compositeness searches, leptoquarks, large extra dimensions, Randall-Sundrum gravitons, and extra gauge bosons. No deviations from the standard model expectations are found, and the presented limits on new physics are in many cases the world's best.

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For all of the deficits of the standard model (SM) that we know about since many years – be it the non-unification of couplings at a high scale, the quadratic divergences in the loop corrections to the Higgs boson mass, or the lack of a decent dark matter candidate – a large number of solutions has been proposed. The most popular models of new physics involve without doubt supersymmetry. However, supersymmetry doesn't explain the number of fermion generations, or their mass spectrum and charges. In this talk, recent results from the D0 experiment for searches for manifestations of new physics are reported, in the areas of extra gauge bosons, leptoquarks, extra dimensions, and lepton compositeness. Searches for long-lived particles are presented in a separate talk. Details for all results can be found in [1].

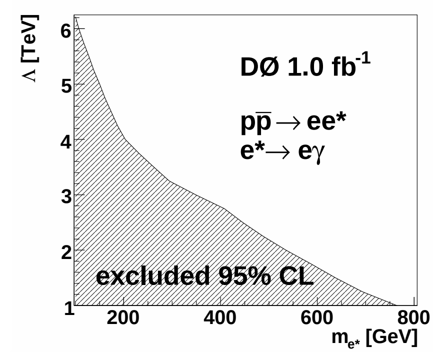

FIGURE 1. Exclusion region from the search for excited electrons produced in contact interactions in the decay mode $e^* \to e\gamma$.

LEPTON COMPOSITENESS: e^*

D0 has searched both for excited electrons and muons [2] as signs of lepton compositeness. Recently, an analysis of excited electron production has been published. D0 searched for associated production of an electron and an excited electron, with the latter decaying to an electron and a photon. The production is approximated as a contact interaction, while the decay is assumed to proceed either exclusively through a gauge interaction, or a combination of gauge and contact interactions, with the relative fraction of the two depending on the mass of the excited muon and the compositeness scale Λ. The DØ result, based on 1.0 fb^{-1} of data, is shown in Fig. 1, excluding $m_{e^*} < 756$ GeV for $\Lambda = 1$ TeV at 95% C.L.; depending on the value of Λ and the assumed branching fractions, masses up to about 1 TeV are excluded.

RESONANCES IN $Z+\gamma$

Many extensions of the standard model lead to the diboson final state $Z\gamma$. Examples include decays of a scalar Higgs boson, pseudo-scalar toponium, vector Z' bosons, and techniparticles. D0 has searched [3] for a narrow scalar or vector resonance in this channel, based on 1 fb^{-1} of data. Using both the e^+e^- and $\mu^+\mu^-$ decays of the Z, 49 events in the electron channel and 50 events in the muon channel have been found, consistent with expectations from SM processes. Upper limits of 0.19 (0.20) pb at 95% C.L. for the production of a scalar (vector) resonance with a mass of 600 GeV have been set. For a resonance mass of 140 GeV, the limits are 2.5 (3.1) pb.

LARGE EXTRA DIMENSIONS

Models postulating the existence of extra spatial dimensions have been proposed to solve the hierarchy problem posed by the large difference between the Planck scale

$M_{pl} \simeq 10^{16}$ TeV, at which gravity is expected to become strong, and the scale of electroweak symmetry breaking, $\simeq 1$ TeV. In the large extra dimensions model of Arkani-Hamed, Dimopoulos and Dvali, in which only gravitons propagate in the bulk but all standard model fields are confined to a 3-brane, a tower of Kaluza-Klein (KK) excitations of the graviton emerges. The graviton states are too close in mass to be distinguished individually, and the coupling remains small, but the number of accessible states is very large. It is therefore possible to produce gravitons which immediately disappear into bulk space, leading to an excess of events with a high transverse energy photon and large missing transverse energy. Using 2.7 fb^{-1} of data, D0 has updated [4] their published analysis, and set limits on the effective Planck scale between $M_D > 970$ GeV and $M_D > 816$ GeV at 95% C.L. for numbers of extra dimensions ranging from 2 to 8 (Fig. 2).

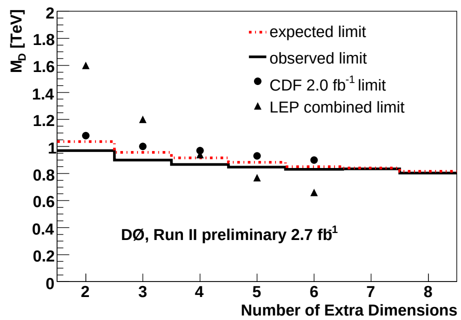

FIGURE 2. Limits on the effective Planck scale M_D as a function of the number of extra dimensions in the single photon channel, compared to previous results.

The virtual exchange of KK gravitons would modify the cross sections for SM processes like the production of fermion or boson pairs. The sensitivity is expressed in terms of the scale M_s, which is expected to be close to M_D. In a recent analysis [5] based on an integrated luminosity of 1.05 fb^{-1}, D0 has investigated the high mass dielectron and diphoton mass spectrum, and has found no indications for large extra dimensions. Limits on M_s are set as shown in Fig. 3, for example $M_s >$ 1.62 TeV for $n_d = 4$ at 95% C.L..

RANDALL-SUNDRUM GRAVITONS

In the model by Randall and Sundrum, gravity is located on a $(3+1)$-dimensional brane, the Planck brane, that is separated from the standard model brane in a fifth dimension with warped metric. In the simplest version of this model gravitons are the only particles that can propagate in the extra dimension. The gravitons appear as towers of KK excitations with masses and widths determined by model parameters. These parameters can be expressed in

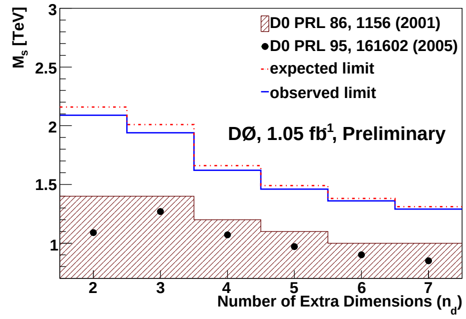

FIGURE 3. Limits on the effective Planck scale M_s as a function of the number of extra dimensions, compared to previous results.

terms of the mass of the first excited mode of the graviton, M_1, and the dimensionless coupling to the standard model fields, $k\sqrt{8\pi}/M_{pl}$. If it is light enough, the first excited graviton mode could be resonantly produced at the Tevatron.

D0 has published [6] new results in the search for Randall-Sundrum gravitons based on 1 fb^{-1}of data. The invariant mass spectrum in the e^+e^- and $\gamma\gamma$ final states has been used. General agreement between data and the background expectation is observed. Using a sliding mass window, upper cross section limits are derived, which are then translated into lower mass limits for the lowest excited mode of RS gravitons (Fig. 4). For a coupling parameter $k\sqrt{8\pi}/M_{pl} = 0.1$ (0.01), masses $M_1 < 900$ (300) GeV are excluded at 95% C.L..

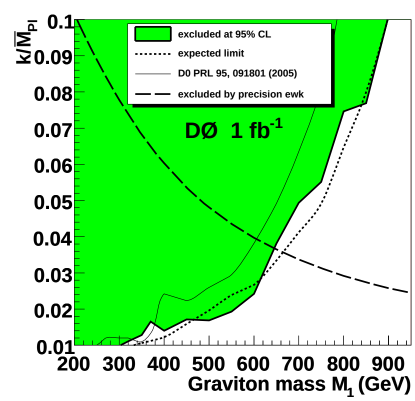

FIGURE 4. Excluded region in the plane of $k\sqrt{8\pi}/M_{pl}$ and graviton mass.

NEW CHARGED GAUGE BOSONS W'

A possible way of resolving the inherent problems of the standard model is by extending the gauge sector of the theory. New heavy gauge bosons are predicted in many extensions of the standard model. For example, in little Higgs models, the quadratically divergent radiative corrections to the Higgs mass are canceled individually, leading to the appearance of partners of the W and Z bosons at the TeV scale. In grand unified theories heavy partners of the electroweak bosons generally appear; the left-right symmetric model is a $SO(10)$ GUT extension of the SM, postulating the existence of a right-handed version of the weak interaction as well as an additional Z boson.Finally, the sequential standard model, where the couplings to quarks and leptons are as in the SM, may not be gauge invariant, but it serves as a good benchmark.

In the search for singly charged gauge bosons, D0 looked for a SM-like W' decaying to an electron and a neutrino [7]. The limit, obtained from a study of the transverse mass spectrum in 1 fb^{-1} of data, requires $m(W') > 1.0$ TeV at 95% C.L. (Fig. 5).

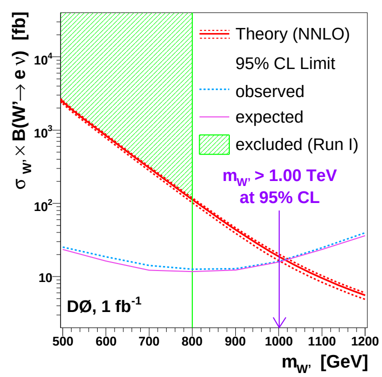

FIGURE 5. Cross section upper limits for the production of a SM-like W'.

LEPTOQUARKS

Leptoquarks are a natural consequence of the unification of quarks and leptons into a single multiplet, and as such are expected to be gauge bosons as well. While their masses may naturally be expected to be of the order of the unification scale, in some models they can be relatively light. Experimentally, it is customary to consider one leptoquark per generation. These are assumed to be very short-lived and decay to a quark and a lepton. The branching fraction to a charged lepton and a quark is then denoted as β. At hadron colliders, leptoquarks can be pair-produced through the strong interaction, or are singly produced. In the latter case the production cross section depends on the (unknown) quark-lepton coupling, which is generally taken to be of the same order of magnitude as the fine structure constant.

D0 has searched for leptoquarks of all three generations in different decay modes. A typical result is the

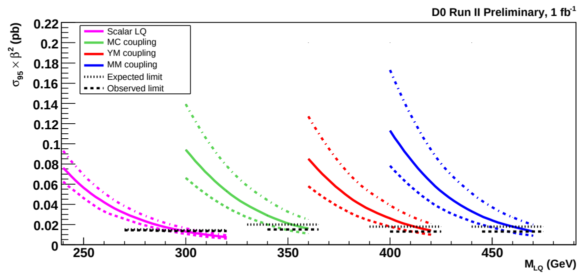

FIGURE 6. Cross sections and limits as a function of the scalar and vector LQ mass (for three different coupling scenarios in the vector case). The LO (vector LQ) or NLO (scalar) theoretical cross sections are drawn for different values of the renormalization scale. The observed (expected) cross section limits are indicated by dashed (dotted) lines.

recent update [8] in the channel $e^+e^-q\bar{q}$, sensitive for first generation leptoquarks with large β. A lower limit of 299 GeV at 95% C.L. on the mass of a scalar leptoquark with $\beta = 1$ is set (see Fig. 6).

SUMMARY

D0 has searched for a wide variety of models beyond supersymmetry. No signs for new physics have been found using an integrated luminosity of $1-3$ fb^{-1}. With more than 4 fb^{-1} recorded by the experiment, updates will remain interesting until the LHC delivers results.

REFERENCES

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