1303: Searches for New Particles in Photon Final States at the Tevatron

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Abstract. Searches for new physics at the Tevatron collider experiments, using signatures involving photons, are described.

1 Photon Signatures

Photon final states can provide a clean and interesting channel for new physics at hadron colliders:

- electromagnetic objects can be triggered on with good efficiency;
- there is better missing E_T resolution in events with photons than in multijet signatures, which may be important for supersymmetry;
- the background cross section for real and fake photons is of order 10^{-3} times that for jets, so one can hope to access rare processes by selecting photon-rich final states.

In both CDF and DØ, photons are identified as isolated electromagnetic clusters in the calorimeter, with a shower shape consistent with expectations and no associated track. The results described here are all based on the full Run I dataset of approximately 100 pb^{-1} per detector accumulated in 1992–95.

2 Supersymmetry

Much interest has been generated by the observation of a single anomalous event at CDF[1], containing two photons, two electrons and missing transverse energy($\not{E}_T$) (Fig. 1). The standard model probability to have observed such an event is extremely small, and the presence of $\not{E}_T$ has led many to interpret this as a supersymmetry (SUSY) candidate (see references in [1]).

There are two ways in which photon-rich final states can result from supersymmetric particle production:

- "light neutralino" models in which the second lightest neutralino decays to the lightest plus a photon, $\chi_2^0 \rightarrow \chi_1^0\gamma$. This can occur in a small part of the MSSM parameter space.

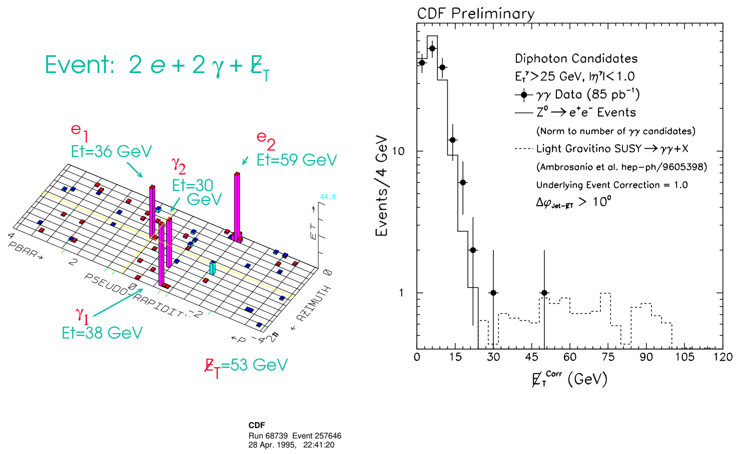

Fig. 1. (left) CDF $ee\gamma\gamma$ $\not{E}_T$ event; (right) Spectrum of $\not{E}_T$ for events with two photons in CDF.

- "light gravitino" models in which the lightest neutralino itself can decay to a gravitino plus a photon, $\chi_1^0 \to \tilde{G}\gamma$. This occurs in models with gauge-mediated SUSY breaking, where supersymmetry is broken at scales as low as 100 TeV, and also in "no-scale" supergravity-inspired models.

2.1 Two photons + $\not{E}_T$ + X

Both CDF and DØ have carried out searches inspired by these possibilities. The first is a generic search for the pair production of SUSY particles with decays to photons:

$$p\overline{p} \to \gamma\gamma \not{E}_T + X.$$

CDF required two photons with $E_T > 25$ GeV and $|\eta| < 1.0$; no excess is seen at large $\not{E}_T$. (see Fig. 1).

DØ has also carried out two analyses in this channel[2, 3]. The most recent requires two photons with $E_T > 20$ and 12 GeV respectively, and $|\eta| < 2.0$. For $\not{E}_T > 25$ GeV, two events are seen where 2.3 ± 0.9 are expected. In the "light gravitino" scenario, this can be translated into limits in the (μ, M_2) plane as shown in Fig. 2) which are sufficient to rule out the "chargino" interpretation of the CDF event quoted in [4]. They also exclude lightest charginos $\chi_1^\pm$ and neutralinos χ_1^0 with masses less than 150 GeV/c^2 and 75 GeV/c^2 respectively (95% C.L.).

DØ has also obtained limits on production cross sections for selectrons, sneutrinos, and neutralinos in the "light neutralino" model. They range from 400 fb to 1 pb for $m_{\chi_2^0} - m_{\chi_1^0} > 20$ GeV/c^2. A general limit on the cross section

$$\sigma(p\overline{p} \to \gamma\gamma \not{E}_T + X) < 185 \text{ fb (95\% C.L.)}$$

for $E_T^\gamma > 12$ GeV, $|\eta| < 1.1$, and $\not{E}_T > 25$ GeV, is also obtained.

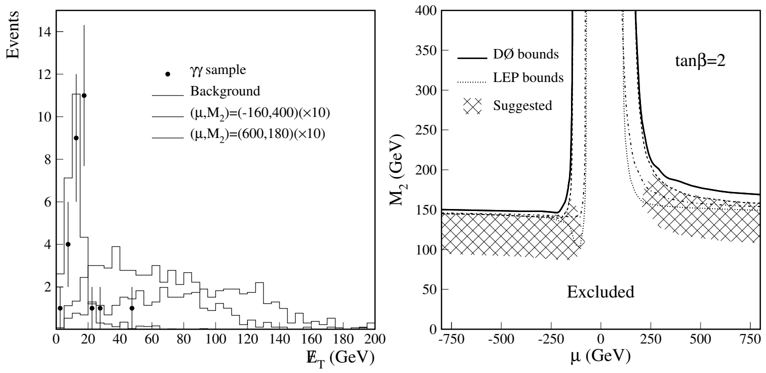

Fig. 2. (left) Spectrum of $\not\!\!E_T$ for events with two photons in DØ; (right) Exclusion region in the (μ, M_2) plane from this analysis. The hatched region is that proposed in [4] to explain the CDF $ee\gamma\gamma \not\!\!E_T$ event. These limits are only very weakly dependent on $\tan\beta$.

2.2 Photon + Tagged Jet + $\not\!\!E_T$

CDF has also searched for single photons produced together with b-jets and $\not\!\!E_T$. This could occur from the light stop squark which is expected in the light neutralino scenario.

The analysis requires one photon with $E_T > 25$ GeV, one jet with $E_T > 15$ GeV, and an SVX b-tag. The $\not\!\!E_T$ distribution for these events is shown in Fig. 3. Two events are observed with $\not\!\!E_T > 40$ GeV. Without attempting to perform a background subtraction, the upper limit is then 6.4 events, which marginally excludes (6.7 events expected) a baseline model of Ambrosanio *et al.*[5] with a 40 GeV χ_1^0, a 70 GeV χ_2^0, 60 GeV stop squark, 225 GeV gluinos and 250 GeV squarks. If the lighter sparticle masses are held constant, limits may be set on the squark and gluino masses: $m_{\tilde{q}}, m_{\tilde{g}} < 200$ GeV$/c^2$ is excluded, and for $m_{\tilde{q}} = m_{\tilde{g}}$ the limit is 225 GeV$/c^2$.

3 Search for High-Mass Photon Pairs

DØ has carried out a search for massive objects decaying into two photons which might be produced in association with a vector boson:

$$p\overline{p} \rightarrow X(W/Z) \rightarrow \gamma\gamma \text{ jet jet}$$

Here X might be technipion or a Higgs with nonstandard couplings. In particular the case where X is a so-called "bosonic Higgs" was investigated: this is a Higgs with SM couplings to vector bosons but zero couplings to fermions[6]. Two photons were required with $E_T > 20$ and 15 GeV and $|\eta| < 2.0$ and 2.25 respectively; also two jets satisfying the same kinematic requirements,

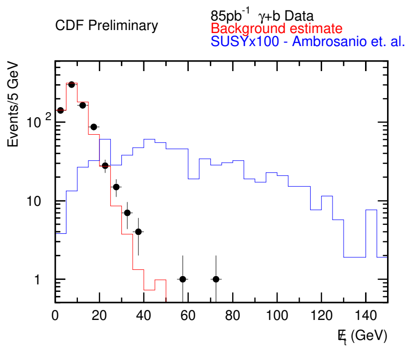

Fig. 3. Spectrum of $\not{E}_T$ for events with $\gamma+$ tagged jet from CDF.

and with a dijet mass between 40 and 150 GeV/c^2 (consistent with W or Z decay). Additionally it was required that both the diphoton system and the dijet system have $p_T > 10$ GeV/c, to select events where the diphoton and dijet recoil against each other. Seven events are observed, with 10.5 ± 4.0 expected. No indication of new physics is seen, and the case of a "bosonic Higgs" can be excluded for $m_H < 81(86)$ GeV/c^2 at 90(95)% C.L.

4 Conclusions

Photons offer productive search channels for new physics. While the CDF $ee\gamma\gamma$ event is still interesting, there is no sign of a confirming observation in any other channel. Twenty times the present dataset will be accumulated in Run II, starting in 1999; if new physics is indeed just around the corner, it will be hard to miss. For example, we might have 20 "$ee\gamma\gamma$" events in CDF and DØ by 2002.

References

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