Search for Diphoton Events with Large Missing Transverse Energy in $p\overline{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

S. Abachi,[14] B. Abbott,[28] M. Abolins,[25] B. S. Acharya,[43] I. Adam,[12] D. L. Adams,[37] M. Adams,[17] S. Ahn,[14] H. Aihara,[22] G. Álvarez,[18] G. A. Alves,[10] E. Amidi,[29] N. Amos,[24] E. W. Anderson,[19] S. H. Aronson,[4] R. Astur,[42] M. M. Baarmand,[42] A. Baden,[23] V. Balamurali,[32] J. Balderston,[16] B. Baldin,[14] S. Banerjee,[43] J. Bantly,[5] J. F. Bartlett,[14] K. Bazizi,[39] A. Belyaev,[26] J. Bendich,[22] S. B. Beri,[34] I. Bertram,[31] V. A. Bezzubov,[35] P. C. Bhat,[14] V. Bhatnagar,[34] M. Bhattacharjee,[13] A. Bischoff,[9] N. Biswas,[32] G. Blazey,[30] S. Blessing,[15] P. Bloom,[7] A. Boehnlein,[14] N. I. Bojko,[35] F. Borcherding,[14] J. Borders,[39] C. Boswell,[9] A. Brandt,[14] R. Brock,[25] A. Bross,[14] D. Buchholz,[31] V. S. Burtovoi,[35] J. M. Butler,[3] W. Carvalho,[10] D. Casey,[39] H. Castilla-Valdez,[11] D. Chakraborty,[42] S.-M. Chang,[29] S. V. Chekulaev,[35] L.-P. Chen,[22] W. Chen,[42] S. Choi,[41] S. Chopra,[24] B. C. Choudhary,[9] J. H. Christenson,[14] M. Chung,[17] D. Claes,[27] A. R. Clark,[22] W. G. Cobau,[23] J. Cochran,[9] W. E. Cooper,[14] C. Cretsinger,[39] D. Cullen-Vidal,[5] M. A. C. Cummings,[16] D. Cutts,[5] O. I. Dahl,[22] K. De,[44] K. Del Signore,[24] M. Demarteau,[14] D. Denisov,[14] S. P. Denisov,[35] H. T. Diehl,[14] M. Diesburg,[14] G. Di Loreto,[25] P. Draper,[44] J. Drinkard,[8] Y. Ducros,[40] L. V. Dudko,[26] S. R. Dugad,[43] D. Edmunds,[25] J. Ellison,[9] V. D. Elvira,[42] R. Engelmann,[42] S. Eno,[23] G. Eppley,[37] P. Ermolov,[26] O. V. Eroshin,[35] V. N. Evdokimov,[35] S. Fahey,[25] T. Fahland,[5] M. Fatyga,[4] M. K. Fatyga,[39] J. Featherly,[4] S. Feher,[14] D. Fein,[2] T. Ferbel,[39] G. Finocchiaro,[42] H. E. Fisk,[14] Y. Fisyak,[7] E. Flattum,[25] G. E. Forden,[2] M. Fortner,[30] K. C. Frame,[25] P. Franzini,[12] S. Fuess,[14] E. Gallas,[44] A. N. Galyaev,[35] P. Gartung,[9] T. L. Geld,[25] R. J. Genik II,[25] K. Genser,[14] C. E. Gerber,[14] B. Gibbard,[4] V. Glebov,[39] S. Glenn,[7] B. Gobbi,[31] M. Goforth,[15] A. Goldschmidt,[22] B. Gómez,[1] G. Gómez,[23] P. I. Goncharov,[35] J. L. González Solís,[11] H. Gordon,[4] L. T. Goss,[45] A. Goussiou,[42] N. Graf,[4] P. D. Grannis,[42] D. R. Green,[14] J. Green,[30] H. Greenlee,[14] G. Griffin,[8] G. Grim,[7] N. Grossman,[14] P. Grudberg,[22] S. Grünendahl,[39] G. Guglielmo,[33] J. A. Guida,[2] J. M. Guida,[5] W. Guryn,[4] S. N. Gurzhiev,[35] P. Gutierrez,[33] Y. E. Gutnikov,[35] N. J. Hadley,[23] H. Haggerty,[14] S. Hagopian,[15] V. Hagopian,[15] K. S. Hahn,[39] R. E. Hall,[8] S. Hansen,[14] J. M. Hauptman,[19] D. Hedin,[30] A. P. Heinson,[9] U. Heintz,[14] R. Hernández-Montoya,[11] T. Heuring,[15] R. Hirosky,[15] J. D. Hobbs,[14] B. Hoeneisen,[1,*] J. S. Hoftun,[5] F. Hsieh,[24] Ting Hu,[42] Tong Hu,[18] T. Huehn,[9] A. S. Ito,[14] E. James,[2] J. Jaques,[32] S. A. Jerger,[25] R. Jesik,[18] J. Z.-Y. Jiang,[42] T. Joffe-Minor,[31] K. Johns,[2] M. Johnson,[14] A. Jonckheere,[14] M. Jones,[16] H. Jöstlein,[14] S. Y. Jun,[31] C. K. Jung,[42] S. Kahn,[4] G. Kalbfleisch,[33] J. S. Kang,[20] R. Kehoe,[32] M. L. Kelly,[32] L. Kerth,[22] C. L. Kim,[20] S. K. Kim,[41] A. Klatchko,[15] B. Klima,[14] B. I. Klochkov,[35] C. Klopfenstein,[7] V. I. Klyukhin,[35] V. I. Kochetkov,[35] J. M. Kohli,[34] D. Koltick,[36] A. V. Kostritskiy,[35] J. Kotcher,[4] A. V. Kotwal,[12] J. Kourlas,[28] A. V. Kozelov,[35] E. A. Kozlovski,[35] J. Krane,[27] M. R. Krishnaswamy,[43] S. Krzywdzinski,[14] S. Kunori,[23] S. Lami,[42] H. Lan,[14,†] G. Landsberg,[14] B. Lauer,[19] J-F. Lebrat,[40] A. Leflat,[26] H. Li,[42] J. Li,[44] Y. K. Li,[31] Q. Z. Li-Demarteau,[14] J. G. R. Lima,[38] D. Lincoln,[24] S. L. Linn,[15] J. Linnemann,[25] R. Lipton,[14] Q. Liu,[14,†] Y. C. Liu,[31] F. Lobkowicz,[39] S. C. Loken,[22] S. Lökös,[42] L. Lueking,[14] A. L. Lyon,[23] A. K. A. Maciel,[10] R. J. Madaras,[22] R. Madden,[15] L. Magaña-Mendoza,[11] S. Mani,[7] H. S. Mao,[14,†] R. Markeloff,[30] L. Markosky,[2] T. Marshall,[18] M. I. Martin,[14] B. May,[31] A. A. Mayorov,[35] R. McCarthy,[42] J. McDonald,[15] T. McKibben,[17] J. McKinley,[25] T. McMahon,[33] H. L. Melanson,[14] K. W. Merritt,[14] H. Miettinen,[37] A. Mincer,[28] J. M. de Miranda,[10] C. S. Mishra,[14] N. Mokhov,[14] N. K. Mondal,[43] H. E. Montgomery,[14] P. Mooney,[1] H. da Motta,[10] M. Mudan,[28] C. Murphy,[17] F. Nang,[2] M. Narain,[14] V. S. Narasimham,[43] A. Narayanan,[2] H. A. Neal,[24] J. P. Negret,[1] P. Nemethy,[28] D. Nešić,[5] M. Nicola,[10] D. Norman,[45] L. Oesch,[24] V. Oguri,[38] E. Oltman,[22] N. Oshima,[14] D. Owen,[25] P. Padley,[37] M. Pang,[19] A. Para,[14] Y. M. Park,[21] R. Partridge,[5] N. Parua,[43] M. Paterno,[39] J. Perkins,[44] M. Peters,[16] H. Piekarz,[15] Y. Pischalnikov,[36] V. M. Podstavkov,[35] B. G. Pope,[25] H. B. Prosper,[15] S. Protopopescu,[4] D. Pušeljić,[22] J. Qian,[24] P. Z. Quintas,[14] R. Raja,[14] S. Rajagopalan,[42] O. Ramirez,[17] P. A. Rapidis,[14] L. Rasmussen,[42] S. Reucroft,[29] M. Rijssenbeek,[42] T. Rockwell,[25] N. A. Roe,[22] P. Rubinov,[31] R. Ruchti,[32] J. Rutherfoord,[2] A. Sánchez-Hernández,[11] A. Santoro,[10] L. Sawyer,[44] R. D. Schamberger,[42] H. Schellman,[31] J. Sculli,[28] E. Shabalina,[26] C. Shaffer,[15] H. C. Shankar,[43] R. K. Shivpuri,[13] M. Shupe,[2] H. Singh,[34] J. B. Singh,[34] V. Sirotenko,[30] W. Smart,[14] A. Smith,[2] R. P. Smith,[14] R. Snihur,[31] G. R. Snow,[27] J. Snow,[33] S. Snyder,[4] J. Solomon,[17] P. M. Sood,[34] M. Sosebee,[44] N. Sotnikova,[26] M. Souza,[10] A. L. Spadafora,[22] R. W. Stephens,[44] M. L. Stevenson,[22] D. Stewart,[24] D. A. Stoianova,[35] D. Stoker,[8] K. Streets,[28] M. Strovink,[22] A. Sznajder,[10] P. Tamburello,[23] J. Tarazi,[8] M. Tartaglia,[14] T. L. T. Thomas,[31] J. Thompson,[23] T. G. Trippe,[22] P. M. Tuts,[12] N. Varelas,[25] E. W. Varnes,[22] D. Vititoe,[2] A. A. Volkov,[35] A. P. Vorobiev,[35] H. D. Wahl,[15] G. Wang,[15] J. Warchol,[32] G. Watts,[5] M. Wayne,[32] H. Weerts,[25] A. White,[44] J. T. White,[45] J. A. Wightman,[19] S. Willis,[30] S. J. Wimpenny,[9] J. V. D. Wirjawan,[45] J. Womersley,[14] E. Won,[39]

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D. R. Wood,[29] H. Xu,[5] R. Yamada,[14] P. Yamin,[4] C. Yanagisawa,[42] J. Yang,[28] T. Yasuda,[29] P. Yepes,[37] C. Yoshikawa,[16] S. Youssef,[15] J. Yu,[14] Y. Yu,[41] Q. Zhu,[28] Z. H. Zhu,[39] D. Zieminska,[18] A. Zieminski,[18] E. G. Zverev,[26] and A. Zylberstejn[40]

(D0 Collaboration)

[1]*Universidad de los Andes, Bogotá, Colombia*
[2]*University of Arizona, Tucson, Arizona 85721*
[3]*Boston University, Boston, Massachusetts 02215*
[4]*Brookhaven National Laboratory, Upton, New York 11973*
[5]*Brown University, Providence, Rhode Island 02912*
[6]*Universidad de Buenos Aires, Buenos Aires, Argentina*
[7]*University of California, Davis, California 95616*
[8]*University of California, Irvine, California 92717*
[9]*University of California, Riverside, California 92521*
[10]*LAFEX, Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brazil*
[11]*CINVESTAV, Mexico City, Mexico*
[12]*Columbia University, New York, New York 10027*
[13]*Delhi University, Delhi, India 110007*
[14]*Fermi National Accelerator Laboratory, Batavia, Illinois 60510*
[15]*Florida State University, Tallahassee, Florida 32306*
[16]*University of Hawaii, Honolulu, Hawaii 96822*
[17]*University of Illinois at Chicago, Chicago, Illinois 60607*
[18]*Indiana University, Bloomington, Indiana 47405*
[19]*Iowa State University, Ames, Iowa 50011*
[20]*Korea University, Seoul, Korea*
[21]*Kyungsung University, Pusan, Korea*
[22]*Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720*
[23]*University of Maryland, College Park, Maryland 20742*
[24]*University of Michigan, Ann Arbor, Michigan 48109*
[25]*Michigan State University, East Lansing, Michigan 48824*
[26]*Moscow State University, Moscow, Russia*
[27]*University of Nebraska, Lincoln, Nebraska 68588*
[28]*New York University, New York, New York 10003*
[29]*Northeastern University, Boston, Massachusetts 02115*
[30]*Northern Illinois University, DeKalb, Illinois 60115*
[31]*Northwestern University, Evanston, Illinois 60208*
[32]*University of Notre Dame, Notre Dame, Indiana 46556*
[33]*University of Oklahoma, Norman, Oklahoma 73019*
[34]*University of Panjab, Chandigarh 16-00-14, India*
[35]*Institute for High Energy Physics, 142-284 Protvino, Russia*
[36]*Purdue University, West Lafayette, Indiana 47907*
[37]*Rice University, Houston, Texas 77005*
[38]*Universidade Estadual do Rio de Janeiro, Rio de Janeiro, Brazil*
[39]*University of Rochester, Rochester, New York 14627*
[40]*CEA, DAPNIA/Service de Physique des Particules, CE-Saclay, Gif-sur-Yvette, France*
[41]*Seoul National University, Seoul, Korea*
[42]*State University of New York, Stony Brook, New York 11794*
[43]*Tata Institute of Fundamental Research, Colaba, Bombay 400005, India*
[44]*University of Texas, Arlington, Texas 76019*
[45]*Texas A&M University, College Station, Texas 77843*
(Received 12 December 1996)

A search for new physics has been carried out in the channel $p\overline{p} \to \gamma\gamma + \not\!\!E_T$, as expected in various supersymmetric models. We require two photons with transverse energy $E_T^\gamma > 12$ GeV and pseudorapidity $|\eta^\gamma| < 1.1$. The distribution of missing transverse energy ($\not\!\!E_T$) is consistent with background and no events have $\not\!\!E_T > 25$ GeV. We set limits on production cross sections for selectron, sneutrino, and neutralino pairs, decaying into photons, which range from about 400 fb to 1 pb depending on the sparticle masses. A general limit of 185 fb (95% C.L.) is set on $\sigma(p\overline{p} \to \gamma\gamma\not\!\!E_T + X)$, where $E_T^\gamma > 12$ GeV, $|\eta^\gamma| < 1.1$, and $\not\!\!E_T > 25$ GeV. [S0031-9007(97)02738-5]

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We have searched for new physics in the channel $p\overline{p} \rightarrow \gamma\gamma \not\!\!E_T + X$ (where $\not\!\!E_T$ denotes missing transverse energy). This was motivated by recent suggestions that low-energy supersymmetry (SUSY) may result in signatures involving one or more photons together with missing transverse energy. Such signatures could arise from the decay $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \gamma$ in models with a light neutralino [1,2], from the decay $\tilde{\chi}_1^0 \rightarrow \tilde{G}\gamma$ in supergravity models with a light gravitino [3], or in models of gauge-mediated supersymmetry breaking [4–7]. It is suggested that the cross sections might be sufficient to lead to several tens of events in present data, making signals easily detectable. Recent theoretical interest stems from a desire to explain a single $ee\gamma\gamma + \not\!\!E_T$ event observed by the CDF collaboration [8].

For this analysis, data corresponding to an integrated luminosity of 93.3 ± 11.2 pb^{-1}, recorded during 1992–1995 with the D0 detector [9], were used. Photons were identified using the uranium-liquid argon sampling calorimeter, which covers the region of pseudorapidity $|\eta| = |-\ln\tan\frac{\theta}{2}| \lesssim 4$. The electromagnetic (EM) energy resolution is $\sigma_E/E = 15\%/\sqrt{E(\mathrm{GeV})} \oplus 0.3\%$. The EM calorimeter is segmented into four longitudinal sections, and transversely into towers in pseudorapidity and azimuthal angle, of size $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$ (0.05×0.05 at shower maximum). Drift chambers in front of the calorimeter were used to distinguish photons from electrons and photon conversions. A three-level triggering system was employed. The first level used scintillation counters near the beam pipe to detect an inelastic interaction; the second level summed the EM energy in calorimeter towers of size $\Delta\eta \times \Delta\phi = 0.2 \times 0.2$. The third level was a software trigger which formed clusters of calorimeter cells and applied loose cuts on the shower shape.

Events were selected which had two photon candidates, each with transverse energy $E_T^\gamma > 12$ GeV and $|\eta^\gamma| < 1.1$. Each cluster was required to pass photon-selection requirements [10], namely, to have a shape consistent with that of a single EM shower, to have more than 96% of its energy in the EM section of the calorimeter, and to be isolated. The latter was based on the transverse energy E_T^{iso} in the annular region between $\mathcal{R} = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.2$ and $\mathcal{R} = 0.4$ around the cluster, requiring $E_T^{\mathrm{iso}} < 2$ GeV. Candidates were rejected if the cluster was near an azimuthal module boundary, if there was a track (or a significant number of drift-chamber hits) in a tracking road $\Delta\theta \times \Delta\phi = 0.2 \times 0.2$ between the cluster and the vertex, if the invariant mass of the photon pair was between 80 and 100 GeV$/c^2$ (to reject misidentified $Z \rightarrow ee$ events), or if the azimuthal angle between the two photons was less than 90° (to reduce the background from $W\gamma$ production and radiative $W \rightarrow e\nu\gamma$ decays, with the electron misidentified as a photon). The beam pipe of the Main Ring accelerator passes through the outermost layer of the calorimeter. Losses of accelerated particles from the Main Ring can lead to energy deposits in the calorimeter and thus to spurious missing transverse energy. To eliminate this source of background the $\not\!\!E_T$ was required to have an azimuthal separation $20° < \Delta\phi < 160°$ from the Main Ring. To eliminate events where the $\not\!\!E_T$ was due to mismeasured jet energy, it was also required to have an azimuthal separation $\Delta\phi < 160°$ from either of the leading two jets (provided $E_T^{\mathrm{jet}} > 12$ GeV).

These selections yielded 842 events, whose $\not\!\!E_T$ distribution is plotted in Fig. 1. No events are observed with $\not\!\!E_T > 25$ GeV. The resolution of the detector in $\not\!\!E_T$ is about 4 GeV for diphoton final states passing these kinematic selections.

The dominant background to diphotons with large $\not\!\!E_T$ arises from QCD events where jet or vertex mismeasurement leads to excess $\not\!\!E_T$. Therefore, starting with the same trigger and dataset, a background sample was selected which was expected to suffer from the same mismeasurements. Two EM clusters, satisfying the same kinematic and fiducial cuts as the signal, were required. Both were required to have more than 90% of their energy in the EM section of the calorimeter. At least one of the two EM clusters was required to fail the strict photon isolation criterion ($E_T^{\mathrm{iso}} < 2$ GeV) but both were required to have $E_T^{\mathrm{iso}} < 5$ GeV; at least one of the clusters was required to have a bad shower shape, and both were required to have either no track in the road, or a track with a bad match to the cluster. Electron backgrounds are evaluated separately. The resulting sample was expected to contain both QCD multijet events where two jets fluctuated into highly EM clusters, and the $\not\!\!E_T$ was due to mismeasurement; and QCD photon + jets events, where one photon was real and the other a fluctuated jet, and the $\not\!\!E_T$ was again due to mismeasurement. This selection yielded 1678 events. The distribution was normalized to the $\gamma\gamma$ sample over the range $\not\!\!E_T < 20$ GeV to estimate the background at higher $\not\!\!E_T$. The resulting number of events expected with $\not\!\!E_T > 25$ GeV is 1.0 ± 0.7.

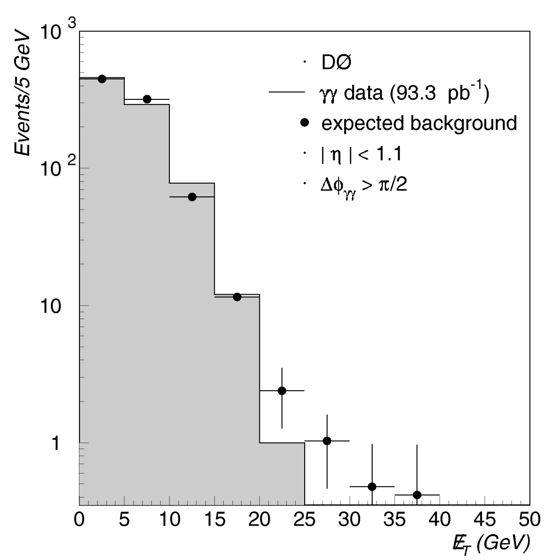

FIG. 1. Distribution of $\not\!\!E_T$ for $\gamma\gamma$ data (shaded histogram), and for the total expected background (black circles).

Processes such as $W \to e\nu$, $\tau \to eX$, and even $t\bar{t} \to eX$ contain genuine $\not{E}_T$ and an electron whose track may be lost. If these are combined with a real or fake photon, as apparent $\gamma\gamma\not{E}_T + X$ signal can result. Again, starting with the same trigger and dataset, a sample of $e\gamma + X$ events was selected, having two EM clusters satisfying the same kinematic and fiducial cuts as the signal; both of the clusters were required to pass the strict photon selection (isolation, shower shape, EM fraction); one of the two clusters had to have exactly one drift chamber track in the road, with a good match to the cluster, and the other cluster had to have no associated drift chamber hits or track. These selections yielded 321 $e\gamma + X$ events. To estimate the contribution of such events to the $\gamma\gamma\not{E}_T + X$ signal, it is first necessary to remove the QCD background component from the $e\gamma + X$ candidate sample. This was done by normalizing these two distributions in the region of low missing transverse energy ($\not{E}_T < 20$ GeV), then subtracting the QCD distribution from that of the $e\gamma + X$ candidates. The resulting distribution was then multiplied by the ratio of probabilities for a genuine electron to be reconstructed as a photon or as an electron, which is estimated (from $Z \to ee$ events) to be 0.14 ± 0.01 for the selection criteria used here. The resulting $e\gamma + X$ contribution to the $\gamma\gamma\not{E}_T + X$ sample is estimated to be 1.1 ± 0.1 events.

The total expected background is shown in Fig. 1, and agrees well with the observed data. There is no evidence for nonstandard sources of $\gamma\gamma$ events. The expected number of background events with $\not{E}_T > 25$ GeV is 2.0 ± 0.9 and none is observed. If we extend the pseudorapidity coverage for photons to $|\eta^\gamma| < 2.5$, we observe only one event with $\not{E}_T > 30$ GeV, with an expected background of 4.6 ± 0.8.

Simulated supersymmetry events were generated using the ISAJET Monte Carlo, version 7.20 [11]. The events were then processed through the detector simulation, trigger simulation, and the reconstruction software. One thousand events were generated for each of the processes and mass combinations listed in Table I. For the sneutrino-pair events, parameters were selected to keep the chargino mass large enough so that the decay $\tilde{\nu} \to \tilde{\chi}_1^\pm \ell$ remained kinematically forbidden. In all cases the decay $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0\gamma$ was forced. The mean $\not{E}_T$ and the mean photon E_T in these events is typically $\sim m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$, so we will primarily be sensitive to cases where this mass difference exceeds about 20 GeV$/c^2$. Both photons are usually produced centrally, motivating our requirement that $|\eta^\gamma| < 1.1$.

The product of signal acceptance and efficiency, as estimated from these Monte Carlo samples, is typically 0.05–0.10 for $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} \gtrsim 20$ GeV$/c^2$. In addition to the Monte Carlo statistical error, a systematic uncertainty of 8% has been included (based on the level of agreement between Monte Carlo and data-based estimates of the photon selection efficiencies).

Upper limits on the allowed cross sections for the process $p\bar{p} \to \tilde{x}\tilde{x}$ were evaluated, based on no events being observed for $\not{E}_T > 25$ GeV. (This range of $\not{E}_T$ is found to maximize the significance of the Monte Carlo supersymmetry signals, given the observed background distribution.) Here $\tilde{x} = \tilde{e}, \tilde{\nu}, \tilde{\chi}_2^0$, with subsequent decays $\tilde{e}, \tilde{\nu} \to \tilde{\chi}_2^0$ and $\tilde{\chi}_2^0 \to \gamma + \tilde{\chi}_1^0$. No background contribution was subtracted. The results are shown in Table I and Fig. 2. The 95% C.L. upper limits range from about 400 fb to 1 pb for the cases with $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} \geq 20$ GeV$/c^2$.

The results quoted above are somewhat model dependent. They are also difficult to relate to the light gravitino scenario of [4] and [6]. A general limit on final states with similar topologies has therefore been derived. It is found that, provided $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} \geq 20$ GeV$/c^2$, the acceptance for events with two photons having $E_T^\gamma > 12$ GeV and $|\eta^\gamma| < 1.1$, and with measured $\not{E}_T > 25$ GeV, is independent of the production process ($\tilde{e}\tilde{e}, \tilde{\nu}\tilde{\nu}, \tilde{\chi}_2^0\tilde{\chi}_2^0$) and the sparticle masses (see Fig. 2). The acceptance $\times$ efficiency is 0.183 ± 0.016. (This includes a diphoton acceptance and topological cut efficiency of 0.55, an identification efficiency per photon of 0.75, an azimuthal acceptance of 0.78 for the $\not{E}_T$, and an efficiency of 0.79 for the $\not{E}_T$ not to lie too close to a jet direction). The resulting limits are

$$\sigma(p\bar{p} \to \gamma\gamma\not{E}_T + X) < 185 \text{ fb (95\% C.L.)}$$
$$< 140 \text{ fb (90\% C.L.)},$$

where $E_T^\gamma > 12$ GeV, $|\eta^\gamma| < 1.1$, and $\not{E}_T > 25$ GeV. These limits are stricter than those placed on the

TABLE I. Upper limits on pair production cross section (95% C.L.) obtained for each of the Monte Carlo samples generated for this analysis, based on zero observed events. (A $\cdots$ in the limits column indicates that there were insufficient acceptance for a limit to be set on this combination of masses.)

Process	Masses (GeV/c^2) $\tilde{e}$	$\tilde{\nu}$	$\tilde{\chi}_2^0$	$\tilde{\chi}_1^0$	σ (95% C.L.) (pb)
$\tilde{e}\tilde{e}$	100	⋯	90	50	0.715
$\tilde{\nu}\tilde{\nu}$	⋯	70	50	30	0.995
	⋯	70	60	30	0.805
	⋯	70	60	50	⋯
	⋯	80	65	55	21.6
	⋯	80	70	60	20.8
	⋯	90	70	65	⋯
	⋯	90	80	65	2.13
	⋯	90	80	70	54.7
	⋯	100	90	70	0.765
	⋯	100	90	80	4.65
$\tilde{\chi}_2^0\tilde{\chi}_2^0$	⋯	⋯	60	30	0.715
	⋯	⋯	60	40	0.935
	⋯	⋯	70	30	0.555
	⋯	⋯	70	40	0.68
	⋯	⋯	70	50	1.03
	⋯	⋯	80	30	0.471
	⋯	⋯	80	40	0.610
	⋯	⋯	80	50	0.750
	⋯	⋯	90	40	0.424
	⋯	⋯	90	50	0.478

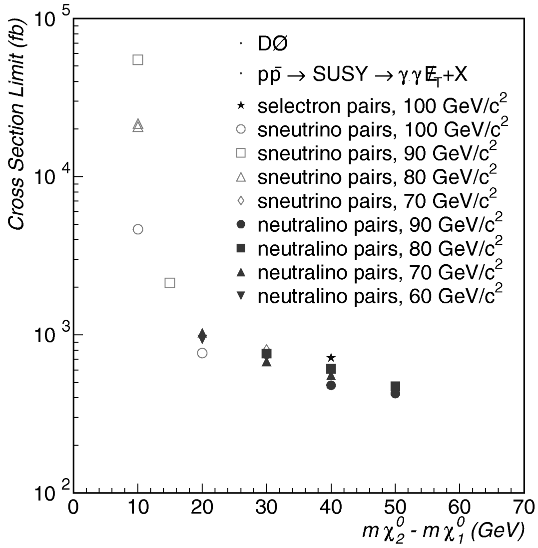

FIG. 2. Upper limits on pair production cross sections (95% C.L.) plotted as a function of neutralino mass difference. The decay $\tilde{\chi}_2^0 \to \gamma + \tilde{\chi}_1^0$ was forced (see text).

pair-production cross sections (Table I) because typically only 25%–50% of the supersymmetry events satisfy these kinematic requirements. Comparisons with Fig. 3 and 7 in Ref. [6] shows that this limit is sufficient to rule out a large fraction of the proposed parameter space for light gravitino models.

In obtaining this limit we used our simulated supersymmetry events to estimate the efficiency loss due to the relative azimuthal angle requirement between the $\not{E}_T$ and the leading two jets ($E_T^j > 12$ GeV). In the simulated events there was an average of 1.2 jets per event with $E_T^j > 12$ GeV. For final states with higher jet multiplicity we would expect a small additional loss of efficiency ($\sim$10%) due to the exclusion of additional azimuth.

To summarize, a search for signals of new physics has been carried out in the channel $p\overline{p} \to \gamma\gamma\not{E}_T + X$. This signature is expected in various recently proposed supersymmetric models. We observe 842 events with two photons having $E_T^\gamma > 12$ GeV and $|\eta^\gamma| < 1.1$. Of these, none have $\not{E}_T > 25$ GeV. The distribution of $\not{E}_T$ is consistent with that of the expected background. We therefore set limits on production cross sections for selectron, sneutrino and neutralino pairs decaying into photons and noninteracting particles; limits range from about 400 fb to 1 pb, depending on the sparticle masses. A general limit of 185 fb (95% C.L.) may also be set on $\sigma(p\overline{p} \to \gamma\gamma\not{E}_T + X)$, where $E_T^\gamma > 12$ GeV, $|\eta^\gamma| < 1.1$, and $\not{E} > 25$ GeV. This is sufficient to exclude a considerable fraction of the parameter space of recently proposed models.

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*Visitor from Universidad San Francisco de Quito, Quito, Ecuador.
†Visitor from IHEP, Beijing, China.

[1] S. Ambrosanio *et al.*, Phys. Rev. Lett. **76**, 3498 (1996).
[2] S. Ambrosanio *et al.*, Phys. Rev. D **55**, 1372 (1997).
[3] J. L. Lopez and D. V. Nanopoulos, Mod. Phys. Lett. A **10**, 2473 (1996).
[4] S. Dimopoulos, S. Thomas, and J. D. Wells, Phys. Rev. D **54**, 3283 (1996).
[5] S. Dimopoulos *et al.*, Phys. Rev. Lett. **76**, 3494 (1996).
[6] S. Ambrosanio *et al.*, Phys. Rev. D **54**, 5395 (1996).
[7] H. Baer *et al.*, Report No. hep-ph/9610358.
[8] S. Park, in *Proceedings of the 10th Topical Workshop on Proton-Antiproton Collider Physics*, edited by R. Raja and J. Yoh (AIP Press, New York, 1995).
[9] D0 Collaboration, S. Abachi *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **338**, 185 (1994).
[10] D0 Collaboration, S. Abachi *et al.*, Phys. Rev. Lett. **77**, 5041 (1996).
[11] H. Baer, F. E. Paige, S. D. Protopopescu, and X. Tata, "ISAJET A Monte Carlo Event Generator for *pp* and $p\overline{p}$ Reactions," see http://penguin.phy.bnl.gov/~paige/isajet.doc