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Search for Beyond Standard Model Physics (non-SUSY) in Final States with Photons at the Tevatron

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We present the results of searches for non-standard model phenomena in photon final states. These searches use data from integrated luminosities of $\sim$1–4 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, collected with the CDF and DØ detectors at the Fermilab Tevatron. No significant excess in data has been observed. We report limits on the parameters of several BSM models (excluding SUSY) for events containing photons.

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1. Introduction

To date, almost all experimental results have agreed with the predictions by the standard model (SM) of particle physics. However, several limitations indicate that the SM is not the final theory, and many extensions of the SM have been developed. In this document, we focus on the searches in final states that contain photons. We present the searches for large extra dimensions and fermiophobic Higgs, and, finally, two signature based searches. These searches are based on 1–4 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, recorded with the CDF and DØ detectors at the Fermilab Tevatron.

2. Large Extra Dimensions

In the large extra spatial dimensions model (LED) [1], SM particles are confined to a 4-dimensional membrane and graviton propagates in the 4+n_d dimension, where n_d stands for the number of additional compactified spatial dimensions. The observed Planck scale M_{pl}, the fundamental Planck scale M_D, and the size of the extra dimensions R are related by the Gauss Law: $\left[M_{pl}\right]^2 = 8\pi R^{n_d} \left[M_D\right]^{n_d+2}$. If R is large compared to the Planck length $\approx 1.6 \times 10^{-33}$ cm, M_D can be as low as 1 TeV and effectively solves the hierarchy problem.

In hadron colliders, we can use two methods to search for indications of LED:

1. Look for emission of real Kaluza-Klein graviton states, G_{KK}, through the production channels $q\bar{q} \to gG_{KK}$, $qg \to qG_{KK}$, and $q\bar{q} \to \gamma G_{KK}$, with signatures of mono-jet or mono-photon and large missing transverse energy ($\not{E}_T$). Section 2.1 describes this type of LED search using the $\gamma\not{E}_T$ final state.

2. Look for deviations of the production cross-sections from the SM either in absolute values or in shapes, due to exchange of the virtual graviton that travels through the extra dimensions. Section 2.2 describes this type of LED search using the invariant mass and angular distributions of di-electromagnetic (di-EM) and dijet channels, respectively.

2.1 Search for LED in the Mono-photon and Large Missing Energy Channel

The CDF and DØ Collaborations have searched for LED in 2.0 fb^{-1} and 2.7 fb^{-1} of $p\bar{p}$ collisions, respectively, using events with mono-photon and large $\not{E}_T$ [2, 3]. The analyses basically require one central photon with $E_T > 90$ GeV and $\not{E}_T > 50/70$ GeV for CDF/DØ. After all selections, the dominant background in both analyses is the SM $Z\gamma \to \nu\nu\gamma$ production. Both analyses have not found significant excess in data: 40 observed vs. 46.3 ± 3.0 expected (CDF) and 51 observed vs. 49.9 ± 4.1 expected (DØ). The lower limits on the fundamental Planck scale, M_D, are obtained at the 95% C.L.: 1080–900 GeV for $n_d = 2-6$ from CDF, and 970–804 GeV for $n_d = 2-8$ from DØ.

2.2 Dielectron and Diphoton Channels

The DØ Collaboration has looked for LED in 1.1 fb^{-1} of $p\bar{p}$ collisions, using the two-dimensional distributions of invariant mass $M_{ee,\gamma\gamma}$ and angular variable $|\cos\theta^*|$ [1] of two EM objects (combining dielectron and diphoton channels) [4]. Figure 1 shows the $M_{ee,\gamma\gamma}$ and $|\cos\theta^*|$ distributions. No discrepancy in shape and yields is found with respect to bkg predictions, therefore lower limits on the effective Planck scale M_S are obtained at the 95% confidence level (C.L.): 1.62 TeV using the

[1] $\cos\theta^* = \tanh(y^*)$, where $\pm y^*$ is the rapidity of each EM object in the center-of-mass frame and $y^* = \frac{1}{2}(y_1 - y_2)$.

GRW formalism [5], and 2.09–1.29 TeV using the HLZ formalism [6] for $n_d = 2-7$. These are currently the best limits on M_S.

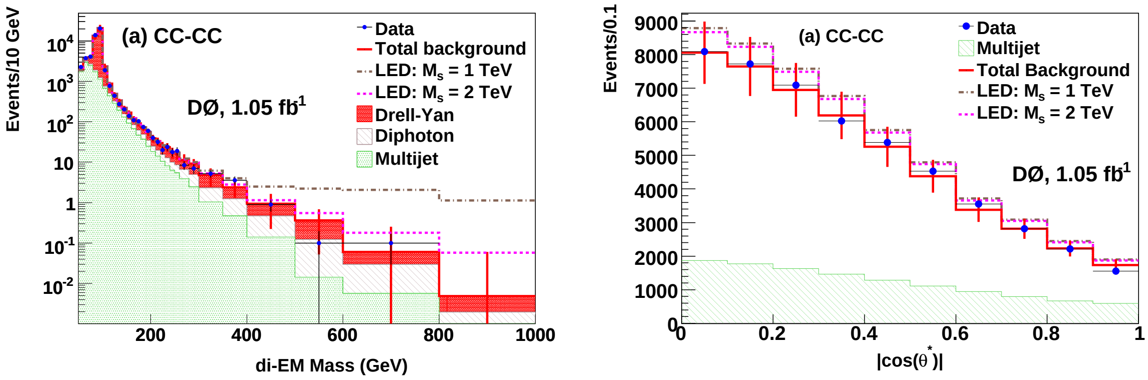

Figure 1: The DØ LED search: the $M_{ee,\gamma\gamma}$ (left) and $|\cos\theta^*|$ (right) distributions, where both EM objects are reconstructed in the central calorimeter. .

3. Fermiophobic Higgs

In the standard model, the branching fraction for the di-photon ($\gamma\gamma$) final state, Br(h $\rightarrow \gamma\gamma$), has a maximal value of approximately 0.2 % for Higgs boson masses of about 120 GeV/c^2 and this fact renders a discovery in this channel impossible. In addition to standard model h $\rightarrow \gamma\gamma$ production, one can devise many possible beyond standard model scenarios where the Br(h $\rightarrow \gamma\gamma$) is enhanced [7]. Here, the consequences of a so-called "fermiophobic" model where the Higgs boson has suppressed couplings to fermions will be studied. The fermiophobic Higgs (h_f) benchmark model considered here assumes standard model coupling to bosons and vanishing couplings to all fermions. For such a model, the branching fractions for h$\rightarrow \gamma\gamma$ is significant for low Higgs masses. In the case of h_f the gluon-fusion production diagram vanishes and only associated production with a W or Z boson and vector boson fusion (VBF) production processes are possible. This results in a reduction in production cross section by about a factor of four; however, this reduction is compensated by the increased diphoton branching fraction in these models, which are enhanced by more than two orders of magnitude. Furthermore, the di-photon final state is appealing because the photon ID efficiency and energy resolution are much better than *b*-jets. Better energy resolution leads to a narrow M$\gamma\gamma$ mass peak which can be exploited to reduce background.

Both collaborations follow the same analysis strategy: since $p_T(\gamma\gamma)$ is large, both experiments cut very hard on $p_T(\gamma\gamma)$ and search for a narrow resonance in M($\gamma\gamma$). CDF has a tighter cut on $P_T^{\gamma\gamma}$ (>75 GeV/c) which removes more than 99.5% of background while roughly 30% of the associated production signal is maintained.

No evidence of a resonance in the di-phtoton mass spectrum is found and lower limits at the 95% C.L. on the branching fraction are obtained. A lower limit on the mass of 106 and 102.5 GeV/c^2 is set for the benchmark model by the CDF [8] and DØ [9] analyses, respectively. These are the strongest limit so far from a hadron collider and is only slightly below the limit set by LEP of 109.7 GeV/c^2. In addition, above 110 GeV/c^2 these result excludes a region of branching fractions that has not been excluded by previous collider studies.

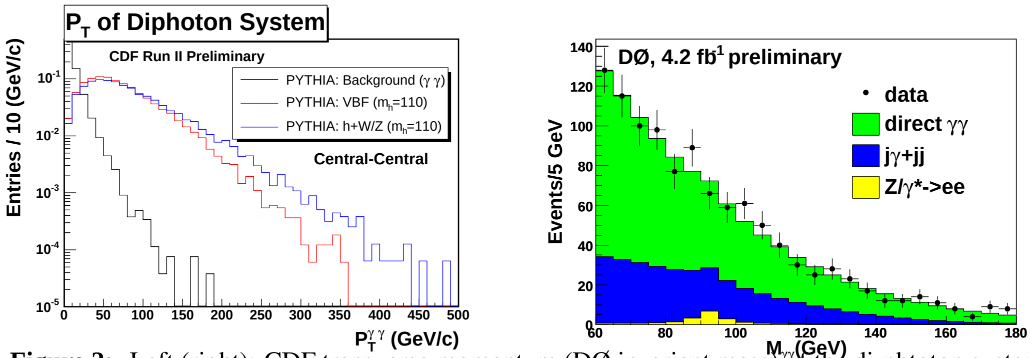

Figure 2: Left (right): CDF transverse momentum (DØ invariant mass) of the di-phtoton system.

4. Signature Based Searches

The unknown nature of possible new phenomena in the energy range accessible at the Tevatron is the motivation for a “signature-based" search strategy that does not focus on a single model or class of models of new physics, but presents a wide net for new phenomena.

The CDF collaboration has performed two searches, one for anomalous production of γ + jet + b-jet + $E\!\!\!/_T$ events [10] and another one for γ + b-jet + jet + $E\!\!\!/_T$ events [11]. In both cases, no structure peaking strongly over the background prediction is observed in any of the kinematic distributions studied. Furthermore, the number of events observed in data is consistent with the number of events expected from the SM background prediction. We conclude that both samples are consistent with SM background expectations.

5. Conclusion

The CDF and DØ collaborations have a broad program of searching for new physics in photon final states. We have not yet found significant excess in 0.7–2.7 fb^{-1} of $p\bar{p}$ collisions. More details can be found in [12] and [13].

References

[1] N. Arkani-Hamed, S. Dimopoulos, and G. R. Dvali, *Phys. Lett.* B **429**, 263 (1998).

[2] T. Aaltonen *et al.* (CDF Collaboration), *Phys. Rev. Lett.* **101**, 181602 (2008).

[3] E. Carrera (DØ Collaboration), arXiv:0810.1331 [hep-ex].

[4] V. M. Abazov *et al.* (DØ Collaboration), *Phys. Rev. Lett.* **102**, 051601 (2009).

[5] G. F. Giudice, R. Rattazzi, and J. D. Wells, *Nucl. Phys.* B **544**, 3 (1999).

[6] T. Han, J. D. Lykken, and R. J. Zhang, *Phys. Rev.* D **59**, 105006 (1999).

[7] S. Mrenna and J. D. Wells, *Phys. Rev.* D **D63**, 015006 (2001).

[8] T. Aaltonen *et al.* (CDF Collaboration), arXiv:0905.0413 [hep-ex].

[9] DØ public note http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/HIGGS/H70/H70.pdf

[10] T. Aaltonen *et al.* (CDF Collaboration), arXiv:0906.0518 [hep-ex].

[11] T. Aaltonen *et al.* (CDF Collaboration), arXiv:0905.0231 [hep-ex].

[12] CDF public web page: http://www-cdf.fnal.gov/physics/exotic/exotic.html

[13] DØ public web page: http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm