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Explaining Tevatron leptons photons missing-E_T events with supersymmetry

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Abstract. The CDF experiment reported a lepton photon missing transverse energy ($\not{E}_T$) signal 3σ in excess of the standard model prediction in Tevatron Run I data. The excess can be explained by the resonant production of a smuon, which subsequently decays to a muon, a photon and a gravitino. Here, we perform combined fits of this model to the CDF $\gamma l \not{E}_T$ excess, the D0 measurement of the same channel and the CDF $\gamma \not{E}_T$ channel. Although the rates of the latter two analyses are in agreement with the standard model prediction, our model is in good agreement with these data because their signal to background efficiency is low at the best-fit point. However, they help to constrain the model away from the best fit point.

Keywords. Gauge mediated; Tevatron.

1. Introduction

The CDF experiment has recently discovered an anomaly in the production rate of lepton-photon-$\not{E}_T$ in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV, using 86.34 pb^{-1} of Tevatron 1994–95 data [1]. While the number of events expected from the standard model (SM) were 7.6 ± 0.7, the experimentally measured number corresponded to 16. Moreover, 11 of these events involved muons (with 4.2 ± 0.5 expected) and 5 electrons (with 3.4 ± 0.3 expected).

In earlier papers [2] we suggested that the excess can be simply understood in terms of the minimal supersymmetric standard model (MSSM) which has the following ingredients: (1) the model is R-parity violating with an L-violating λ'_{211} coupling, and (2) the supersymmetric spectrum includes an ultra-light gravitino of mass $\sim 10^{-3}$ eV. A single smuon thus produced decays predominantly into a bino-dominated neutralino and a muon, with the neutralino further decaying into a photon and a gravitino.

In the current article, we extend the previous studies by including two additional pieces of independent empirical information. We include the D0 Run I measurement [3] of the $\mu\gamma$ missing E_T process, as well as γ missing E_T data coming from CDF in Run I [4]. Our scenario predicts excesses in each of these channels, and we determine to what extent it is in accord with their measured rates. By performing a combined fit to all three event rates, we constrain the masses of the relevant sparticles in the event, as well as λ'_{211}.

Table 1. Observed number of events passing cuts in the text and standard model backgrounds for the three pieces of data included in the combined fit. The integrated luminosity for each analysis is also listed.

Experiment	Luminosity	Observed number	Background
CDF $l\gamma\not{E}_T$	86 pb^{-1}	11	4.2 ± 0.5
D0 $\mu\gamma\not{E}_T$	73 pb^{-1}	58	58 ± 9.75
CDF $\gamma\not{E}_T$	86 pb^{-1}	11	11 ± 2.2

2. The model

In order that the cross-section for the production of the smuon resonance is substantial enough to account for the anomalous events, we need the left-handed smuon to be light, i.e., $m_{\tilde{\mu}_L} \sim 150$ GeV. In our model, we take the squarks to be heavy and so their effects on experimental observables will be negligible. Since $m_{\tilde{\nu}} < m_{\tilde{\mu}_L}$, if we assumed that smuons were produced at the Tevatron Run I energy, we should expect that muon sneutrinos could also be produced. The dominant production mechanism is resonant sneutrino production and subsequent decay. It results in a $\gamma\not{E}_T$ experimental signature.

The pattern of masses of the super-particles suggested by the CDF $\mu\gamma\not{E}_T$ anomaly is the following: the smuon is around 150 GeV, and the only other light sparticles are the neutralino (which is typically about 45 GeV lighter than the smuon) and the ultra-light gravitino (which is as light as 10^{-3} eV). We enforce degeneracy between the first two generations in order to avoid flavour changing neutral currents. Other sparticles do not play a role in this analysis, and are set to be arbitrarily heavy.

3. Simulating the experiments

In our model, we have essentially four free parameters that are relevant to the data we fit: the gravitino mass, $m_{\tilde{G}}$, the neutralino mass $m_{\chi_1^0}$, the smuon mass, $M_{\tilde{\mu}}$ and the R-violating coupling λ'_{211}. The coupling λ'_{211}, is constrained from $R_\pi = \Gamma(\pi \to e\nu)/(\pi \to \mu\nu)$ [5] to be $< 0.059 \times m_{\tilde{d}_R}/100$ GeV [6].

We choose $\tan\beta = 10$ and $A_{t,\tau,b} = 0$. μ together with other flavour diagonal soft supersymmetry breaking parameters are set to be very large.

As stated earlier, we present analyses for three sets of data in this paper: the CDF Run I data on $l\gamma\not{E}_T$ [1], the D0 Run I data on $\mu\gamma\not{E}_T$ [3] and the CDF Run I data on $\gamma\not{E}_T$ [4]. The fiducial efficiencies and cuts used mimic those of the relevant experiments [2].

The observed number of events in the different analyses, and their standard model backgrounds (taken from the experimental papers [1,3,4]) are shown in table 1. We now simulate the signal events for the relevant processes with HERWIG6.4 [7].

4. Combined fits

For each of the three data listed in table 1, we can define a Poissonian log-likelihood convoluted with a Gaussian for the experimental background rates. We will constrain $M_{\chi_1^0} > 100$ GeV, as implied by $\gamma\gamma\not{E}_{\rm T}$ LEP2 data [8].

We provide, as an example, a fit in the $m_{\tilde{G}}, M_{\tilde{\mu}}$ plane. Here we have chosen default values of $\lambda'_{211} = 0.01$ and $M_{\chi_1^0} = 100$ GeV. The ranges $M_{\tilde{\mu}} = 130$–230 GeV, $m_{\tilde{G}} = 10^{-4.5}$–$10^{-1.5}$ eV provide a reasonable combined fit to 90% CL. The best-fit point is $m_{\tilde{G}} = 10^{-3.1}$ eV, $M_{\tilde{\mu}} = 142$ GeV, with $\Delta\chi^2 = 6.8$ for one degree of freedom. Within the good-fit region, we expect between 1 and 6 signal events in the CDF $l\gamma\not{E}_{\rm T}$ channel. 0–4 events are expected at D0, and up to 0.2 signal events were predicted for the CDF $\gamma\not{E}_{\rm T}$ signature, depending on the parameters.

5. Conclusions

We have provided combined fits for a supersymmetric model that explains the $l\gamma\not{E}_{\rm T}$ CDF Run I excess in events, which was at the 2.7σ level [1]. We have used the Run I $\gamma\not{E}_{\rm T}$ data recently presented by CDF, as well as anomalous trilinear gauge boson coupling data from D0. Constraints upon various hyper planes in the gravitino, smuon, neutralino and R-parity violating coupling space have been displayed. In totality, the signal rates predicted by our model for the three analyses fit the data well: $\Delta\chi^2 = 6.8$ less than the standard model, for one degree of freedom at the best-fit point.

Unfortunately, background rates in the D0 anomalous trilinear gauge boson coupling data are too high for it to be very sensitive to the predicted signal rate. The CDF $\gamma\not{E}_{\rm T}$ channel suffers from a high $E_{\rm T}(\gamma) > 55$ cut because of cosmic backgrounds, which unfortunately also cuts most of the signal. Run II will provide sensitivity in these channels, however.

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