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SEARCH FOR NEW PHYSICS WITH PHOTONS AT CDF

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We present searches for signals of new physics beyond the Standard Model. The focus of this paper is on the results obtained with photons in the final state. We report on two model-independent searches for anomalous production of $\gamma\gamma+X$ (where $X=e,\mu,\gamma,\not\!\!E_T$) and $\gamma l+X$ (where $l=e,\mu$ and $X=l,\gamma,\not\!\!E_T$) events and one novel search for delayed photons. The analyses are based on $\sim$1 fb^{-1} of data and significantly update earlier results. No significant excess of data over the predicted background is observed. We report kinematic distributions, data and background counts.

1. Model-independent Approach in Searches with Photons

The single and di- photon signatures in the final state are present in many well motivated theoretical models of new physics beyond the Standard Model. Examples of such models include Gauge-Mediated SUSY (GMSB), mSUGRA, fermiophobic Higgs, RS-graviton production, LED, b' production, compositeness (exited fermions), etc. Chances that any particular model could be the one describing our world are very small. In light of this fact, CDF employed a model-independent approach in searching for new physics in inclusive $\gamma\gamma+X$ and $\gamma l+X$ final states. The analysis strategy for a model-independent search, unlike to conventional model-based searches, is not to optimize the selection requirements for any particular physics model, but rather to apply generic selection criteria to reduce backgrounds. An increased attention is also given to examining various kinematic distributions. Observation of an excess of data over the predicted background would indicate a presence of new physics.

2. Search for Anomalous Production of $\gamma\gamma+X$ Events

There were two very rare di-photon events recorded at the Tevatron experiments: Run I $\gamma\gamma ee\not\!\!E_T$ candidate event at CDF[1]; and Run II $\gamma\gamma e\not\!\!E_T$ event at D0[2]. The observation of the $\gamma\gamma ee\not\!\!E_T$ event is particularly interesting because the total predicted background is only $\sim 10^{-6}$ events, and this event could be a sign of new physics. With $\sim$12 times more data in Run II, CDF has significantly higher potential for detecting signs of new physics in production of rare $\gamma\gamma+X$ events.

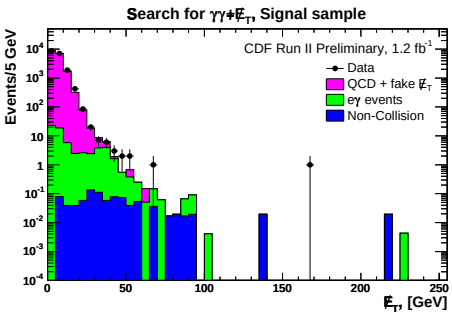

Fig. 1. Distribution of $\not\!\!E_T$ in $\gamma\gamma$ events.

2.1. *The $\gamma\gamma+\not\!\!E_T$ Channel*

Figure 1 shows the $\not\!\!E_T$ distribution in $\gamma\gamma$ events with two isolated photons with E_T^γ>13 GeV and located in the central region ($|\eta_\gamma|$<1.1) of the calorimeter. The results are based on $\sim$1.2 fb^{-1} of data. The overall agreement of data and the predicted background is good. At low values of $\not\!\!E_T$, the

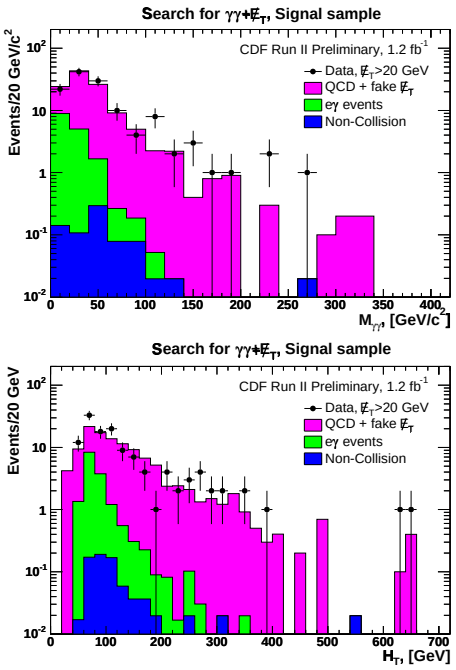

Fig. 2. The invariant mass, $M_{\gamma\gamma}$ (*top*), and H_T (*bottom*) distributions in $\gamma\gamma$ events with $\not\!\!E_T$>20 GeV.

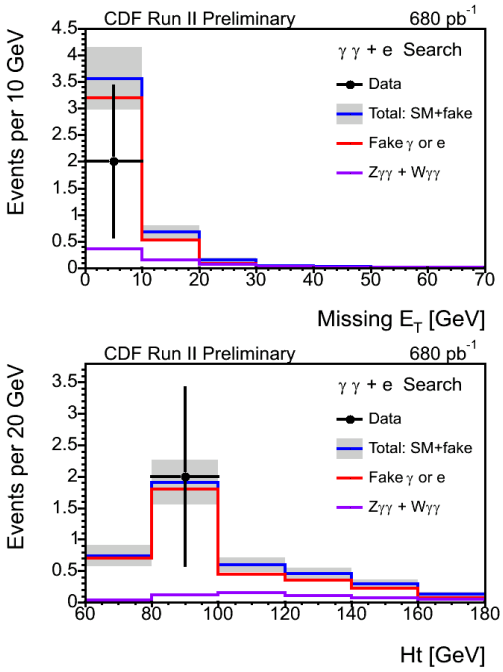

Fig. 3. Distribution of $\not\!\!E_T$ (*top*) and H_T (*bottom*) in $\gamma\gamma$+e events.

background is dominated by regular QCD events[a] with fake[b] $\not\!\!E_T$. The region of intermediate values and tail of the distribution is mostly populated by $W\gamma \to e\bar{\nu}\gamma$ and non-collision[c] events where one or both photons are faked. We observe 22 events with $\not\!\!E_T$>30 GeV at the expected background of 19.5±2.5 events. We have also studied invariant mass, $M_{\gamma\gamma}$, of $\gamma\gamma$ pairs and H_T[d] distribution in the events with $\not\!\!E_T$>20 GeV (Fig. 2). Tails of both $M_{\gamma\gamma}$ and H_T histograms are dominated by QCD events with fake $\not\!\!E_T$. No significant excess of data over the expected background is observed at either of the distributions.

[a]including true $\gamma\gamma$, jet+$\gamma \to \gamma_{fake}\gamma$ and jet+$jet \to \gamma_{fake}\gamma_{fake}$ events
[b]due to energy mis-measurement in the calorimeter
[c]electromagnetic showers due to cosmic rays and beam halo muons
[d]Scalar sum of E_T's of all identified objects: photons, electrons, jets, and $\not\!\!E_T$.

2.2. *The γγ+γ Channel*

The search for an anomalous production of tri-photon events is based on ∼1.2 fb^{-1} of data. All three photons are required to be isolated and have E_T^{γ}>13 GeV and $|\eta_{\gamma}|$<1.1. We observe 4 tri-photon events with the expected background of 2.2±0.7 events. There are two known Standard Model contributions to this channel: true tri-photon production; and events with at least one $jet \to \gamma_{fake}$. All of the studied kinematic distributions ($E_T^{\gamma 3}$, $M_{\gamma\gamma}$, $M_{3\gamma}$, H_T and $\not\!\!E_T$) show good agreement between data and the predicted background.

2.3. *The γγ+e, μ Channel*

CDF has also searched for an anomalous production of $\gamma\gamma$ events (E_T^{γ}>13 GeV, $|\eta_{\gamma}|$<1.1) in association with an additional electron (E_T^{e}>20 GeV, $|\eta_{e}|$<2.0) or a muon (P_T^{μ}>20 GeV/c, $|\eta_{\mu}|$<1.0). This analysis is based on ∼680 pb^{-1} of data. Two events are observed

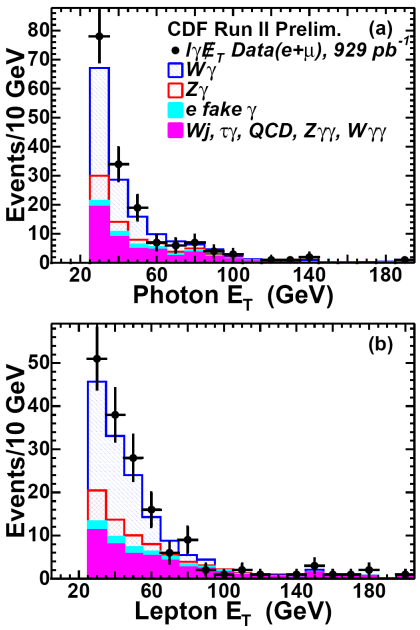

Fig. 4. Distribution of E_T^{γ} and E_T^{l} in γl+$\not\!\!E_T$ events.

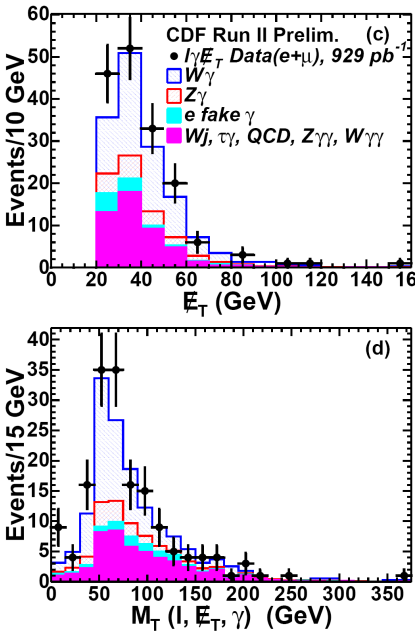

Fig. 5. Distribution of M_T and $\not\!\!E_T$ in γl+$\not\!\!E_T$ events.

in the electron channel which is in agreement with the expected background of 4.49±0.84 events. The major source of background for $\gamma\gamma$+e is events where the electron or one of the photons is fake. No events with an extra muon are found. The expected background for the muon channel is 0.47±0.12 events, and it is dominated by the $Z\gamma\gamma$ and $W\gamma\gamma$ production. As a part of this search, we study various kinematic distributions, two of which, namely $\not\!\!E_T$ and H_T in $\gamma\gamma$+e events, are presented at Fig. 3. Data on these distributions agree well with the expected background.

3. Search for Anomalous Production of γl+X Events

A search for anomalous inclusive production of events containing a photon and a lepton along with any additional particles is interesting in many ways. Events with photons and leptons are potentially related to the Run I $\gamma\gamma ee\not\!\!E_T$ event[1]. In many theoretical models, new massive particles could undergo a cascade decays to Standard Model gauge bosons, one of which could be a photon and the other a W or Z^0 decaying leptonically. The γl+X search also compliments similar searches in $\gamma\gamma$+X, γ+jet+X, and γ+b+X channels. Finally, this new CDF analysis with ∼930 pb^{-1} of data will significantly update the results of previous CDF searches[3] in this channel and shed light on the potential excess in $\gamma l\not\!\!E_T$ channel observed in the Run I analysis[3]. In the current analysis, we require[e] one isolated central photon and lepton (e or μ) with $E_T^{\gamma,l}$>25 GeV. Then, the search is split in two modes: the γl+$\not\!\!E_T$ channel, where $\not\!\!E_T$>25 GeV and l=e,μ; and the γl+l channel, where l=e,μ. Any additional leptons in the γll channel are required to pass relaxed requirements[3]: central μ and e with E_T>20 GeV; and forward e with E_T>15 GeV. In the $\gamma l\not\!\!E_T$ channel, we find 163 events corresponding to an expected background of 148.1±13.0 events with

[e] All requirements are identical to those in the Run I search[3]

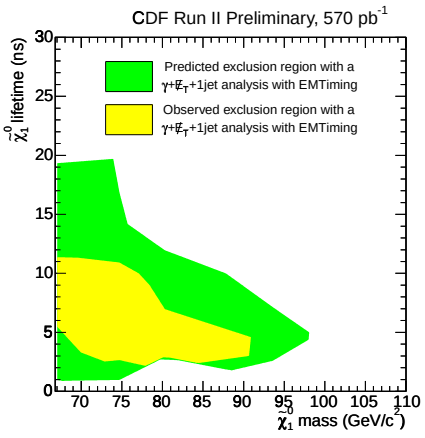

Fig. 6. Exclusion region for $\tilde{\chi}_1^0$ production.

the dominant contribution from the inclusive $W\gamma$ production. Figs. 4,5 show that data agree well with the predicted background distributions for $E_T^{\gamma,l}$, M_T and $\not\!\!E_T$. We also observe 3 $\gamma ll\not\!\!E_T$ events with an expected background of 0.6±0.1 events. No events with an extra photon are found in the $\gamma l\not\!\!E_T$ channel. In the γll channel, we observe 74 events which is in agreement with the expected background of 64.9±7.7 events, dominated by the inclusive $Z\gamma$ production. No $e\mu\gamma$ events or events with extra leptons and photons are found. Data is consistent with the background predictions on all of the studied kinematic distributions (E_T^l, E_T^γ, M_{ll}, and $M_{ll\gamma}$).

4. Search for Delayed Photons

Most searches assume that new particles are produced promptly and registered by detectors in time with the other products of the hard collision. However, it is possible that new exotic particles can have large mass, long lifetime, and move with low velocity. These objects can be charged or neutral and decay inside or outside of the detector volume. An example of a theory that offers such a scenario is the GMSB. The model predicts that neutralino, $\tilde{\chi}_1^0$, has a mass of ~100 GeV/c^2, lifetime of the order of nanoseconds and ~100% branching ratio for $\tilde{\chi}_1^0 \to \tilde{G}\gamma$ where $\tilde{G}$ is an undetectable gravitino. Therefore, pair production of $\tilde{\chi}_1^0$'s in association with jets would result in a signature of a delayed photon, large $\not\!\!E_T$, and jets. This search is performed at CDF with 570 pb^{-1} of data. The analysis is optimized to GMSB and requires a photon and a jet with E_T>30 GeV, and $\not\!\!E_T$>50 GeV. We observe 10 events where a photon's arrival time relative to prompt particles is 1.5 ns<T_γ<10 ns. This is consistent with 7.6±1.9 events of the expected background due to Standard Model γ candidates and electromagnetic showers from cosmic ray and beam halo muons that bremsstrahlung in the calorimeter. In the absence of an excess, we set a limit on $\tilde{\chi}_1^0$ production in the GMSB scenario (Snowmass Slope parameters[4]) as a function of its mass and lifetime, see Fig.6.

5. Summary

We have presented new results[5] on two model-independent searches for anomalous production of $\gamma\gamma+X$ and $\gamma l+X$ events. In both analyses, data are consistent with the background expectations. Therefore, the Run I anomalies seen in these channels are not confirmed. We have also presented the results[5] of a novel search for delayed photons in the context of the GMSB model.

References

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