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Searches for new physics in events with photon final states at CDF at the TeVatron

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Abstract. The first CDF Run II analyses based on about 80 pb^{-1} on searches for events containing photons in the final state are presented. No deviations from the Standard Model predictions are found and limits on some scenarios of physics beyond the Standard Model are presented.

PACS. 01.30.Cc Conference proceedings – 12.60.-i Models beyond the standard model

1 Introduction

A variety of models for physics beyond the Standard Model (SM) predicts observable signatures of new physics in events containing photons in the final state. Here searches for large extra dimensions (LED) and Supersymmetry (SUSY) are presented as well as model independent searches with the CDF detector at the Tevatron.

2 The CDF experiment

The CDF experiment at the Tevatron proton-antiproton collider at Fermilab has taken about $\int \mathcal{L} = 100$ pb^{-1} of data between 1992 and 1996, so-called Run I. Then both CDF and the accelerator have been upgraded substantially between 1996 and 2001, the start of Run II. The results presented here are based on about 80 pb^{-1} of Run II data. The Tevatron is presently the highest energy accelerator and therefore an ideal place to search for new high mass particles. By 2006 an integrated luminosity of 2 fb^{-1} is anticipated.

Photons are selected by requiring an isolated electromagnetic cluster in the central detector ($|\eta| < 1$) with no track pointing to it. The major background to photons are hard π^0's which carry more than 90% of the jet energy. Particularly at high energies the two photons from the π^0 decay can not be separated experimentally. Two independent methods are used to estimate the π^0 background:

- the electromagnetic calorimeter is instrumented with a wire chamber (CES) with a spacial resolution of about 1 cm. Showers from $\pi^0 \to \gamma\gamma$ are typically broader than from single γ's for $E_t^\gamma < 35$ GeV. This difference in the shower profile is exploited to separate π^0's and η's from prompt γ's.
- between the coil (which surrounds the tracking volume) and the electromagnetic calorimeter a proportional drift chamber (CPR) is installed. If a photon converts in the coil charge is deposited in the CPR. For a single photon the probability to convert in the coil is about 60% and thus it is 84% for two photons. By measuring the number of photon candidates which have converted the fraction of prompt photons can be estimated on a statistical basis. This technique works at all values of E_T^γ.

In all measurements presented here the background is estimated from the data and generally referred to as "fakes" or "QCD background".

3 Results

3.1 Di-photon mass spectrum

The Standard Model cross section for di-photon production is relatively low and it therefore is an ideal lace for studies. Furthermore, the di-photon channel is the main discovery channel for the Higgs at the LHC and a solid understanding of di-photon production is thus required. In LED models di-photon signatures are produced via the exchange of a Kaluza-Klein graviton states in addition to the Standard Model processes [1,2].

The di-photon mass spectrum is shown in Fig. 1 for events containing two photon candidates with $E_\mathrm{T} > 7$ GeV and $\eta < 1.1$. The data are compared to the Standard Model expectation estimated from the sum of the SM di-photon prediction and fakes. The data are in excellent agreement with the Standard Model prediction at all mass values. At low masses the jet background is large,

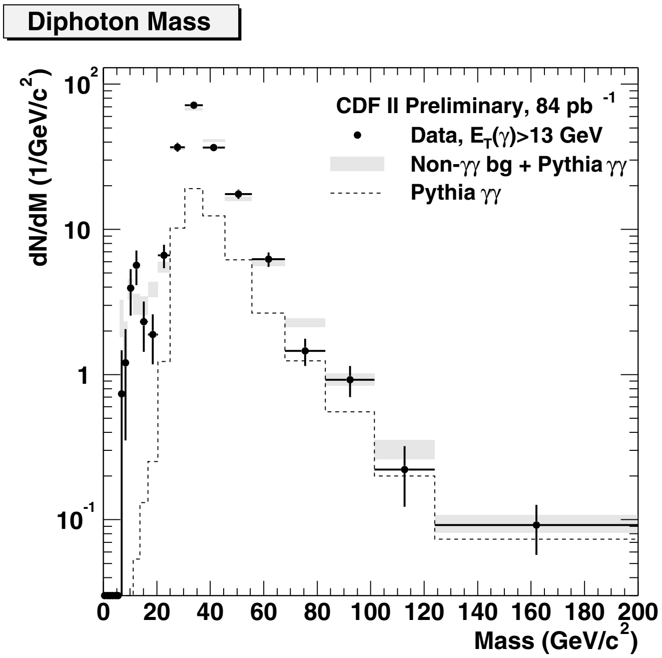

Fig. 1. The invariant mass spectrum of di-photon events for CDF data (*points*), di-photon MC (*dashed histogram*) and the total SM expectation and its uncertainty (*grey shaded area*)

i.e. about 80% of the total sample. At higher masses the di-photon process becomes increasingly dominant.

This analysis will be used to set lower limits on the effective Planck scale M_S.

3.2 GMSB searches: $\gamma\gamma + \not{E}_t$

In models with Gauge Mediated Supersymmetry Breaking (GMSB) a light gravitino is the lightest supersymmetric particle (LSP) [3]. In this case the nest-to-lightest SUSY particle (NLSP) χ_1^0 is no longer stable and decays through $\tilde{\chi}_1^0 \to \gamma\tilde{G}$. Pair production of the $\tilde{\chi}_1^0$ can thus be observed as two photons and an imbalance in transverse momentum ($\not{E}_t$) in the detector.

Requiring two photons with $E_{\mathrm{T}} > 13$ GeV and $\not{E}_t >$ 20 GeV two events are observed and a background of 2 ± 2 is expected. The largest background contribution comes from $W\gamma \to e\nu\gamma$ where the electron is misidentified as a photon. Since the data are consistent with the background an upper limit on the cross section is placed. This is shown in Fig. 2 versus the chargino mass. A lower limit on the chargino mass in the GMSB model of $m_{\chi^\pm} > 113$ GeV is placed.

This analysis is particularly interesting since in Run I there was one event observed at $\not{E}_t \approx 60$ GeV which not only had two photon candidates and large $\not{E}_t$ but also contains two electrons candidates and the SM expectation for this event was estimated as 10^{-6} [4]. No such event has yet been observed in Run II. We also performed a search for $\gamma\gamma+$ lepton and observed no event consistent with the SM expectation.

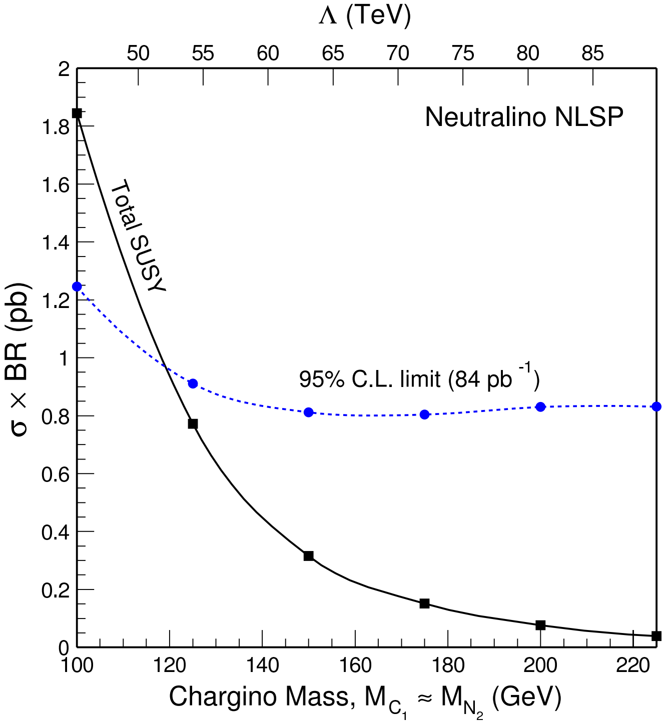

Fig. 2. $\gamma\gamma+\not{E}_t$ cross section × branching ratio versus Chargino mass for GMSB model where the neutralino is the NLSP. Shown is the predicted cross section and the 95% upper limit from this analysis

3.3 Large extra dimensions: $\gamma + \not{E}_t$

A signature for Kaluza-Klein gravitons may be a single photon and large $\not{E}_t$ due to the process $q\bar{q} \to \gamma + G_{KK}$ [1]. The same signature would also be characteristic in some SUSY models through the process $q\bar{q} \to \gamma + \tilde{G}\tilde{G}$ [5].

For photon $E_{\mathrm{T}} > 47$ GeV and $\not{E}_t > 42$ GeV 18.0 ± 2.1 events are expected and 17 observed. The dominant contributions come from cosmic ray background, $Z+\gamma \to \nu\nu\gamma$ and $W \to e\nu$ where the e is misidentified as photon. This analysis can be used to set limits on the above models. In Run I limits on the effective Planck scale scale M_D between 550 and 600 GeV depending on the number of large extra dimensions are placed [6]. These will be improved significantly in Run II due to the higher luminosity and better detector instrumentation.

3.4 $W + \gamma$ and $Z + \gamma$ production

Measurements of the associated production of $W + \gamma$ and $Z + \gamma$ are made in the kinematic range $E_{\mathrm{T}}^{\gamma} > 7$ GeV and $\Delta R_{l,\gamma} > 0.7$. In the $W + \gamma$ channel 81 events are observed and $83.1 \pm 2.0 \pm 7.5$ expected whilst in the $Z + \gamma$ channel 25 are observed compared to $23.2 \pm 2.1 \pm 1.3$ expected. The photon transverse momentum spectrum is shown in Fig. 3 and 4 for the $W + \gamma$ and $W + \gamma$ channels respectively. Neither distribution shows any deviations from the Standard Model expectation. In Run I a 2.8σ excess of events was found in the $W + \gamma$ channel for $E_{\mathrm{T}}^{\gamma} > 25$ GeV: 16 events

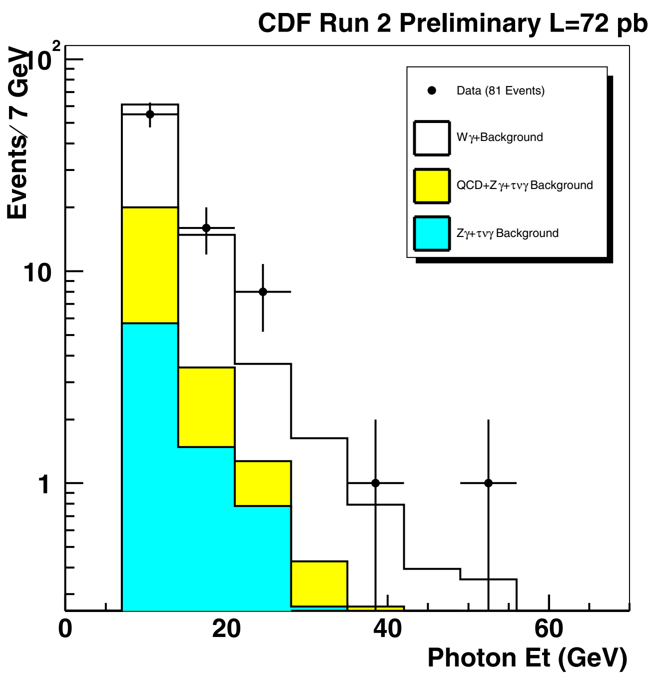

Fig. 3. The transverse momentum of the photon in $W+\gamma \to l\nu\gamma$ candidate events where $l = e, \mu$. The data (*points*) are compared to the SM prediction (*open histogram*)

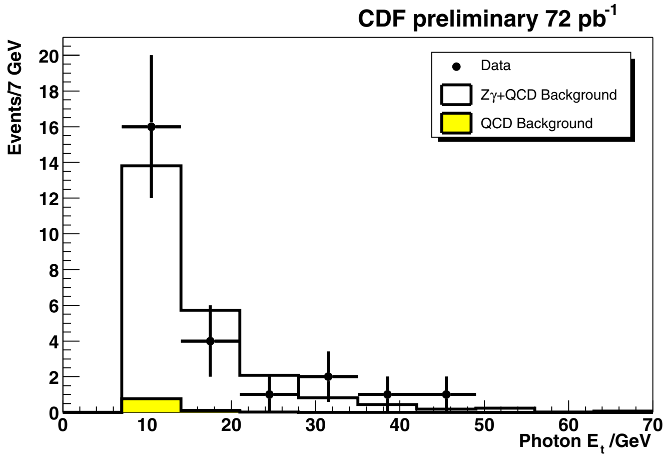

Fig. 4. The transverse momentum of the photon in $Z+\gamma \to ll\gamma$ candidate events. The data (*points*) are compared to the SM prediction (*open histogram*)

had been observed and 7.6± are expected [7]. There is no sign of an excess in the Run II data yet.

These measurements will be used to constrain anomalous couplings of the $WW\gamma$, $ZZ\gamma$ and $Z\gamma\gamma$ vertices.

3.5 Excited electrons

In compositeness models the new strong interaction that binds the constituents (preons) may be expected to produce excited leptons [8]. These can then decay into their light partner. We select the channel $e^* \to e\gamma$ because of the distinct signature and the good mass resolution that can be obtained on the e^* mass. The two electron and the photon are all required to have $E_T > 25$ GeV and events where the di-electron mass is between 80 and 100 GeV are vetoed to suppress background from $Z\gamma$ production. No events are found and 0.037 ± 0.004 background events are expected. Thus an upper limit on the cross section is placed. It is shown in Fig. 5 together with model predictions for different compositeness scales Λ, e.g. for $\Lambda = 6 \cdot M_{e^*}$ GeV the lower limit on M_{e^*} is 325 GeV.

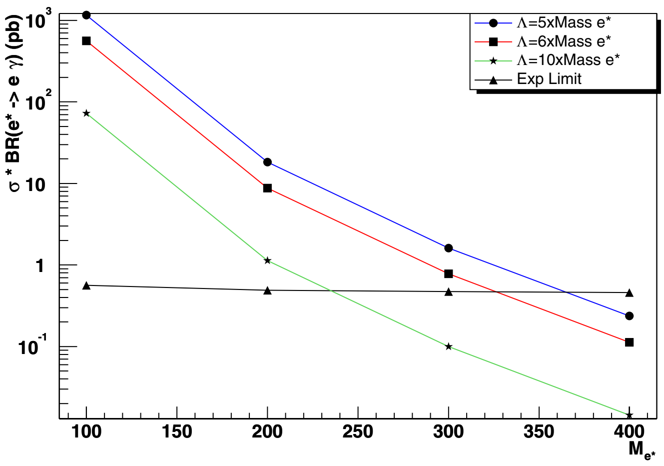

Fig. 5. The transverse momentum of the Photon in $Z+\gamma \to ll\gamma$ candidate events. The data (*points*) are compared to the SM prediction (*open histogram*): the $Z+\gamma$ MC and the $Z+jet$ background (*yellow histogram*)

4 Conclusions

The CDF collaboration has analysed the first ≈ 80 pb^{-1} of Run II data and searched for new physics involving photons in the final state were presented. The data are found to agree with the Standard Model in all channels and used to place limits on various SUSY and Large Extra Dimension inspired models. A significant improvement in sensitivity is expected in the next 2-3 years when the luminosity will increase by about a factor of 20.

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