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Evidence for Top Quark Production in $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV

F. Abe,[13] M. G. Albrow,[7] S. R. Amendolia,[23] D. Amidei,[16] J. Antos,[28] C. Anway-Wiese,[4] G. Apollinari,[26] H. Areti,[7] P. Auchincloss,[25] M. Austern,[14] F. Azfar,[21] P. Azzi,[20] N. Bacchetta,[18] W. Badgett,[16] M. W. Bailey,[24] J. Bao,[34] P. de Barbaro,[25] A. Barbaro-Galtieri,[14] V. E. Barnes,[24] B. A. Barnett,[12] P. Bartalini,[23] G. Bauer,[15] T. Baumann,[9] F. Bedeschi,[23] S. Behrends,[2] S. Belforte,[23] G. Bellettini,[23] J. Bellinger,[33] D. Benjamin,[32] J. Benlloch,[15] J. Bensinger,[2] D. Benton,[21] A. Beretvas,[7] J. P. Berge,[7] S. Bertolucci,[8] A. Bhatti,[26] K. Biery,[11] M. Binkley,[7] F. Bird,[29] D. Bisello,[20] R. E. Blair,[1] C. Blocker,[29] A. Bodek,[25] V. Bolognesi,[23] D. Bortoletto,[24] C. Boswell,[12] T. Boulos,[14] G. Brandenburg,[9] E. Buckley-Geer,[7] H. S. Budd,[25] K. Burkett,[16] G. Busetto,[20] A. Byon-Wagner,[7] K. L. Byrum,[1] C. Campagnari,[7] M. Campbell,[16] A. Caner,[7] W. Carithers,[14] D. Carlsmith,[33] A. Castro,[20] Y. Cen,[21] F. Cervelli,[23] J. Chapman,[16] M.-T. Cheng,[28] G. Chiarelli,[8] T. Chikamatsu,[31] S. Cihangir,[7] A. G. Clark,[23] M. Cobal,[23] M. Contreras,[5] J. Conway,[27] J. Cooper,[7] M. Cordelli,[8] D. P. Coupal,[29] D. Crane,[7] J. D. Cunningham,[2] T. Daniels,[15] F. DeJongh,[7] S. Delchamps,[7] S. Dell'Agnello,[23] M. Dell'Orso,[23] L. Demortier,[26] B. Denby,[23] M. Deninno,[3] P. F. Derwent,[16] T. Devlin,[27] M. Dickson,[25] S. Donati,[23] R. B. Drucker,[14] A. Dunn,[16] K. Einsweiler,[14] J. E. Elias,[7] R. Ely,[14] E. Engels, Jr.,[22] S. Eno,[5] D. Errede,[10] S. Errede,[10] Q. Fan,[25] B. Farhat,[15] I. Fiori,[3] B. Flaugher,[7] G. W. Foster,[7] M. Franklin,[9] M. Frautschi,[18] J. Freeman,[7] J. Friedman,[15] H. Frisch,[5] A. Fry,[29] T. A. Fuess,[1] Y. Fukui,[13] S. Funaki,[31] G. Gagliardi,[23] S. Galeotti,[23] M. Gallinaro,[20] A. F. Garfinkel,[24] S. Geer,[7] D. W. Gerdes,[16] P. Giannetti,[23] N. Giokaris,[26] P. Giromini,[8] L. Gladney,[21] D. Glenzinski,[12] M. Gold,[18] J. Gonzalez,[21] A. Gordon,[9] A. T. Goshaw,[6] K. Goulianos,[26] H. Grassmann,[6] A. Grewal,[21] G. Grieco,[23] L. Groer,[27] C. Grosso-Pilcher,[5] C. Haber,[14] S. R. Hahn,[7] R. Hamilton,[9] R. Handler,[33] R. M. Hans,[34] K. Hara,[31] B. Harral,[21] R. M. Harris,[7] S. A. Hauger,[6] J. Hauser,[4] C. Hawk,[27] J. Heinrich,[21] D. Cronin-Hennessy,[6] R. Hollebeek,[21] L. Holloway,[10] A. Hölscher,[11] S. Hong,[16] G. Houk,[21] P. Hu,[22] B. T. Huffman,[22] R. Hughes,[25] P. Hurst,[9] J. Huston,[17] J. Huth,[9] J. Hylen,[7] M. Incagli,[23] J. Incandela,[7] H. Iso,[31] H. Jensen,[7] C. P. Jessop,[9] U. Joshi,[7] R. W. Kadel,[14] E. Kajfasz,[7a] T. Kamon,[30] T. Kaneko,[31] D. A. Kardelis,[10] H. Kasha,[34] Y. Kato,[19] L. Keeble,[30] R. D. Kennedy,[27] R. Kephart,[7] P. Kesten,[14] D. Kestenbaum,[9] R. M. Keup,[10] H. Keutelian,[7] F. Keyvan,[4] D. H. Kim,[7] H. S. Kim,[11] S. B. Kim,[16] S. H. Kim,[31] Y. K. Kim,[14] L. Kirsch,[2] P. Koehn,[25] K. Kondo,[31] J. Konigsberg,[9] S. Kopp,[5] K. Kordas,[11] W. Koska,[7] E. Kovacs,[7a] W. Kowald,[6] M. Krasberg,[16] J. Kroll,[7] M. Kruse,[24] S. E. Kuhlmann,[1] E. Kuns,[27] A. T. Laasanen,[24] S. Lammel,[4] J. I. Lamoureux,[33] T. LeCompte,[10] S. Leone,[23] J. D. Lewis,[7] P. Limon,[7] M. Lindgren,[4] T. M. Liss,[10] N. Lockyer,[21] O. Long,[21] M. Loreti,[20] E. H. Low,[21] J. Lu,[30]

D. Lucchesi,[23] C. B. Luchini,[10] P. Lukens,[7] J. Lys,[14] P. Maas,[33] K. Maeshima,[7] A. Maghakian,[26] P. Maksimovic,[15] M. Mangano,[23] J. Mansour,[17] M. Mariotti,[23] J. P. Marriner,[7] A. Martin,[10] J. A. J. Matthews,[18] R. Mattingly,[2] P. McIntyre,[30] P. Melese,[26] A. Menzione,[23] E. Meschi,[23] G. Michail,[9] S. Mikamo,[13] M. Miller,[5] R. Miller,[17] T. Mimashi,[31] S. Miscetti,[8] M. Mishina,[13] H. Mitsushio,[31] S. Miyashita,[31] Y. Morita,[13] S. Moulding,[26] J. Mueller,[27] A. Mukherjee,[7] T. Muller,[4] P. Musgrave,[11] L. F. Nakae,[29] I. Nakano,[31] C. Nelson,[7] D. Neuberger,[4] C. Newman-Holmes,[7] L. Nodulman,[1] S. Ogawa,[31] S. H. Oh,[6] K. E. Ohl,[34] R. Oishi,[31] T. Okusawa,[19] C. Pagliarone,[23] R. Paoletti,[23] V. Papadimitriou,[7] S. Park,[7] J. Patrick,[7] G. Pauletta,[23] M. Paulini,[14] L. Pescara,[20] M. D. Peters,[14] T. J. Phillips,[6] G. Piacentino,[3] M. Pillai,[25] R. Plunkett,[7] L. Pondrom,[33] N. Produit,[14] J. Proudfoot,[1] F. Ptohos,[9] G. Punzi,[23] K. Ragan,[11] F. Rimondi,[3] L. Ristori,[23] M. Roach-Bellino,[32] W. J. Robertson,[6] T. Rodrigo,[7] J. Romano,[5] L. Rosenson,[15] W. K. Sakumoto,[25] D. Saltzberg,[5] A. Sansoni,[8] V. Scarpine,[30] A. Schindler,[14] P. Schlabach,[9] E. E. Schmidt,[7] M. P. Schmidt,[34] O. Schneider,[14] G. F. Sciacca,[23] A. Scribano,[23] S. Segler,[7] S. Seidel,[18] Y. Seiya,[31] G. Sganos,[11] A. Sgolacchia,[3] M. Shapiro,[14] N. M. Shaw,[24] Q. Shen,[24] P. F. Shepard,[22] M. Shimojima,[31] M. Shochet,[5] J. Siegrist,[29] A. Sill,[7a] P. Sinervo,[11] P. Singh,[22] J. Skarha,[12] K. Sliwa,[32] D. A. Smith,[23] F. D. Snider,[12] L. Song,[7] T. Song,[16] J. Spalding,[7] L. Spiegel,[7] P. Sphicas,[15] A. Spies,[12] L. Stanco,[20] J. Steele,[33] A. Stefanini,[23] K. Strahl,[11] J. Strait,[7] D. Stuart,[7] G. Sullivan,[5] K. Sumorok,[15] R. L. Swartz, Jr.,[10] T. Takahashi,[19] K. Takikawa,[31] F. Tartarelli,[23] W. Taylor,[11] Y. Teramoto,[19] S. Tether,[15] D. Theriot,[7] J. Thomas,[29] T. L. Thomas,[18] R. Thun,[16] M. Timko,[32] P. Tipton,[25] A. Titov,[26] S. Tkaczyk,[7] K. Tollefson,[25] A. Tollestrup,[7] J. Tonnison,[24] J. F. de Troconiz,[9] J. Tseng,[12] M. Turcotte,[29] N. Turini,[3] N. Uemura,[31] F. Ukegawa,[21] G. Unal,[21] S. van den Brink,[22] S. Vejcik, III,[16] R. Vidal,[7] M. Vondracek,[10] R. G. Wagner,[1] R. L. Wagner,[7] N. Wainer,[7] R. C. Walker,[25] G. Wang,[23] J. Wang,[5] M. J. Wang,[28] Q. F. Wang,[26] A. Warburton,[11] G. Watts,[25] T. Watts,[27] R. Webb,[30] C. Wendt,[33] H. Wenzel,[14] W. C. Wester, III,[14] T. Westhusing,[10] A. B. Wicklund,[1] R. Wilkinson,[21] H. H. Williams,[21] P. Wilson,[5] B. L. Winer,[25] J. Wolinski,[30] D. Y. Wu,[16] X. Wu,[23] J. Wyss,[20] A. Yagil,[7] W. Yao,[14] K. Yasuoka,[31] Y. Ye,[11] G. P. Yeh,[7] P. Yeh,[28] M. Yin,[6] J. Yoh,[7] T. Yoshida,[19] D. Yovanovitch,[7] I. Yu,[34] J. C. Yun,[7] A. Zanetti,[23] F. Zetti,[23] L. Zhang,[33] S. Zhang,[15] W. Zhang,[21] and S. Zucchelli[3]

(CDF Collaboration)

[1] *Argonne National Laboratory, Argonne, Illinois 60439*

[2] *Brandeis University, Waltham, Massachusetts 02254*

[3] *Istituto Nazionale di Fisica Nucleare, University of Bologna, I-40126 Bologna, Italy*

[4] *University of California at Los Angeles, Los Angeles, California 90024*

[5] *University of Chicago, Chicago, Illinois 60637*

[6] *Duke University, Durham, North Carolina 27708*

[7] *Fermi National Accelerator Laboratory, Batavia, Illinois 60510*

[8] *Laboratori Nazionali di Frascati, Istituto Nazionale di Fisica Nucleare, I-00044 Frascati, Italy*

[9] *Harvard University, Cambridge, Massachusetts 02138*

[10] *University of Illinois, Urbana, Illinois 61801*
[11] *Institute of Particle Physics, McGill University, Montreal H3A 2T8, and University of Toronto, Toronto M5S 1A7, Canada*
[12] *The Johns Hopkins University, Baltimore, Maryland 21218*
[13] *National Laboratory for High Energy Physics (KEK), Tsukuba, Ibaraki 305, Japan*
[14] *Lawrence Berkeley Laboratory, Berkeley, California 94720*
[15] *Massachusetts Institute of Technology, Cambridge, Massachusetts 02139*
[16] *University of Michigan, Ann Arbor, Michigan 48109*
[17] *Michigan State University, East Lansing, Michigan 48824*
[18] *University of New Mexico, Albuquerque, New Mexico 87131*
[19] *Osaka City University, Osaka 588, Japan*
[20] *Universita di Padova, Instituto Nazionale di Fisica Nucleare, Sezione di Padova, I-35131 Padova, Italy*
[21] *University of Pennsylvania, Philadelphia, Pennsylvania 19104*
[22] *University of Pittsburgh, Pittsburgh, Pennsylvania 15260*
[23] *Istituto Nazionale di Fisica Nucleare, University and Scuola Normale Superiore of Pisa, I-56100 Pisa, Italy*
[24] *Purdue University, West Lafayette, Indiana 47907*
[25] *University of Rochester, Rochester, New York 14627*
[26] *Rockefeller University, New York, New York 10021*
[27] *Rutgers University, Piscataway, New Jersey 08854*
[28] *Academia Sinica, Taiwan 11529, Republic of China*
[29] *Superconducting Super Collider Laboratory, Dallas, Texas 75237*
[30] *Texas A&M University, College Station, Texas 77843*
[31] *University of Tsukuba, Tsukuba, Ibaraki 305, Japan*
[32] *Tufts University, Medford, Massachusetts 02155*
[33] *University of Wisconsin, Madison, Wisconsin 53706*
[34] *Yale University, New Haven, Connecticut 06511*

Abstract

We summarize a search[1] for the top quark with the Collider Detector at Fermilab (CDF) in a sample of $\bar{p}p$ collisions at $\sqrt{s}$= 1.8 TeV with an integrated luminosity of 19.3 pb^{-1}. We find 12 events consistent with either two W bosons, or a W boson and at least one b jet. The probability that the measured yield is consistent with the background is 0.26%. Though the statistics are too limited to establish firmly the existence of the top quark, a natural interpretation of the excess is that it is due to $t\bar{t}$ production. Under this assumption, constrained fits to individual events yield a top quark mass of $174 \pm 10^{+13}_{-12}$ GeV/c^2. The $t\bar{t}$ production cross section is measured to be $13.9^{+6.1}_{-4.8}$ pb.

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The Standard Model has enjoyed outstanding success, yet the top quark, which is required as the weak-isospin partner of the bottom quark, has remained unobserved. Direct searches at the Fermilab Tevatron have placed a 95% confidence level lower limit of $M_{top} > 131$ GeV/c^2[2]. Global fits to precision electroweak measurements yield a favored mass of $M_{top} = 177^{+11+18}_{-11-19}$ GeV/c^2 [3].

One expects that, at Tevatron energies, most top quarks are produced in pairs. For $M_{top} \gtrsim 85$ GeV/c^2, each top quark decays to a real W boson and a b quark. The observed event topology is then determined by the decay mode of the two W bosons. About 5% of the time both W bosons decay to $e\nu$ or $\mu\nu$ (the "dilepton mode"), giving two high-P_T leptons with opposite charge, two b jets, and large missing transverse energy ($\not\!\!E_{\mathrm{T}}$) from the undetected neutrinos[4]. In another 30% of the cases one W boson decays to $e\nu$ or $\mu\nu$, and the other to a $q\bar{q}'$ pair (the "lepton+jets mode"). This final state includes a high-P_T charged lepton, $\not\!\!E_{\mathrm{T}}$, and jets from the W and the two b quarks. The remaining 65% of the final states involve the hadronic decays of both W bosons, or the decay of one or both of the W bosons into τ leptons. These channels have larger backgrounds and are not considered here. This analysis is based on a sample of $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV with an integrated luminosity of 19.3$\pm$0.7 pb^{-1}, collected at the Fermilab Tevatron by the CDF detector[5] in 1992-3. The details of the analysis are presented in Ref. [1].

The momenta of charged particles are measured in the central tracking chamber (CTC), which sits inside a 1.4-T superconducting solenoidal magnet. Outside the CTC, electromagnetic and hadronic calorimeters, arranged in a projective tower geometry, cover the pseudorapidity region $|\eta| < 3.6$, allowing reliable measurements of the $\not\!\!E_{\mathrm{T}}$. The calorimeters are also used to identify jets and electron candidates. Outside the calorimeters, drift chambers in the region $|\eta| < 1.0$ provide muon identification. A silicon vertex detector (SVX)[6], located immediately outside the beampipe, provides precise track reconstruction in the plane transverse to the beam, and is used to identify secondary vertices that can be produced by b and c quark decays. A three-level trigger selects the inclusive electron and muon events used in this analysis.

In the dilepton search, both leptons are required to have $P_T > 20$ GeV/c and to have opposite charge. At least one of the leptons is required to have $|\eta| < 1.0$ and to be isolated[1]. In addition, we require $\not\!\!E_{\mathrm{T}} > 25$ GeV[7]. To remove background from Z production, we reject ee and $\mu\mu$ events with $75 < M_{\ell\ell} < 105$ GeV/c^2. For $M_{top} > 120$ GeV/c^2, the two b quarks have significant energy and are detected with good efficiency as jets. By requiring two jets with $|\eta| < 2.4$ and $E_T > 10$ GeV[7], we reduce backgrounds by a factor of four while preserving 84% of the signal for $M_{top} = 160$ GeV/c^2. To achieve additional rejection against $Z \to \tau\tau$ events and events with $\not\!\!E_{\mathrm{T}}$ induced by jet mismeasurement, we require, for $\not\!\!E_{\mathrm{T}} < 50$ GeV, that the azimuthal angle between the $\not\!\!E_{\mathrm{T}}$ and the nearest lepton or jet exceed 20°. No ee or $\mu\mu$ events pass all cuts. Two $e\mu$ events survive.

We use the ISAJET[8] Monte Carlo program to determine the acceptance and the efficiency of the event-selection criteria. The fractional uncertainty in the efficiency of the two-jet requirement, due mostly to the limited understanding of gluon radiation, decreases from 13% for M_{top}=120 GeV/c^2 to 3% for M_{top}=180 GeV/c^2. Other uncertainties in the detection efficiency come from the lepton-identification cuts (6%), lepton-isolation cuts (2%), $\not\!\!E_{\mathrm{T}}$ cuts (2%), structure functions (2%), and Monte Carlo statistics (3%). The overall acceptance, ϵ_{DIL}, for the dilepton search is shown in Table 1. The number of expected dilepton events from $t\bar{t}$ production, using this acceptance and the theoretical cross section[9], is shown in Table 2.

The dilepton background from WW production is calculated using ISAJET, assuming a total WW cross section of 9.5 pb[10], and is found to be 0.16 ± 0.06 events. WW events may contain two jets due to initial-state gluon radiation. The treatment of initial-state radiation in the ISAJET calculation is checked using Z+jets data, and good agreement is found. The background from $Z \to \tau\tau$ is estimated using $Z \to ee$ data, where each electron is replaced by a simulated τ that decays leptonically. This background contributes 0.13 ± 0.04 events. We estimate backgrounds from $b\bar{b}$ and $c\bar{c}$ using ISAJET to model production processes, and the CLEO Monte Carlo program[11] to model B-meson decay. The Monte Carlo rates are normalized to a sample of $e\mu$ data collected with lower trigger thresholds. We estimate 0.10 ± 0.06 background events from these sources. Backgrounds from hadrons misidentified as leptons (0.07 ± 0.05 events) and the Drell-Yan production of lepton pairs ($0.10^{+0.23}_{-0.08}$) are estimated from inclusive-jet and Z data respectively. The total expected background is $0.56^{+0.25}_{-0.13}$ events, with two candidates observed.

Events selected for the lepton+jets search are required to have an isolated lepton with E_T (P_T for muons) > 20 GeV and $|\eta| < 1.0$, and to have $\not{E}_T > 20$ GeV[7]. Events containing Z bosons are removed by rejecting events with an ee or $\mu\mu$ invariant mass between 70 and 110 GeV/c^2. In Table 3 we classify the remaining events according to the multiplicity, N_{jet}, of jets with $E_T > 15$ GeV and $|\eta| < 2.0$[7]. The dominant background in the lepton+jets search is the direct production of W+jets. The ratio of the $t\bar{t}$ signal to W+jets background can be greatly improved by requiring $N_{jet} \geq 3$. This requirement has a rejection factor of $\approx$400 against inclusive W production while keeping approximately 75% of the $t\bar{t}$ signal in the lepton+jets mode for $M_{top} =$ 160 GeV/c^2. In the $W+ \geq$3-jet sample, we expect 12 ± 2 (6.6 ± 0.7) $t\bar{t}$ events for $M_{top} = 160$ (180) GeV/c^2, using the acceptance discussed below and the theoretical cross section. We observe 52 events with $N_{jet} \geq 3$.

The VECBOS Monte Carlo program[12] can be used to make estimates of direct W+jets production. Table 3 shows the results of a particular calculation which predicts 46 events with $\geq$3 jets and seven events with $\geq$4 jets. The VECBOS predictions for ≥ 3 jets have uncertainties of about a factor of two due to the choice of Q^2 scale and cannot be used for a reliable absolute background calculation. We have therefore developed a technique for estimating backgrounds in the lepton+jets search directly from the data. This technique is described below. Other backgrounds (direct $b\bar{b}$, Z bosons, W pairs, and hadrons misidentified as leptons) contribute 12.2 ± 3.1 events[1]. Additional background rejection is needed to isolate a possible $t\bar{t}$ signal. Requiring the presence of a b quark, tagged either by a secondary vertex or by a semileptonic decay, provides such rejection.

The lifetime of b hadrons can cause the b-decay vertex to be measurably displaced from the $\bar{p}p$ interaction vertex. When associated with jets with $E_T > 15$ GeV and $|\eta| < 2.0$, SVX tracks with $P_T \geq 2$ GeV/c and impact-parameter significance $|d|/\sigma_d \geq 3$ are used in a vertex-finding algorithm[1]. Using these tracks, the decay length transverse to the beam, L_{xy}, and its uncertainty (typically $\sigma_{L_{xy}} \approx 130$ μm) are calculated using a three-dimensional fit, with the tracks constrained to originate from a common vertex. Jets that have a secondary vertex displaced in the direction of the jet, with significance $|L_{xy}|/\sigma_{L_{xy}} \geq 3.0$, are defined to be "SVX-tagged."

We use a control sample, enriched in b-decays, of inclusive electrons ($E_T >$

10 GeV) to measure the efficiency for SVX-tagging a semileptonic b jet[1]. We compare this efficiency with that predicted by the ISAJET+CLEO $b\bar{b}$ Monte Carlo and find our measured efficiency to be lower than the Monte Carlo prediction by a factor of 0.72±0.21. We then determine the efficiency for tagging at least one b jet in a $t\bar{t}$ event with three or more observed jets, ϵ_{tag}, from $t\bar{t}$ Monte Carlo rescaled by the factor determined above. We find $\epsilon_{tag} = 22 \pm 6\%$ independent of top mass for $M_{top} > 120$ GeV/c^2. The efficiency, ϵ_{SVX}, for inclusive $t\bar{t}$ events to pass the lepton-identification, kinematic, and SVX b-tag requirements is shown in Table 1. The number of expected SVX-tagged $t\bar{t}$ events with $N_{jet} \geq 3$ is shown in Table 2. Six SVX-tagged events are observed in the 52-event $W+\geq$3-jet sample.

Rather than rely on Monte Carlo predictions, we estimate directly from our data how many tags we would expect in the 52-event sample if it were entirely background. We assume that the heavy-quark (b and c) content of jets in W+jets background events is the same as in an inclusive-jet sample[1]. This assumption is expected to be conservative, since the inclusive-jet sample contains heavy-quark contributions from direct production (e.g. $gg \to b\bar{b}$), gluon splitting (where a final-state gluon branches into a heavy-quark pair), and flavor excitation (where an initial-state gluon excites a heavy quark in the proton or antiproton sea), while heavy quarks in W+jets background events are expected to be produced almost entirely from gluon splitting[13]. We apply the tag rates measured in the inclusive-jet sample, parametrized by the E_T and track multiplicity of each jet, to the jets in the 52 events to yield the total expected number of SVX-tagged events from $Wb\bar{b}$, $Wc\bar{c}$, and fake tags due to track mismeasurement. We have tested this technique in a number of control samples and use the level of agreement with the number of observed tags to determine the systematic uncertainty on the predicted tag rate. The backgrounds from non-W sources (direct $b\bar{b}$ production and hadrons misidentified as leptons) are also determined from the data[1]. The small contributions from Wc, from WW and WZ production, and from $Z \to \tau\tau$ are estimated from Monte Carlo events. The total estimated background to SVX tags in the 52-event sample is 2.3±0.3 events. An alternate background estimate, using Monte Carlo calculations of the heavy-quark processes in W+jets events and a fake-tag estimate from jet data, predicts a heavy-quark content per jet approximately a factor of three lower than in inclusive-jet events and gives an overall background estimate a factor of 1.6 lower than the number presented above, supporting the conservative nature of our background estimate.

In the W+jets sample, the L_{xy} distribution of observed SVX tags is consistent with that of heavy-quark jets. The tags in the W events with one and two jets are expected to come mainly from sources other than $t\bar{t}$ decay, and the rate of these tags is consistent with the background prediction, with 16 events tagged and 22.1±4.0 predicted.

A second technique for tagging b quarks is to search for leptons arising from the decays $b \to \ell\nu X$ ($\ell = e$ or μ), or $b \to c \to \ell\nu X$. Because these leptons typically have lower P_T than leptons from W decays, we refer to them as "soft lepton tags", or SLT. We require lepton $P_T > 2$ GeV/c. To keep this analysis statistically independent of the dilepton search, leptons that pass the dilepton requirements are not considered as SLT candidates.

In searching for electrons from b and c decays, each CTC track is extrapolated to the calorimeter, and a match is sought to an electromagnetic cluster consistent in size, shape, and position with expectations for electron showers. The efficiency of the electron selection criteria, excluding isolation cuts, is determined from a sample of electron pairs from photon conversions, where the first electron is identified in the calorimeter and the second, unbiased, electron is selected using a track-pairing algorithm. The electron isolation efficiency is determined from $t\bar{t}$ Monte Carlo events. The total efficiencies are (53$\pm$3)% and (23$\pm$3)% (statistical uncertainties only) for electrons from b and sequential c decays respectively. To identify muons, track segments in the muon chambers are matched to tracks in the CTC. The efficiency for reconstructing track segments in the muon chambers is measured to be 96% using $J/\psi \rightarrow \mu^+\mu^-$ and $Z \rightarrow \mu^+\mu^-$ decays. This number is combined with the P_T-dependent efficiency of the track-matching requirements to give an overall efficiency of approximately 85% for muons from both b and c decays.

The acceptance of the SLT analysis for $t\bar{t}$ events is calculated using the ISAJET and CLEO Monte Carlo programs. The efficiency for tagging at least one jet in a $t\bar{t}$ event by detecting an additional lepton with $P_T > 2$ GeV/c is $\epsilon_{tag} = 16 \pm 2\%$, approximately independent of M_{top}. The efficiency, ϵ_{SLT}, for inclusive $t\bar{t}$ events to pass the lepton-identification, kinematic, and SLT b-tag requirements is shown in Table 1. The number of expected SLT-tagged $t\bar{t}$ events is shown in Table 2. We find seven SLT-tagged events with $N_{jet} \geq 3$. Three of the seven also have SVX tags.

The main backgrounds to the SLT search are hadrons misidentified as leptons, and $Wb\bar{b}$, $Wc\bar{c}$ production. As in the SVX analysis, we estimate these backgrounds from the data by conservatively assuming that the heavy-quark content per jet in W+jets events is the same as in inclusive-jet events. By studying tracks in such events, we measure the probability of misidentifying a hadron as an electron or muon, or of tagging a true semileptonic decay. We use these probabilities to predict the number of tags in a variety of control samples, and obtain good agreement with the number observed. We expect 2.70$\pm$0.27 tags in the $W+ \geq$3 jet sample from these sources. Other sources (direct $b\bar{b}$, W/Z pairs, $Z \rightarrow \tau\tau$, Wc, and Drell-Yan) contribute 0.36$\pm$0.09 events, for a total SLT background of 3.1$\pm$0.3 events. The number of SLT tags in the W+1 and W+2-jet samples, which should have only a small contribution from $t\bar{t}$, agrees with the background expectation (45 events tagged, 44$\pm$3.4 predicted). Figure 1 shows the combined number of SVX and SLT tags, together with the estimated background, as a function of jet multiplicity.

Each of the analyses presented above shows an excess of events over expected backgrounds, as shown in Table 2. The dilepton analysis observes two events with a background of $0.56^{+0.25}_{-0.13}$. The lepton+jets b-tag analysis identifies ten events: six events with a background of 2.3$\pm$0.3 using the SVX tagging algorithm, and seven events with a background of 3.1$\pm$0.3 using the SLT tagging algorithm, with three of these events tagged by both algorithms. For each of these results we calculate the probability, $\mathcal{P}$, that the estimated background has fluctuated up to the number of candidate events seen or greater. We find $\mathcal{P}_{DIL}$=12%, $\mathcal{P}_{SVX}$=3.2%, and $\mathcal{P}_{SLT}$=4.1%.

To calculate the probability $\mathcal{P}_{combined}$ that all three results together are due only to an upward fluctuation of the background, we use the observation of 15 "counts":

the two dilepton events, the six SVX tags, and the seven SLT tags. This procedure gives extra weight to the double-tagged events, which are approximately six times more likely to come from b and c jets than from fakes, and therefore have a significantly smaller background than the single-tagged events. We have checked that we understand SVX$-$SLT correlations by correctly predicting the number of double-tagged jets and events in the inclusive-jet sample. We calculate $\mathcal{P}_{combined}$ using a Monte Carlo program that generates many samples of 52 background events, with fractions of W+light quark and gluon jets, $Wb\bar{b}$, $Wc\bar{c}$, and other backgrounds distributed according to Poisson statistics with mean values and uncertainties predicted by Monte Carlo calculations[1]. The number of events with heavy-quark jets is scaled up to agree with the more conservative background estimate from inclusive-jet data. The predicted number of SVX plus SLT-tagged events is obtained by applying the measured efficiencies and correlations in the SVX and SLT fake rates. This number is combined with a Poisson-distributed number of dilepton background events to determine the fraction of experiments with 15 or more counts from background alone. We find $\mathcal{P}_{combined}$=0.26%. This corresponds to a 2.8σ excess for a Gaussian probability function.

Assuming the excess events to be from $t\bar{t}$, we calculate the cross section for $t\bar{t}$ production in $p\bar{p}$ collisions at $\sqrt{s}$=1.8 TeV. The calculation uses the $t\bar{t}$ acceptance, the derived efficiencies for tagging jets in $t\bar{t}$ events and a revised estimate of the background appropriate for a mixture of $t\bar{t}$ events and background in the 52-event W+jets sample (rather than assuming it to contain all background as above). In Table 1 we summarize the acceptances, and the theoretical and measured cross sections as a function of M_{top}.

We have also studied[1] distributions of kinematic quantities for the 52 $W+\geq 3$ jet events. If the top quark is very massive the decay jets will typically be more energetic than jets in W+jets background events. One variable with discrimination is $E_{T23} = (E_{T2} + E_{T3})$, where E_{T2} and E_{T3} refer to the E_T's of the second- and third-most energetic jets in the event. The VECBOS Monte Carlo program predicts that in W+jets background events the median of E_{T23} is 71 GeV, while 93% of HERWIG[14] $t\bar{t}$ events (M_{top} = 160 GeV/c^2) have $E_{T23} > 71$ GeV. In the 52-event sample, 39 events have $E_{T23} > 71$ GeV, as do eight of the ten b-tagged events. This is qualitatively consistent with the $t\bar{t}$ hypothesis; however additional studies in progress are needed to reduce systematic uncertainties on the jet energy scale and on the E_{T23} distribution of the background.

Assuming that the excess of b-tagged events is due to $t\bar{t}$ production, we estimate M_{top} using a constrained fit[15] to each tagged event with four jets. Using the 52-event $W+\geq$3-jet sample, we require a fourth jet with $\mathrm{E_T} > 8$ GeV and $|\eta| < 2.4$. Seven of the ten b-tagged events identified in the lepton+jets analysis pass this requirement. These seven events are fitted individually to the hypothesis that three of the jets come from one t or $\bar{t}$ through its decay to Wb, and that the lepton, $\not\!\!E_{\mathrm{T}}$, and the remaining jet come from the other t or $\bar{t}$ decay[7]. If the event contains additional jets, only the four highest-E_T jets are used in the fit. The fit is made for all six jet configurations, with the requirement that the tagged jet in the event must be one of the b quarks. There are two solutions in each case for the longitudinal momentum of the neutrino, and the one corresponding to the best χ^2 is chosen.

Application of this method to $t\bar{t}$ Monte Carlo events ($M_{top} = 170$ GeV/c^2) gives a distribution with a peak at 168 GeV/c^2 and a rms spread of 23 GeV/c^2. Fitting Monte Carlo W+jets background events to the $t\bar{t}$ hypothesis yields a mass distribution with a broad peak centered at about 140 GeV/c^2.

The results of the fits to the seven events are presented in Figure 2. In this sample, $1.4^{+2.0}_{-1.1}$ events are expected to come from background[1]. To find the most likely top mass from the seven events, we perform a likelihood fit of their mass distribution to a sum of the expected distributions from W+jets and a top quark of mass M_{top}. The $-\log$(likelihood) distribution from this fit is shown in the inset to Figure 2. Systematic uncertainties in this fit arise from the background estimation, the effects of gluon radiation on the determination of parton energies, the jet energy scale, kinematic bias in the tagging algorithms, and different methods of performing the likelihood fit. Combining these uncertainties yields a top mass of $M_{top} = 174 \pm 10^{+13}_{-12}$ GeV/c^2, where the first uncertainty is statistical and the second is systematic. The statistical uncertainty includes the effects of detector resolution and incorrect assignments of jets to their parent partons. Using the acceptance for this top mass and our measured excess over background we find $\sigma_{t\bar{t}}(M_{top} = 174$ GeV/c$^2) = 13.9^{+6.1}_{-4.8}$ pb. By performing a simple χ^2 analysis on the theoretical prediction for the cross section as a function of M_{top}, our measured mass, and our measured cross section, we find that the three results are compatible at a confidence level of 13% (1.5σ).

We have performed many consistency checks, and have found some features of the data that do not support the $t\bar{t}$ hypothesis. The sample of inclusive Z events serves as a control sample for studying the production of a vector boson plus jets, as Z bosons are not produced in $t\bar{t}$ decay. We find two b-tagged $Z+\geq 3$ jet events with 0.64 expected. Both events have four jets and are SVX-tagged. Though the statistics are limited, these events could indicate an additional (non-$t\bar{t}$) source of vector boson plus heavy quark production, not accounted for in our background estimates. Higher-statistics checks of the b-tagging rate in W or Z+1 and 2-jet events are consistent with expectations. We also find that the measured $t\bar{t}$ cross section is large enough to account for all observed W+4 jet events. The apparent deficit of events from direct production of W+4 jets and other backgrounds is a 1.5-2σ effect.

Other features do support the $t\bar{t}$ hypothesis. One of the dilepton candidate events is b-tagged by both the SVX and SLT algorithms, with approximately 0.01 double-tagged background events (0.13 signal events) expected. This, together with the excess of b-tagged W+jets events, provides evidence for an excess of both $Wb\bar{b}$ and $WWb\bar{b}$ production, as expected from $t\bar{t}$ decays. We have performed a kinematic analysis of the lepton+jets sample and conclude that it can accommodate the top content implied by our measured cross section. Furthermore, a likelihood fit to the top mass distributions obtained from the b-tagged W+4-jet events prefers the $t\bar{t}$+background hypothesis over the background-only hypothesis by 2.3 standard deviations.

In conclusion, the data presented here give evidence for, but do not firmly establish, the existence of the top quark. Work is continuing on kinematic analyses of the present data, and we hope for an approximate four-fold increase in data from the 1994-95 Tevatron collider run.

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M_{top}	120 GeV/c^2	140 GeV/c^2	160 GeV/c^2	180 GeV/c^2
ϵ_{DIL}	$0.49 \pm .07\%$	$0.66 \pm .07\%$	$0.78 \pm .07\%$	$0.86 \pm .07\%$
ϵ_{SVX}	$1.0 \pm 0.3\%$	$1.5 \pm 0.4\%$	$1.7 \pm 0.5\%$	$1.8 \pm 0.6\%$
ϵ_{SLT}	$0.84 \pm 0.17\%$	$1.1 \pm 0.2\%$	$1.2 \pm 0.2\%$	$1.3 \pm 0.2\%$
$\sigma_{t\bar{t}}^{Theor}$ (pb)	$38.9^{+10.8}_{-5.2}$	$16.9^{+3.6}_{-1.8}$	$8.2^{+1.4}_{-0.8}$	$4.2^{+0.6}_{-0.4}$
$\sigma_{t\bar{t}}^{Expt}$(pb)	$22.7^{+10.0}_{-7.9}$	$16.8^{+7.4}_{-5.9}$	$14.7^{+6.5}_{-5.1}$	$13.7^{+6.0}_{-4.7}$

Table 1: Summary of top acceptance (including branching ratios) and the theoretical cross section[9]. The last line gives the $t\bar{t}$ production cross section obtained from this measurement.

Channel:	Dilepton	SVX	SLT
$N_{expected}$, $M_{top} = 120$ GeV/c^2	3.7 ± 0.6	7.7 ± 2.5	6.3 ± 1.3
$N_{expected}$, $M_{top} = 140$ GeV/c^2	2.2 ± 0.2	4.8 ± 1.7	3.5 ± 0.7
$N_{expected}$, $M_{top} = 160$ GeV/c^2	1.3 ± 0.1	2.7 ± 0.9	1.9 ± 0.3
$N_{expected}$, $M_{top} = 180$ GeV/c^2	0.68 ± 0.06	1.4 ± 0.4	1.1 ± 0.2
Total Background	$0.56^{+0.25}_{-0.13}$	2.3 ± 0.3	3.1 ± 0.3
Observed Events	2	6	7

Table 2: Number of $t\bar{t}$ events expected assuming the theoretical cross section, and the number of candidate events observed with expected backgrounds.

N_{jet}	Electrons	Muons	Total	VECBOS ($Q^2 = < {P_T}^2 >$)
0 Jet	10,663	6,264	16,927	——
1 Jet	1058	655	1713	1571^{+285}_{-227}
2 Jets	191	90	281	267^{+80}_{-57}
3 Jets	30	13	43	39^{+12}_{-10}
≥ 4 Jets	7	2	9	$7^{+3.2}_{-2.2}$

Table 3: Summary of W candidate event yields as a function of jet multiplicity. Jets have $\mathrm{E_T} \geq 15$ GeV and $|\eta| \leq 2.0$. Also shown are the predicted number of W events from the VECBOS Monte Carlo program. The uncertainties shown in the VECBOS predictions are dominated by the uncertainty in the jet energy scale; the uncertainty in the Q^2-scale is not included.

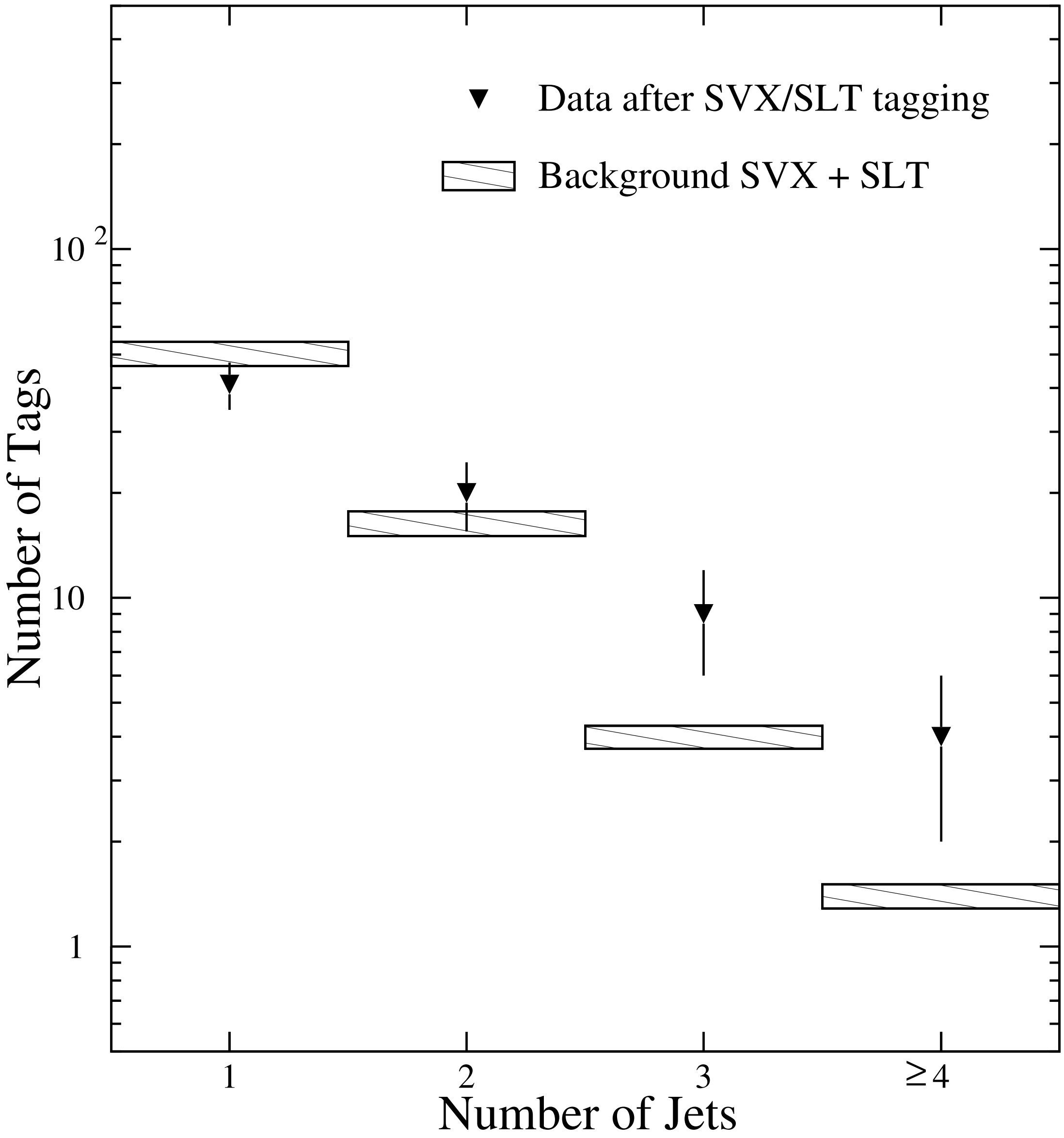

Figure 1: The sum of SVX and SLT tags observed in the W+jets data (solid triangles). Events tagged by both algorithms are counted twice. The shaded area is the sum of the background estimates for SVX and SLT, with its uncertainty. The three-jet and four-or-more-jet bins are the $t\bar{t}$ signal region.

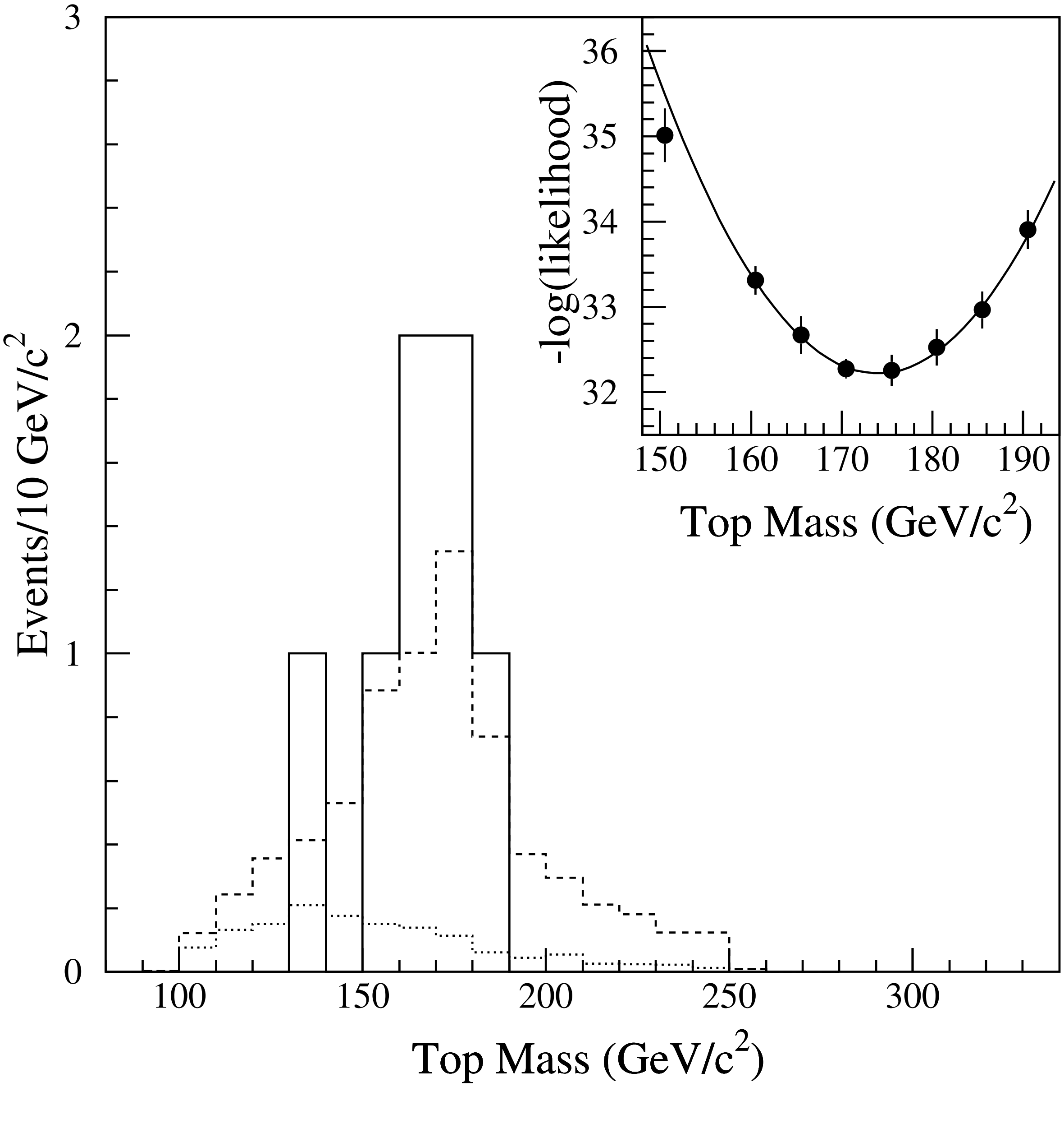

Figure 2: Top mass distribution for the data (solid histogram), the W+jets background (dots), and the sum of background + Monte Carlo $t\bar{t}$ for $M_{top} = 175$ GeV/c^2 (dashed). The background distribution has been normalized to the 1.4 background events expected in the mass-fit sample. The inset shows the likelihood fit used to determine the top mass.