Search for New Physics with Photons at the Tevatron

Shin-Shan Yu on behalf of the CDF and D0 collaborations
Fermilab, MS 318, P.O. Box 500, Batavia, IL 60510, USA
E-mail: eikoyu@fnal.gov

Abstract. We report on a search for compositeness in $ee\gamma$ events and a search for gauge-mediated supersymmetry in $\gamma\gamma\not\!\!E_T$ events. We also report on two signature-based searches for anomalous production of $\gamma\gamma + X$ (where $X = e, \mu, \gamma, \not\!\!E_T$) and $\gamma\ell + X$ (where $X = \not\!\!E_T, \ell, \gamma$). The analyses are based on 0.9–1.2 fb^{-1} of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV collected with the CDF and D0 detectors at the Fermilab Tevatron. No significant excess of data over the predicted background has been observed.

1. Introduction

Physics beyond standard model (SM) predicts a rich spectrum of inclusive photon final states with additional detectable objects, such as leptons, heavy-flavor jets, and missing transverse energy ($\not\!\!E_T$). Examples of the extension of SM include technicolor, large extra dimensions, 4^{th} generation, compositeness, and supersymmetry (SUSY): gravity-mediated (mSUGRA) and gauge-mediated (GMSB) supersymmetry breaking. The D0 collaboration has performed searches for compositeness in $ee\gamma$ [1] and GMSB in $\gamma\gamma\not\!\!E_T$ [2] signatures, while the CDF collaboration chose to conduct model-independent searches for anomalous production of $\gamma\gamma + X$ (where $X = e, \mu, \gamma, \not\!\!E_T$) [3] and $\gamma\ell + X$ (where $X = \not\!\!E_T, \ell, \gamma$) [4]. The following sections present results of the searches mentioned above. Data for these analyses were collected from February 2002 to February 2006. The CDF and D0 detectors are described in detail in [5] and [6].

2. D0 Search for excited electrons in the $ee\gamma$ channel

The compositeness model postulates that SM quarks and leptons are composed of yet-to-be-observed scalar and spin-1/2 elementary particles. The substructure within quarks and leptons implies a large spectrum of excited states, including excited electrons [7]. In this search, the excited electrons (e^*) are assumed to be produced via contact interactions $p\bar{p} \rightarrow ee^*$, with subsequent decay of e^* into $e\gamma$ and resulting in a $ee\gamma$ final state. We select events containing two isolated electrons with transverse energy (E_T) greater than 25 and 15 GeV, and one isolated photon with E_T greater than 15 GeV, all within the detector pseudorapidity [8] range of $|\eta_{\text{det}}| < 1.1$ or $1.5 < |\eta_{\text{det}}| < 2.5$. We further optimize the requirements on $M_{e\gamma}$ and $\Delta R(e, \gamma)$ [9] as a function of the mass of the excited electron (M_{e^*}). The dominant background after all requirements is the Drell-Yan process $Z/\gamma^* \rightarrow ee$ where an additional photon is radiated (see Figure 1). Without any excess observed in 1 fb^{-1} of data, we set a 95% confidence level (CL) lower limit on the M_{e^*} as a function of the compositeness scale Λ. For $\Lambda = 1$ TeV, the lower limit is found to be 756 GeV/c^2.

3. D0 Search for gauge-mediated supersymmetry breaking in the $\gamma\gamma\not\!\!E_T$ events

The lightest SUSY particle in GMSB is the gravitino ($\widetilde{G}$) with a mass of a few keV. Assuming R-parity conservation, pair production of massive SUSY particles, such as $\widetilde{\chi}_2^0\widetilde{\chi}_1^\pm$ or $\widetilde{\chi}_1^+\widetilde{\chi}_1^-$, results in a final state with two photons and large $\not\!\!E_T$ due to the escape of the $\widetilde{G}$ from the detector. This analysis considers a minimal GMSB model (Snowmass Slope SPS 8 [10]) with only one dimensioned parameter Λ that determines the effective scale of SUSY breaking. We look for two isolated central photons ($|\eta_{\rm det}| < 1.1$) with E_T greater than 25 GeV each. The $\not\!\!E_T$ is determined from energy deposited in the calorimeter for $|\eta_{\rm det}| < 4.0$. We compare the observed $\not\!\!E_T$ distribution with that from the expected. The dominant expected background arises from mis-measured $\not\!\!E_T$ which we model with two templates from: 1. $Z \to ee$ events (two real electromagnetic objects), 2. multijet sample, by reversing electron identification requirements (mis-identified jet). We find no significant discrepancy in the $\not\!\!E_T$ distribution in 1.1 fb^{-1} of data (see Figure 2), and obtain the following 95% CL limits: $\Lambda > 88.5$ TeV, $M_{\widetilde{\chi}_1^0} > 120$ GeV/c^2, and $M_{\widetilde{\chi}_1^+} > 220$ GeV/c^2.

4. CDF Search for anomalous production of $\gamma\gamma + X$ ($X = e, \mu, \gamma, \not\!\!E_T$)

We first select events containing two isolated central photons ($|\eta_{\rm det}| < 1.1$) with E_T greater than 13 GeV each. Then, we look for additional e, μ, γ or large $\not\!\!E_T$ in the diphoton sample. In the $\gamma\gamma e$ and $\gamma\gamma\mu$ final states, we require the electron ($|\eta_{\rm det}| < 1.1$ or $1.2 < |\eta_{\rm det}| < 2.8$) or the muon ($|\eta_{\rm det}| < 1.0$) to have E_T greater than 20 GeV and be isolated. The dominant background in the electron channel is $Z\gamma$ with an electron from Z mis-identified as a photon, while the dominant background in the muon channel is SM $Z\gamma\gamma$ production with a muon from Z not reconstructed. In the tri-photon search, we require the third photon to satisfy the same requirements as those for the other two photons. Here, the two leading backgrounds are from SM tri-photon production and multi-jets which are mis-identified as photons. For the $\gamma\gamma\not\!\!E_T$ search, the $\not\!\!E_T$ is determined from energy deposited in the calorimeter for $|\eta_{\rm det}| < 3.6$. We model the mis-measured $\not\!\!E_T$ distribution by studying: 1. the resolution of unclustered energy with zero-jet events in the $Z \to ee$ and fake photon data, 2. the resolution of jet energy with the dijet data. The expected $\not\!\!E_T$ distribution is a sum of mis-measured $\not\!\!E_T$, non-collision background (cosmics, beam halo, photo-tube spikes), and inclusive $W\gamma$ events where the electron from W is mis-identified as a photon. In all four $\gamma\gamma + X$ searches, we observe no significant excess in 1.0–1.2 fb^{-1} of data. Selected kinematic distributions are shown in Figures 3–5.

5. CDF Search for anomalous production of $\gamma\ell + X$ ($X = \not\!\!E_T, \ell, \gamma$; $\ell = e, \mu$)

We select events which contain one isolated central lepton (e,μ) and one isolated central photon with E_T greater than 25 GeV each. In those events we find additional objects: $\not\!\!E_T$ greater than 25 GeV, a central photon with E_T greater than 25 GeV, a central lepton with E_T greater than 20 GeV, or a forward electron with E_T greater than 15 GeV. Backgrounds from $W\gamma$, $Z\gamma$, $W\gamma\gamma$, $Z\gamma\gamma$ processes are estimated with Madgraph [11]. Jets mis-identified as photons are estimated by fitting the calorimetric isolation distribution [12] in our data to a signal isolation template from $Z \to ee$ events plus a linear background. We observe no excess in all channels in 0.9 fb^{-1} of data (See Figure 6).

6. Conclusion

The CDF and D0 collaborations have carried out both model-driven and signature-based searches for new physics in the photon final states. There are no hints of new physics in 0.9–1.2 fb^{-1} of data. However, a factor of 4-8 times more data are expected by the end of Run II. In addition, we have not fully explored all possible photon final states. Photon identification requirements may be improved in the near future, too. We will keep searching.

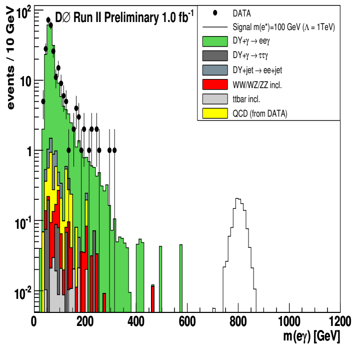

Figure 1. The $M_{e\gamma}$ distribution from the D0 data and the expected background for mass of M_{e^*}=800 GeV/c^2.

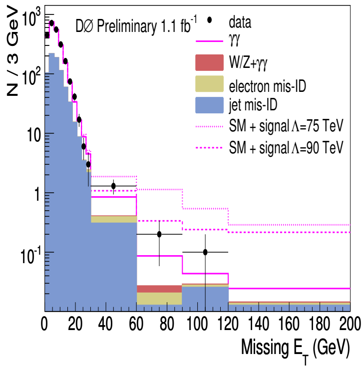

Figure 2. The $\not\!\!E_T$ distribution from the D0 $\gamma\gamma$ data, the expected background, and the GMSB SUSY signal.

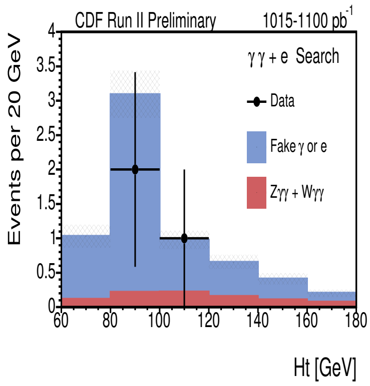

Figure 3. The H_t distribution [13] of CDF $\gamma\gamma e$ events and the expected background.

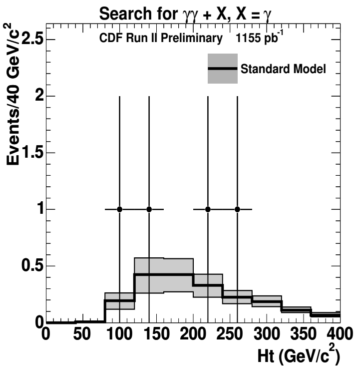

Figure 4. The H_t distribution [13] of CDF $\gamma\gamma\gamma$ events and the expected background.

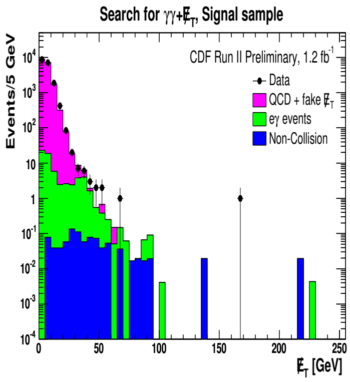

Figure 5. The $\not\!\!E_T$ distribution of CDF $\gamma\gamma\not\!\!E_T$ events and the expected background.

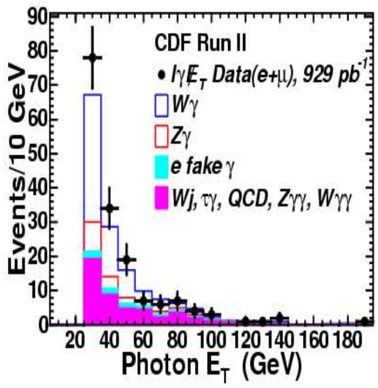

Figure 6. The central photon E_T distribution of CDF $\gamma\ell\not\!\!E_T$ events and the expected background.

References

[1] *http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/NP/N51/N51.pdf*

[2] *http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/NP/N54/N54.pdf*

[3] *http://www-cdf.fnal.gov/physics/exotic/r2a/20060908.diphotonPlusX/pub.ps*

[4] A. Abulencia *et al.* (CDF Collaboration), Phys. Rev. D **75**, 112001 (2007).

[5] D. Acosta *et al.* (CDF Collaboration), Phys. Rev. D **71**, 032001 (2005).

[6] V. M. Abazov *et al.* (D0 Collaboration), Nucl. Instrum. Meth. A **565**, 463 (2006).

[7] U. Baur, M. Spira, and P. M. Zerwas, Phys. Rev. D **42**, 815 (1990).

[8] The pseudorapidity, $\eta_{\rm det}$, is defined as $-\ln\tan(\theta/2)$, where θ is the polar angle to the detector origin.

[9] $\Delta R(e,\gamma) \equiv \sqrt{\Delta\phi(e,\gamma)^2 + \Delta\eta(e,\gamma)^2}$. Here, e and γ are the daughters of e^* candidate.

[10] S. P. Martin, S. Moretti, J. m. Qian, and G. W. Wilson, in *Proc. of the APS/DPF/DPB Summer Study on the Future of Particle Physics (Snowmass 2001), pp P346* ed. N. Graf.

[11] F. Maltoni and T. Stelzer, "Madgraph", Comput. Phys. Commum. **357**, 81 (1994).

[12] The calorimetric isolation is defined as: the transverse energy deposited in the calorimeter in a cone of $\Delta R \leq 0.4$ around the photon cluster centroid after subtracting the photon transverse energy.

[13] The scalar sum E_T of all identified objects ($\not\!\!E_T$, γ, e μ, jet).