

# Search for Pair Production of Supersymmetric Top Quarks in Dilepton Events from $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV

T. Aaltonen,<sup>24</sup> J. Adelman,<sup>14</sup> T. Akimoto,<sup>56</sup> B. Álvarez González<sup>s</sup>,<sup>12</sup> S. Amerio<sup>y</sup>,<sup>44</sup> D. Amidei,<sup>35</sup> A. Anastassov,<sup>39</sup> A. Annovi,<sup>20</sup> J. Antos,<sup>15</sup> G. Apollinari,<sup>18</sup> A. Apresyan,<sup>49</sup> T. Arisawa,<sup>58</sup> A. Artikov,<sup>16</sup> W. Ashmanskas,<sup>18</sup> A. Attal,<sup>4</sup> A. Aurisano,<sup>54</sup> F. Azfar,<sup>43</sup> W. Badgett,<sup>18</sup> A. Barbaro-Galtieri,<sup>29</sup> V.E. Barnes,<sup>49</sup> B.A. Barnett,<sup>26</sup> P. Barria<sup>aa</sup>,<sup>47</sup> V. Bartsch,<sup>31</sup> G. Bauer,<sup>33</sup> P.-H. Beauchemin,<sup>34</sup> F. Bedeschi,<sup>47</sup> D. Beecher,<sup>31</sup> S. Behari,<sup>26</sup> G. Bellettini<sup>z</sup>,<sup>47</sup> J. Bellinger,<sup>60</sup> D. Benjamin,<sup>17</sup> A. Beretvas,<sup>18</sup> J. Beringer,<sup>29</sup> A. Bhatti,<sup>51</sup> M. Binkley,<sup>18</sup> D. Bisello<sup>y</sup>,<sup>44</sup> I. Bizjak<sup>ee</sup>,<sup>31</sup> R.E. Blair,<sup>2</sup> C. Blocker,<sup>7</sup> B. Blumenfeld,<sup>26</sup> A. Bocci,<sup>17</sup> A. Bodek,<sup>50</sup> V. Boisvert,<sup>50</sup> G. Bolla,<sup>49</sup> D. Bortoletto,<sup>49</sup> J. Boudreau,<sup>48</sup> A. Boveia,<sup>11</sup> B. Brau<sup>a</sup>,<sup>11</sup> A. Bridgeman,<sup>25</sup> L. Brigliadori<sup>x</sup>,<sup>6</sup> C. Bromberg,<sup>36</sup> E. Brubaker,<sup>14</sup> J. Budagov,<sup>16</sup> H.S. Budd,<sup>50</sup> S. Budd,<sup>25</sup> S. Burke,<sup>18</sup> K. Burkett,<sup>18</sup> G. Busetto<sup>y</sup>,<sup>44</sup> P. Bussey,<sup>22</sup> A. Buzatu,<sup>34</sup> K. L. Byrum,<sup>2</sup> S. Cabrera<sup>u</sup>,<sup>17</sup> C. Calancha,<sup>32</sup> M. Campanelli,<sup>36</sup> M. Campbell,<sup>35</sup> F. Canelli<sup>l</sup>,<sup>14</sup>,<sup>18</sup> A. Canepa,<sup>46</sup> B. Carls,<sup>25</sup> D. Carlsmith,<sup>60</sup> R. Carosi,<sup>47</sup> S. Carrillo<sup>n</sup>,<sup>19</sup> S. Carron,<sup>34</sup> B. Casal,<sup>12</sup> M. Casarsa,<sup>18</sup> A. Castro<sup>x</sup>,<sup>6</sup> P. Catastini<sup>aa</sup>,<sup>47</sup> D. Cauz<sup>dd</sup>,<sup>55</sup> V. Cavaliere<sup>aa</sup>,<sup>47</sup> M. Cavalli-Sforza,<sup>4</sup> A. Cerri,<sup>29</sup> L. Cerrito<sup>o</sup>,<sup>31</sup> S.H. Chang,<sup>28</sup> Y.C. Chen,<sup>1</sup> M. Chertok,<sup>8</sup> G. Chiarelli,<sup>47</sup> G. Chlachidze,<sup>18</sup> F. Chlebana,<sup>18</sup> K. Cho,<sup>28</sup> D. Chokheli,<sup>16</sup> J.P. Chou,<sup>23</sup> G. Choudalakis,<sup>33</sup> S.H. Chuang,<sup>53</sup> K. Chung,<sup>13</sup> W.H. Chung,<sup>60</sup> Y.S. Chung,<sup>50</sup> T. Chwalek,<sup>27</sup> C.I. Ciobanu,<sup>45</sup> M.A. Ciocci<sup>aa</sup>,<sup>47</sup> A. Clark,<sup>21</sup> D. Clark,<sup>7</sup> G. Compostella,<sup>44</sup> M.E. Convery,<sup>18</sup> J. Conway,<sup>8</sup> M. Cordelli,<sup>20</sup> G. Cortiana<sup>y</sup>,<sup>44</sup> C.A. Cox,<sup>8</sup> D.J. Cox,<sup>8</sup> F. Crescioli<sup>z</sup>,<sup>47</sup> C. Cuenca Almenar<sup>u</sup>,<sup>8</sup> J. Cuevas<sup>s</sup>,<sup>12</sup> R. Culbertson,<sup>18</sup> J.C. Cully,<sup>35</sup> D. Dagenhart,<sup>18</sup> M. Datta,<sup>18</sup> T. Davies,<sup>22</sup> P. de Barbaro,<sup>50</sup> S. De Cecco,<sup>52</sup> A. Deisher,<sup>29</sup> G. De Lorenzo,<sup>4</sup> M. Dell'Orso<sup>z</sup>,<sup>47</sup> C. Deluca,<sup>4</sup> L. Demortier,<sup>51</sup> J. Deng,<sup>17</sup> M. Deninno,<sup>6</sup> P.F. Derwent,<sup>18</sup> A. Di Canto<sup>z</sup>,<sup>47</sup> G.P. di Giovanni,<sup>45</sup> C. Dionisi<sup>cc</sup>,<sup>52</sup> B. Di Ruzza<sup>dd</sup>,<sup>55</sup> J.R. Dittmann,<sup>5</sup> M. D'Onofrio,<sup>4</sup> S. Donati<sup>z</sup>,<sup>47</sup> P. Dong,<sup>9</sup> J. Donini,<sup>44</sup> T. Dorigo,<sup>44</sup> S. Dube,<sup>53</sup> J. Efron,<sup>40</sup> A. Elagin,<sup>54</sup> R. Erbacher,<sup>8</sup> D. Errede,<sup>25</sup> S. Errede,<sup>25</sup> R. Eusebi,<sup>18</sup> H.C. Fang,<sup>29</sup> S. Farrington,<sup>43</sup> W.T. Fedorko,<sup>14</sup> R.G. Feild,<sup>61</sup> M. Feindt,<sup>27</sup> J.P. Fernandez,<sup>32</sup> C. Ferrazza<sup>bb</sup>,<sup>47</sup> R. Field,<sup>19</sup> G. Flanagan,<sup>49</sup> R. Forrest,<sup>8</sup> M.J. Frank,<sup>5</sup> M. Franklin,<sup>23</sup> J.C. Freeman,<sup>18</sup> I. Furic,<sup>19</sup> M. Gallinaro,<sup>52</sup> J. Galyardt,<sup>13</sup> F. Garbersson,<sup>11</sup> J.E. Garcia,<sup>21</sup> A.F. Garfinkel,<sup>49</sup> P. Garosi<sup>aa</sup>,<sup>47</sup> K. Genser,<sup>18</sup> H. Gerberich,<sup>25</sup> D. Gerdes,<sup>35</sup> A. Gessler,<sup>27</sup> S. Giagu<sup>cc</sup>,<sup>52</sup> V. Giakoumopoulou,<sup>3</sup> P. Giannetti,<sup>47</sup> K. Gibson,<sup>48</sup> J.L. Gimmell,<sup>50</sup> C.M. Ginsburg,<sup>18</sup> N. Giokaris,<sup>3</sup> M. Giordani<sup>dd</sup>,<sup>55</sup> P. Giromini,<sup>20</sup> M. Giunta,<sup>47</sup> G. Giurgiu,<sup>26</sup> V. Glagolev,<sup>16</sup> D. Glenzinski,<sup>18</sup> M. Gold,<sup>38</sup> N. Goldschmidt,<sup>19</sup> A. Golossanov,<sup>18</sup> G. Gomez,<sup>12</sup> G. Gomez-Ceballos,<sup>33</sup> M. Goncharov,<sup>33</sup> O. González,<sup>32</sup> I. Gorelov,<sup>38</sup> A.T. Goshaw,<sup>17</sup> K. Goulianos,<sup>51</sup> A. Gresele<sup>y</sup>,<sup>44</sup> S. Grinstein,<sup>23</sup> C. Grosso-Pilcher,<sup>14</sup> R.C. Group,<sup>18</sup> U. Grundler,<sup>25</sup> J. Guimaraes da Costa,<sup>23</sup> Z. Gunay-Unalan,<sup>36</sup> C. Haber,<sup>29</sup> K. Hahn,<sup>33</sup> S.R. Hahn,<sup>18</sup> E. Halkiadakis,<sup>53</sup> B.-Y. Han,<sup>50</sup> J.Y. Han,<sup>50</sup> F. Happacher,<sup>20</sup> K. Hara,<sup>56</sup> D. Hare,<sup>53</sup> M. Hare,<sup>57</sup> S. Harper,<sup>43</sup> R.F. Harr,<sup>59</sup> R.M. Harris,<sup>18</sup> M. Hartz,<sup>48</sup> K. Hatakeyama,<sup>51</sup> C. Hays,<sup>43</sup> M. Heck,<sup>27</sup> A. Heijboer,<sup>46</sup> J. Heinrich,<sup>46</sup> C. Henderson,<sup>33</sup> M. Herndon,<sup>60</sup> J. Heuser,<sup>27</sup> S. Hewamanage,<sup>5</sup> D. Hidas,<sup>17</sup> C.S. Hill<sup>c</sup>,<sup>11</sup> D. Hirschbuehl,<sup>27</sup> A. Hocker,<sup>18</sup> S. Hou,<sup>1</sup> M. Houlden,<sup>30</sup> S.-C. Hsu,<sup>29</sup> B.T. Huffman,<sup>43</sup> R.E. Hughes,<sup>40</sup> U. Husemann,<sup>61</sup> M. Hussein,<sup>36</sup> J. Huston,<sup>36</sup> J. Incandela,<sup>11</sup> G. Introzzi,<sup>47</sup> M. Iori<sup>cc</sup>,<sup>52</sup> A. Ivanov,<sup>8</sup> E. James,<sup>18</sup> D. Jang,<sup>13</sup> B. Jayatilaka,<sup>17</sup> E.J. Jeon,<sup>28</sup> M.K. Jha,<sup>6</sup> S. Jindariani,<sup>18</sup> W. Johnson,<sup>8</sup> M. Jones,<sup>49</sup> K.K. Joo,<sup>28</sup> S.Y. Jun,<sup>13</sup> J.E. Jung,<sup>28</sup> T.R. Junk,<sup>18</sup> T. Kamon,<sup>54</sup> D. Kar,<sup>19</sup> P.E. Karchin,<sup>59</sup> Y. Kato<sup>l</sup>,<sup>42</sup> R. Kephart,<sup>18</sup> W. Ketchum,<sup>14</sup> J. Keung,<sup>46</sup> V. Khotilovich,<sup>54</sup> B. Kilminster,<sup>18</sup> D.H. Kim,<sup>28</sup> H.S. Kim,<sup>28</sup> H.W. Kim,<sup>28</sup> J.E. Kim,<sup>28</sup> M.J. Kim,<sup>20</sup> S.B. Kim,<sup>28</sup> S.H. Kim,<sup>56</sup> Y.K. Kim,<sup>14</sup> N. Kimura,<sup>56</sup> L. Kirsch,<sup>7</sup> S. Klimentenko,<sup>19</sup> B. Knuteson,<sup>33</sup> B.R. Ko,<sup>17</sup> K. Kondo,<sup>58</sup> D.J. Kong,<sup>28</sup> J. Konigsberg,<sup>19</sup> A. Korytov,<sup>19</sup> A.V. Kotwal,<sup>17</sup> M. Kreps,<sup>27</sup> J. Kroll,<sup>46</sup> D. Krop,<sup>14</sup> N. Krumnack,<sup>5</sup> M. Kruse,<sup>17</sup> V. Krutelyov,<sup>11</sup> T. Kubo,<sup>56</sup> T. Kuhr,<sup>27</sup> N.P. Kulkarni,<sup>59</sup> M. Kurata,<sup>56</sup> S. Kwang,<sup>14</sup> A.T. Laasanen,<sup>49</sup> S. Lami,<sup>47</sup> S. Lammel,<sup>18</sup> M. Lancaster,<sup>31</sup> R.L. Lander,<sup>8</sup> K. Lannon<sup>r</sup>,<sup>40</sup> A. Lath,<sup>53</sup> G. Latino<sup>aa</sup>,<sup>47</sup> I. Lazzizzera<sup>y</sup>,<sup>44</sup> T. LeCompte,<sup>2</sup> E. Lee,<sup>54</sup> H.S. Lee,<sup>14</sup> S.W. Lee<sup>t</sup>,<sup>54</sup> S. Leone,<sup>47</sup> J.D. Lewis,<sup>18</sup> C.-S. Lin,<sup>29</sup> J. Linacre,<sup>43</sup> M. Lindgren,<sup>18</sup> E. Lipeles,<sup>46</sup> A. Lister,<sup>8</sup> D.O. Litvintsev,<sup>18</sup> C. Liu,<sup>48</sup> T. Liu,<sup>18</sup> N.S. Lockyer,<sup>46</sup> A. Loginov,<sup>61</sup> M. Loreti<sup>y</sup>,<sup>44</sup> L. Lovas,<sup>15</sup> D. Lucchesi<sup>y</sup>,<sup>44</sup> C. Luci<sup>cc</sup>,<sup>52</sup> J. Lueck,<sup>27</sup> P. Lujan,<sup>29</sup> P. Lukens,<sup>18</sup> G. Lungu,<sup>51</sup> L. Lyons,<sup>43</sup> J. Lys,<sup>29</sup> R. Lysak,<sup>15</sup> D. MacQueen,<sup>34</sup> R. Madrak,<sup>18</sup> K. Maeshima,<sup>18</sup> K. Makhoul,<sup>33</sup> T. Maki,<sup>24</sup> P. Maksimovic,<sup>26</sup> S. Malde,<sup>43</sup> S. Malik,<sup>31</sup> G. Manca<sup>e</sup>,<sup>30</sup> A. Manousakis-Katsikakis,<sup>3</sup> F. Margaroli,<sup>49</sup> C. Marino,<sup>27</sup> C.P. Marino,<sup>25</sup> A. Martin,<sup>61</sup> V. Martin<sup>k</sup>,<sup>22</sup> M. Martínez,<sup>4</sup> R. Martínez-Ballarín,<sup>32</sup> T. Maruyama,<sup>56</sup> P. Mastrandrea,<sup>52</sup> T. Masubuchi,<sup>56</sup> M. Mathis,<sup>26</sup> M.E. Mattson,<sup>59</sup> P. Mazzanti,<sup>6</sup> K.S. McFarland,<sup>50</sup> P. McIntyre,<sup>54</sup> R. McNulty<sup>j</sup>,<sup>30</sup> A. Mehta,<sup>30</sup> P. Mehtala,<sup>24</sup> A. Menzione,<sup>47</sup> P. Merkel,<sup>49</sup> C. Mesropian,<sup>51</sup> T. Miao,<sup>18</sup> N. Miladinovic,<sup>7</sup> R. Miller,<sup>36</sup> C. Mills,<sup>23</sup> M. Milnik,<sup>27</sup> A. Mitra,<sup>1</sup> G. Mitselmakher,<sup>19</sup> H. Miyake,<sup>56</sup> N. Moggi,<sup>6</sup>

C.S. Moon,<sup>28</sup> R. Moore,<sup>18</sup> M.J. Morello,<sup>47</sup> J. Morlock,<sup>27</sup> P. Movilla Fernandez,<sup>18</sup> J. Mülmenstädt,<sup>29</sup> A. Mukherjee,<sup>18</sup> Th. Muller,<sup>27</sup> R. Mumford,<sup>26</sup> P. Murat,<sup>18</sup> M. Mussini<sup>x</sup>,<sup>6</sup> J. Nachtman,<sup>18</sup> Y. Nagai,<sup>56</sup> A. Nagano,<sup>56</sup> J. Naganoma,<sup>56</sup> K. Nakamura,<sup>56</sup> I. Nakano,<sup>41</sup> A. Napier,<sup>57</sup> V. Necula,<sup>17</sup> J. Nett,<sup>60</sup> C. Neu<sup>v</sup>,<sup>46</sup> M.S. Neubauer,<sup>25</sup> S. Neubauer,<sup>27</sup> J. Nielsen<sup>g</sup>,<sup>29</sup> L. Nodulman,<sup>2</sup> M. Norman,<sup>10</sup> O. Norniella,<sup>25</sup> E. Nurse,<sup>31</sup> L. Oakes,<sup>43</sup> S.H. Oh,<sup>17</sup> Y.D. Oh,<sup>28</sup> I. Oksuzian,<sup>19</sup> T. Okusawa,<sup>42</sup> R. Orava,<sup>24</sup> K. Osterberg,<sup>24</sup> S. Pagan Griso<sup>y</sup>,<sup>44</sup> E. Palencia,<sup>18</sup> V. Papadimitriou,<sup>18</sup> A. Papaikonomou,<sup>27</sup> A.A. Paramonov,<sup>14</sup> B. Parks,<sup>40</sup> S. Pashapour,<sup>34</sup> J. Patrick,<sup>18</sup> G. Pauletta<sup>dd</sup>,<sup>55</sup> M. Paulini,<sup>13</sup> C. Paus,<sup>33</sup> T. Peiffer,<sup>27</sup> D.E. Pellett,<sup>8</sup> A. Penzo,<sup>55</sup> T.J. Phillips,<sup>17</sup> G. Piacentino,<sup>47</sup> E. Pianori,<sup>46</sup> L. Pinera,<sup>19</sup> K. Pitts,<sup>25</sup> C. Plager,<sup>9</sup> L. Pondrom,<sup>60</sup> O. Poukhov<sup>\*</sup>,<sup>16</sup> N. Pounder,<sup>43</sup> F. Prakoshyn,<sup>16</sup> A. Pronko,<sup>18</sup> J. Proudfoot,<sup>2</sup> F. Ptohos<sup>i</sup>,<sup>18</sup> E. Pueschel,<sup>13</sup> G. Punzi<sup>z</sup>,<sup>47</sup> J. Pursley,<sup>60</sup> J. Rademacker<sup>c</sup>,<sup>43</sup> A. Rahaman,<sup>48</sup> V. Ramakrishnan,<sup>60</sup> N. Ranjan,<sup>49</sup> I. Redondo,<sup>32</sup> P. Renton,<sup>43</sup> M. Renz,<sup>27</sup> M. Rescigno,<sup>52</sup> S. Richter,<sup>27</sup> F. Rimondi<sup>x</sup>,<sup>6</sup> L. Ristori,<sup>47</sup> A. Robson,<sup>22</sup> T. Rodrigo,<sup>12</sup> T. Rodriguez,<sup>46</sup> E. Rogers,<sup>25</sup> S. Rolli,<sup>57</sup> R. Roser,<sup>18</sup> M. Rossi,<sup>55</sup> R. Rossin,<sup>11</sup> P. Roy,<sup>34</sup> A. Ruiz,<sup>12</sup> J. Russ,<sup>13</sup> V. Rusu,<sup>18</sup> B. Rutherford,<sup>18</sup> H. Saarikko,<sup>24</sup> A. Safonov,<sup>54</sup> W.K. Sakumoto,<sup>50</sup> O. Saltó,<sup>4</sup> L. Santi<sup>dd</sup>,<sup>55</sup> S. Sarkar<sup>cc</sup>,<sup>52</sup> L. Sartori,<sup>47</sup> K. Sato,<sup>18</sup> A. Savoy-Navarro,<sup>45</sup> P. Schlabach,<sup>18</sup> A. Schmidt,<sup>27</sup> E.E. Schmidt,<sup>18</sup> M.A. Schmidt,<sup>14</sup> M.P. Schmidt<sup>\*</sup>,<sup>61</sup> M. Schmitt,<sup>39</sup> T. Schwarz,<sup>8</sup> L. Scodellaro,<sup>12</sup> A. Scribano<sup>aa</sup>,<sup>47</sup> F. Scuri,<sup>47</sup> A. Sedov,<sup>49</sup> S. Seidel,<sup>38</sup> Y. Seiya,<sup>42</sup> A. Semenov,<sup>16</sup> L. Sexton-Kennedy,<sup>18</sup> F. Sforza<sup>z</sup>,<sup>47</sup> A. Sfyrta,<sup>25</sup> S.Z. Shalhout,<sup>59</sup> T. Shears,<sup>30</sup> P.F. Shepard,<sup>48</sup> M. Shimojima<sup>g</sup>,<sup>56</sup> S. Shiraiishi,<sup>14</sup> M. Shochet,<sup>14</sup> Y. Shon,<sup>60</sup> I. Shreyber,<sup>37</sup> P. Sinervo,<sup>34</sup> A. Sisakyan,<sup>16</sup> A.J. Slaughter,<sup>18</sup> J. Slaunwhite,<sup>40</sup> K. Sliwa,<sup>57</sup> J.R. Smith,<sup>8</sup> F.D. Snider,<sup>18</sup> R. Snihur,<sup>34</sup> A. Soha,<sup>8</sup> S. Somalwar,<sup>53</sup> V. Sorin,<sup>36</sup> T. Spreitzer,<sup>34</sup> P. Squillacioti<sup>aa</sup>,<sup>47</sup> M. Stanitzki,<sup>61</sup> R. St. Denis,<sup>22</sup> B. Stelzer,<sup>34</sup> O. Stelzer-Chilton,<sup>34</sup> D. Stentz,<sup>39</sup> J. Strologas,<sup>38</sup> G.L. Strycker,<sup>35</sup> J.S. Suh,<sup>28</sup> A. Sukhanov,<sup>19</sup> I. Suslov,<sup>16</sup> T. Suzuki,<sup>56</sup> A. Taffard<sup>f</sup>,<sup>25</sup> R. Takashima,<sup>41</sup> Y. Takeuchi,<sup>56</sup> R. Tanaka,<sup>41</sup> M. Tecchio,<sup>35</sup> P.K. Teng,<sup>1</sup> K. Terashi,<sup>51</sup> J. Thom<sup>h</sup>,<sup>18</sup> A.S. Thompson,<sup>22</sup> G.A. Thompson,<sup>25</sup> E. Thomson,<sup>46</sup> P. Tipton,<sup>61</sup> P. Ttito-Guzmán,<sup>32</sup> S. Tkaczyk,<sup>18</sup> D. Toback,<sup>54</sup> S. Tokar,<sup>15</sup> K. Tollefson,<sup>36</sup> T. Tomura,<sup>56</sup> D. Tonelli,<sup>18</sup> S. Torre,<sup>20</sup> D. Torretta,<sup>18</sup> P. Totaro<sup>dd</sup>,<sup>55</sup> S. Tourneur,<sup>45</sup> M. Trovato<sup>bb</sup>,<sup>47</sup> S.-Y. Tsai,<sup>1</sup> Y. Tu,<sup>46</sup> N. Turini<sup>aa</sup>,<sup>47</sup> F. Ukegawa,<sup>56</sup> S. Vallecorsa,<sup>21</sup> N. van Remortel<sup>b</sup>,<sup>24</sup> A. Varganov,<sup>35</sup> E. Vataha<sup>bb</sup>,<sup>47</sup> F. Vázquez<sup>n</sup>,<sup>19</sup> G. Velev,<sup>18</sup> C. Vellidis,<sup>3</sup> M. Vidal,<sup>32</sup> R. Vidal,<sup>18</sup> I. Vila,<sup>12</sup> R. Vilar,<sup>12</sup> T. Vine,<sup>31</sup> M. Vogel,<sup>38</sup> I. Volobouev<sup>t</sup>,<sup>29</sup> G. Volpi<sup>z</sup>,<sup>47</sup> P. Wagner,<sup>46</sup> R.G. Wagner,<sup>2</sup> R.L. Wagner,<sup>18</sup> W. Wagner<sup>w</sup>,<sup>27</sup> J. Wagner-Kuhr,<sup>27</sup> T. Wakisaka,<sup>42</sup> R. Wallny,<sup>9</sup> S.M. Wang,<sup>1</sup> A. Warburton,<sup>34</sup> D. Waters,<sup>31</sup> M. Weinberger,<sup>54</sup> J. Weinelt,<sup>27</sup> W.C. Wester III,<sup>18</sup> B. Whitehouse,<sup>57</sup> D. Whiteson<sup>f</sup>,<sup>46</sup> A.B. Wicklund,<sup>2</sup> E. Wicklund,<sup>18</sup> S. Wilbur,<sup>14</sup> G. Williams,<sup>34</sup> H.H. Williams,<sup>46</sup> P. Wilson,<sup>18</sup> B.L. Winer,<sup>40</sup> P. Wittich<sup>h</sup>,<sup>18</sup> S. Wolbers,<sup>18</sup> C. Wolfe,<sup>14</sup> T. Wright,<sup>35</sup> X. Wu,<sup>21</sup> F. Würthwein,<sup>10</sup> S. Xie,<sup>33</sup> A. Yagil,<sup>10</sup> K. Yamamoto,<sup>42</sup> J. Yamaoka,<sup>17</sup> U.K. Yang<sup>p</sup>,<sup>14</sup> Y.C. Yang,<sup>28</sup> W.M. Yao,<sup>29</sup> G.P. Yeh,<sup>18</sup> J. Yoh,<sup>18</sup> K. Yorita,<sup>58</sup> T. Yoshida<sup>m</sup>,<sup>42</sup> G.B. Yu,<sup>50</sup> I. Yu,<sup>28</sup> S.S. Yu,<sup>18</sup> J.C. Yun,<sup>18</sup> L. Zanello<sup>cc</sup>,<sup>52</sup> A. Zanetti,<sup>55</sup> X. Zhang,<sup>25</sup> Y. Zheng<sup>d</sup>,<sup>9</sup> and S. Zucchelli<sup>x</sup>,<sup>6</sup>

(CDF Collaboration<sup>†</sup>)

<sup>1</sup>*Institute of Physics, Academia Sinica, Taipei, Taiwan 11529, Republic of China*

<sup>2</sup>*Argonne National Laboratory, Argonne, Illinois 60439*

<sup>3</sup>*University of Athens, 157 71 Athens, Greece*

<sup>4</sup>*Institut de Fisica d'Altes Energies, Universitat Autònoma de Barcelona, E-08193, Bellaterra (Barcelona), Spain*

<sup>5</sup>*Baylor University, Waco, Texas 76798*

<sup>6</sup>*Istituto Nazionale di Fisica Nucleare Bologna, <sup>x</sup>University of Bologna, I-40127 Bologna, Italy*

<sup>7</sup>*Brandeis University, Waltham, Massachusetts 02254*

<sup>8</sup>*University of California, Davis, Davis, California 95616*

<sup>9</sup>*University of California, Los Angeles, Los Angeles, California 90024*

<sup>10</sup>*University of California, San Diego, La Jolla, California 92093*

<sup>11</sup>*University of California, Santa Barbara, Santa Barbara, California 93106*

<sup>12</sup>*Instituto de Fisica de Cantabria, CSIC-University of Cantabria, 39005 Santander, Spain*

<sup>13</sup>*Carnegie Mellon University, Pittsburgh, PA 15213*

<sup>14</sup>*Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637*

<sup>15</sup>*Comenius University, 842 48 Bratislava, Slovakia; Institute of Experimental Physics, 040 01 Kosice, Slovakia*

<sup>16</sup>*Joint Institute for Nuclear Research, RU-141980 Dubna, Russia*

<sup>17</sup>*Duke University, Durham, North Carolina 27708*

<sup>18</sup>*Fermi National Accelerator Laboratory, Batavia, Illinois 60510*

<sup>19</sup>*University of Florida, Gainesville, Florida 32611*

<sup>20</sup>*Laboratori Nazionali di Frascati, Istituto Nazionale di Fisica Nucleare, I-00044 Frascati, Italy*

<sup>21</sup>*University of Geneva, CH-1211 Geneva 4, Switzerland*

<sup>22</sup>*Glasgow University, Glasgow G12 8QQ, United Kingdom*

<sup>23</sup>*Harvard University, Cambridge, Massachusetts 02138*

- <sup>24</sup>*Division of High Energy Physics, Department of Physics, University of Helsinki and Helsinki Institute of Physics, FIN-00014, Helsinki, Finland*
- <sup>25</sup>*University of Illinois, Urbana, Illinois 61801*
- <sup>26</sup>*The Johns Hopkins University, Baltimore, Maryland 21218*
- <sup>27</sup>*Institut für Experimentelle Kernphysik, Universität Karlsruhe, 76128 Karlsruhe, Germany*
- <sup>28</sup>*Center for High Energy Physics: Kyungpook National University, Daegu 702-701, Korea; Seoul National University, Seoul 151-742, Korea; Sungkyunkwan University, Suwon 440-746, Korea; Korea Institute of Science and Technology Information, Daejeon, 305-806, Korea; Chonnam National University, Gwangju, 500-757, Korea*
- <sup>29</sup>*Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, California 94720*
- <sup>30</sup>*University of Liverpool, Liverpool L69 7ZE, United Kingdom*
- <sup>31</sup>*University College London, London WC1E 6BT, United Kingdom*
- <sup>32</sup>*Centro de Investigaciones Energeticas Medioambientales y Tecnologicas, E-28040 Madrid, Spain*
- <sup>33</sup>*Massachusetts Institute of Technology, Cambridge, Massachusetts 02139*
- <sup>34</sup>*Institute of Particle Physics: McGill University, Montréal, Québec, Canada H3A 2T8; Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6; University of Toronto, Toronto, Ontario, Canada M5S 1A7; and TRIUMF, Vancouver, British Columbia, Canada V6T 2A3*
- <sup>35</sup>*University of Michigan, Ann Arbor, Michigan 48109*
- <sup>36</sup>*Michigan State University, East Lansing, Michigan 48824*
- <sup>37</sup>*Institution for Theoretical and Experimental Physics, ITEP, Moscow 117259, Russia*
- <sup>38</sup>*University of New Mexico, Albuquerque, New Mexico 87131*
- <sup>39</sup>*Northwestern University, Evanston, Illinois 60208*
- <sup>40</sup>*The Ohio State University, Columbus, Ohio 43210*
- <sup>41</sup>*Okayama University, Okayama 700-8530, Japan*
- <sup>42</sup>*Osaka City University, Osaka 588, Japan*
- <sup>43</sup>*University of Oxford, Oxford OX1 3RH, United Kingdom*
- <sup>44</sup>*Istituto Nazionale di Fisica Nucleare, Sezione di Padova-Trento, <sup>y</sup>University of Padova, I-35131 Padova, Italy*
- <sup>45</sup>*LPNHE, Université Pierre et Marie Curie/IN2P3-CNRS, UMR7585, Paris, F-75252 France*
- <sup>46</sup>*University of Pennsylvania, Philadelphia, Pennsylvania 19104*
- <sup>47</sup>*Istituto Nazionale di Fisica Nucleare Pisa, <sup>z</sup>University of Pisa, <sup>aa</sup>University of Siena and <sup>bb</sup>Scuola Normale Superiore, I-56127 Pisa, Italy*
- <sup>48</sup>*University of Pittsburgh, Pittsburgh, Pennsylvania 15260*
- <sup>49</sup>*Purdue University, West Lafayette, Indiana 47907*
- <sup>50</sup>*University of Rochester, Rochester, New York 14627*
- <sup>51</sup>*The Rockefeller University, New York, New York 10021*
- <sup>52</sup>*Istituto Nazionale di Fisica Nucleare, Sezione di Roma 1, <sup>cc</sup>Sapienza Università di Roma, I-00185 Roma, Italy*
- <sup>53</sup>*Rutgers University, Piscataway, New Jersey 08855*
- <sup>54</sup>*Texas A&M University, College Station, Texas 77843*
- <sup>55</sup>*Istituto Nazionale di Fisica Nucleare Trieste/Udine, I-34100 Trieste, <sup>dd</sup>University of Trieste/Udine, I-33100 Udine, Italy*
- <sup>56</sup>*University of Tsukuba, Tsukuba, Ibaraki 305, Japan*
- <sup>57</sup>*Tufts University, Medford, Massachusetts 02155*
- <sup>58</sup>*Waseda University, Tokyo 169, Japan*
- <sup>59</sup>*Wayne State University, Detroit, Michigan 48201*
- <sup>60</sup>*University of Wisconsin, Madison, Wisconsin 53706*
- <sup>61</sup>*Yale University, New Haven, Connecticut 06520*
- (Dated: November 16, 2009)

We present the results of a search for pair production of the supersymmetric partner of the top quark (the stop quark  $\tilde{t}_1$ ) decaying to a  $b$ -quark and a chargino  $\tilde{\chi}_1^\pm$  with a subsequent  $\tilde{\chi}_1^\pm$  decay into a neutralino  $\tilde{\chi}_1^0$ , lepton  $\ell$ , and neutrino  $\nu$ . Using a data sample corresponding to  $2.7 \text{ fb}^{-1}$  of integrated luminosity of  $p\bar{p}$  collisions at  $\sqrt{s} = 1.96 \text{ TeV}$  collected by the CDF II detector, we reconstruct the mass of candidate stop events and fit the observed mass spectrum to a combination of standard model processes and stop quark signal. We find no evidence for  $\tilde{t}_1\bar{\tilde{t}}_1$  production and set 95% C.L. limits on the masses of the stop quark and the neutralino for several values of the chargino mass and the branching ratio  $\mathcal{B}(\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0 \ell^\pm \nu)$ .

PACS numbers: 12.60.Jv, 14.65.Ha, 14.80.Ly

---

\*Deceased

---

†With visitors from <sup>a</sup>University of Massachusetts Amherst,

Supersymmetry (SUSY) [1] is a plausible extension to the standard model (SM) of particle physics that naturally solves the hierarchy problem, predicts the unification of the gauge coupling constants, and provides a possible candidate for dark matter. In SUSY, a new spin-based symmetry turns a bosonic state into a fermionic state (and vice versa) postulating the existence of a superpartner for each of the known fundamental particles. To be reconciled with experimental data, SUSY must be broken, and thus supersymmetric particles are expected to be much heavier than their SM partners. An exception to this might come from the partner of the top quark  $t$ , the stop quark, whose low-mass eigenstate  $\tilde{t}_1$  may be lighter than the top quark due to the substantial top-Yukawa coupling [2]. This mass inequality  $m_{\tilde{t}_1} \lesssim m_t$  is favored in supersymmetric electroweak baryogenesis scenarios [3].

In canonical SUSY models R-parity is conserved, the lightest supersymmetric particle (LSP) is the neutralino  $\tilde{\chi}_1^0$ , and stop quarks are expected to be pair-produced via the strong interaction. The  $\tilde{t}_1\tilde{t}_1$  cross section depends primarily on the mass of the stop quark  $m_{\tilde{t}_1}$ , and at the Tevatron is expected to be an order of magnitude smaller than that for top quarks of the same mass [4, 5]. If the chargino  $\tilde{\chi}_1^\pm$  is lighter than the stop quark, the decay channel  $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$  becomes dominant. Subsequent chargino decays via  $\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0\ell^\pm\nu$  result in experimental event signatures with two energetic, oppositely charged leptons, two jets from the bottom quarks, and large imbalance in energy from the lack of detection of the neutrinos and neutralinos. This event signature is identical to the dilepton final state of top pair decays ( $t\bar{t} \rightarrow W^+bW^-\bar{b} \rightarrow \ell^+\nu b\ell^-\bar{\nu}\bar{b}$ ). Therefore, an admixture of stop events with the top dilepton events could

impact measurements of the properties of the top quark, such as the mass value. This search was in part motivated by apparent inconsistencies in the top mass measurements between different top decay channels observed in the early CDF and D0 Run II data [6]. Previous searches for stop decays  $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$  [7] did not exclude any region in the SUSY parameter space.

In this Letter we present the results of a search for pair production of scalar top quarks, each decaying as  $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm \rightarrow b\tilde{\chi}_1^0\ell^\pm\nu$ . We analyze a data set corresponding to  $2.7\text{ fb}^{-1}$  of integrated luminosity from  $p\bar{p}$  collisions collected by the upgraded Collider Detector at Fermilab (CDF II) [8, 9], and fit the data with the stop pair production hypothesis.

We identify and record events containing  $e$  or  $\mu$  candidates with large transverse momenta ( $p_T \geq 18\text{ GeV}/c$ ) using high-speed trigger electronics. The performance of the trigger and lepton identification (ID) algorithms is described elsewhere [10]. We identify final state quarks as jets of hadrons in the calorimeter. Jet reconstruction employs an iterative cone-based clustering algorithm that associates calorimeter energy deposits within a cone of  $R \equiv \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.4$ . The energies of reconstructed jets and the missing transverse energy ( $\cancel{E}_T$ ) [11] are corrected for detector non-uniformity and other effects [12]. Bottom quark candidates are identified (or “ $b$ -tagged”) through the presence within the jet cone of a displaced secondary vertex arising from the decay of a long-lived bottom hadron [13].

The first stage of stop candidate event selection requires two leptons ( $e$  or  $\mu$ ) with  $p_T > 20\text{ GeV}/c$ ,  $|\eta| < 2.0(1.0)$  for  $e(\mu)$ , at least one of which is isolated [14], and  $m_{\ell\ell} > 20\text{ GeV}/c^2$ . We also require two or more jets with  $E_T > 12\text{ GeV}$  within the region  $|\eta| < 2.4$ , and  $\cancel{E}_T > 20\text{ GeV}$ . For events with leptons compatible with originating from a  $Z$  boson in the mass window from  $76\text{ GeV}/c^2$  to  $106\text{ GeV}/c^2$ , we apply a requirement on the missing transverse energy significance  $\cancel{E}_T^{sig} > 4\sqrt{\text{GeV}}$  [15]. Selected events are divided into two categories based on whether any of the jets is identified as a  $b$  jet ( $b$ -tagged channel) or not (non- $b$ -tagged channel). Further optimized event selection criteria are used in the last stage of the analysis.

The dominant SM process that contributes to the dilepton + jets +  $\cancel{E}_T$  event signature is  $t\bar{t}$  production. Other SM processes include  $Z/\gamma^* +$  jets, diboson, and  $W +$  jets production, where a real lepton comes from the  $W$  decay and one of the jets is misidentified as a second lepton. We use the PYTHIA v6.216 Monte Carlo (MC) event generator [16] to simulate  $\tilde{t}_1\tilde{t}_1$ ,  $t\bar{t}$ , and diboson processes. The stop signal is normalized according to the next-to-leading order (NLO) theoretical cross section obtained from PROSPINO2 [17] using the CTEQ6M [18] parton density functions (PDF). For  $t\bar{t}$  we use the theoretical cross section value of  $7.3\text{ pb}$ , corresponding to the world average top mass of  $172.5\text{ GeV}/c^2$  [19], which is domi-

---

Amherst, Massachusetts 01003, <sup>b</sup>Universiteit Antwerpen, B-2610 Antwerp, Belgium, <sup>c</sup>University of Bristol, Bristol BS8 1TL, United Kingdom, <sup>d</sup>Chinese Academy of Sciences, Beijing 100864, China, <sup>e</sup>Istituto Nazionale di Fisica Nucleare, Sezione di Cagliari, 09042 Monserrato (Cagliari), Italy, <sup>f</sup>University of California Irvine, Irvine, CA 92697, <sup>g</sup>University of California Santa Cruz, Santa Cruz, CA 95064, <sup>h</sup>Cornell University, Ithaca, NY 14853, <sup>i</sup>University of Cyprus, Nicosia CY-1678, Cyprus, <sup>j</sup>University College Dublin, Dublin 4, Ireland, <sup>k</sup>University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom, <sup>l</sup>University of Fukui, Fukui City, Fukui Prefecture, Japan 910-0017 <sup>m</sup>Kinki University, Higashi-Osaka City, Japan 577-8502 <sup>n</sup>Universidad Iberoamericana, Mexico D.F., Mexico, <sup>o</sup>Queen Mary, University of London, London, E1 4NS, England, <sup>p</sup>University of Manchester, Manchester M13 9PL, England, <sup>q</sup>Nagasaki Institute of Applied Science, Nagasaki, Japan, <sup>r</sup>University of Notre Dame, Notre Dame, IN 46556, <sup>s</sup>University de Oviedo, E-33007 Oviedo, Spain, <sup>t</sup>Texas Tech University, Lubbock, TX 79609, <sup>u</sup>IFIC(CSIC-Universitat de Valencia), 46071 Valencia, Spain, <sup>v</sup>University of Virginia, Charlottesville, VA 22904, <sup>w</sup>Bergische Universität Wuppertal, 42097 Wuppertal, Germany, <sup>ee</sup>On leave from J. Stefan Institute, Ljubljana, Slovenia,

nated by the measurements in the lepton + jets channel of  $t\bar{t}$  decays. Diboson processes ( $WW, WZ, ZZ$ ) are normalized to their theoretical cross-sections [20].  $Z/\gamma^*$  events with associated jets are simulated with the ALPGEN v2.13 matrix element generator [21], interfaced to PYTHIA v6.325, and normalized to data in the  $Z$ -mass-peak region. The detector response in all MC samples is modeled by a GEANT-based CDF II detector simulation [22]. The  $W$ + jets background is modeled using data by measuring relative rates of jets being misidentified as charged leptons in inclusive jet data samples and applying them to data events with exactly one lepton plus jets. We validate the background modeling of dilepton events by comparing the predictions with observations using control samples that are independent of the signal sample. These include samples of events with low  $\cancel{E}_T$ , events with zero or one jet, and events with same-sign charged leptons.

To enhance the search sensitivity, we perform a kinematic reconstruction of events under the stop production and decay hypothesis. We use as inputs the measured four-momenta of the two leptons and of the two largest  $E_T$  jets, and the  $\vec{\cancel{E}}_T$ . Due to the unknown masses of the supersymmetric  $\tilde{\chi}_1^\pm$  and  $\tilde{\chi}_1^0$ , and because the two neutrinos and the two massive neutralinos escape detection, the kinematics of stop events is severely underconstrained. Therefore, we employ the following strategy. First, we use  $m_{\tilde{\chi}_1^\pm}$  as a fixed parameter, and perform the reconstruction for different values of  $m_{\tilde{\chi}_1^\pm}$ . Second, we treat the  $\tilde{\chi}_1^0\nu$  pair corresponding to each  $\tilde{t}_1$  decay as one ‘‘massive particle.’’ To compensate for non-resonant structure of the invariant mass of the  $\tilde{\chi}_1^0\nu$  pair we assign to this ‘‘massive particle’’ a large width. Based on studies carried out on MC samples for a wide range of neutralino masses ( $m_{\tilde{\chi}_1^0} \approx 46 - 90 \text{ GeV}/c^2$ ) we fix the values of  $m_{\tilde{\chi}_1^0\nu}$  and  $\Gamma_{\tilde{\chi}_1^0\nu}$  to  $75 \text{ GeV}/c^2$  and  $10 \text{ GeV}/c^2$ , respectively. Third, to avoid the two-fold ambiguity in assigning a  $b$ -jet to a lepton, we always choose the combination that yields the smallest sum of invariant masses of a paired  $b$ -jet and lepton. This approach identifies the correct pairing in  $\sim 90\%$  of cases in the stop mass regime considered.

The system of kinematic equations consists of constraints imposed on the particle masses  $m_{\tilde{\chi}_1^\pm}$ ,  $m_{\tilde{\chi}_1^0\nu}$ ,  $m_{\tilde{t}_1} = m_{\bar{\tilde{t}}_1}$ , and the requirement of transverse momentum conservation:  $\vec{\cancel{E}}_T = \vec{p}_T(\tilde{\chi}_1^0\nu)_1 + \vec{p}_T(\tilde{\chi}_1^0\nu)_2$ . If the azimuthal directions  $\phi_1$  and  $\phi_2$  of the four-momenta of the  $(\tilde{\chi}_1^0\nu)_1$  and  $(\tilde{\chi}_1^0\nu)_2$  pairs are fixed, the event kinematics (with the exception of the singular points  $\phi_1 - \phi_2 = k\pi$ , where  $k$  is an integer) is constrained. There exist four solutions due to the two-fold ambiguities in resolving the  $z$ -components of the  $(\tilde{\chi}_1^0\nu)_1$  and  $(\tilde{\chi}_1^0\nu)_2$  four-momenta. We perform a scan of the entire parameter space of azimuthal angles wherein we repeat the reconstruction for different values of  $(\phi_1, \phi_2)$ , avoiding the aforementioned

singular points. The stop quark mass is reconstructed by minimizing the event  $\chi^2$ , which takes the following form:

$$\chi^2 = \sum_{k=1,2} \left\{ \frac{\left(m_{(\tilde{\chi}_1^0\nu)_k}^{fit} - m_{\tilde{\chi}_1^0\nu}\right)^2}{\Gamma_{\tilde{\chi}_1^0\nu}^2} + \frac{\left(m_{(\tilde{\chi}_1^0\nu)_k}^{fit} - m_{\tilde{\chi}_1^\pm}\right)^2}{\Gamma_{\tilde{\chi}_1^\pm}^2} + \frac{\left(m_{(\tilde{\chi}_1^0\nu)_k}^{fit} - m_{\tilde{t}_1}^{rec}\right)^2}{\Gamma_{\tilde{t}_1}^2} \right\} + \sum_{i=2\ell, 2jets} \frac{\left(p_{T,i}^{fit} - p_{T,i}^{meas}\right)^2}{\sigma_{p_{T,i}}^2}. \quad (1)$$

Here we assume  $\Gamma_{\tilde{\chi}_1^\pm} \equiv 2 \text{ GeV}/c^2$  and  $\Gamma_{\tilde{t}_1} \equiv 1.5 \text{ GeV}/c^2$ , the  $k$ -index represents the decay products from stop or anti-stop respectively, and the  $m^{fit}$  are the invariant masses of the final decay products from stop quark decays. We let the four-momenta of the leptons and the jets vary in the fit, and use the MINUIT package [23] to minimize the  $\chi^2$ . At each step during the minimization procedure the  $\vec{\cancel{E}}_T$  is re-calculated according to the values of  $p_T^{fit}$  of the leptons and jets. The longitudinal components of  $(\tilde{\chi}_1^0\nu)_1$  and  $(\tilde{\chi}_1^0\nu)_2$  are free parameters in the fit with starting values initialized to the values corresponding to solutions of the system of kinematic equations. All four starting values are tried in the fit, but only the one that gives the lowest  $\chi^2$  is kept. The value  $m_{\tilde{t}_1}^{rec}$  at which  $\chi^2$  is minimized yields the reconstructed mass of the stop quark for a given pair of the azimuthal angles  $(\phi_1, \phi_2)$ . Finally, we integrate  $m_{\tilde{t}_1}^{rec}(\phi_1, \phi_2)$  weighted by the goodness of fit term  $e^{-\chi^2(\phi_1, \phi_2)}$  over  $\phi_1$  and  $\phi_2$  to obtain the reconstructed mass of the stop quark for each event. Running the reconstruction algorithm over simulated stop events yields a distribution with a peak near the generated mass of the stop quark, and provides discrimination between stop and SM backgrounds. Details about the performance of the stop quark mass reconstruction algorithm can be found elsewhere [24].

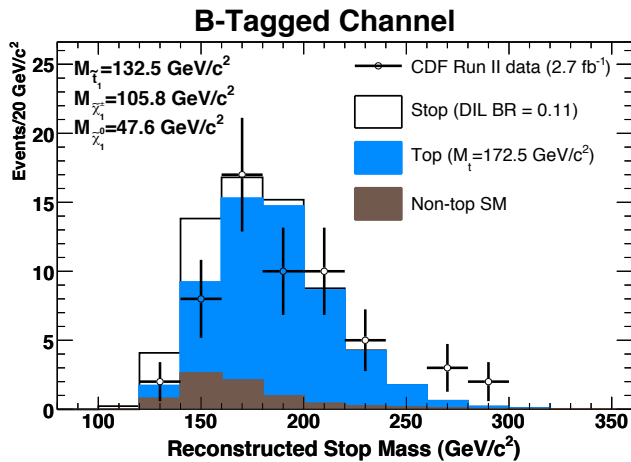
We perform an extended likelihood fit of the observed mass spectrum simultaneously in the  $b$ -tagged and the non- $b$ -tagged channels. To quantify the level of agreement we employ a modified frequentist method,  $CL_s$  [25], based on a log-likelihood ratio test statistic, which involves computing  $p$ -values under the hypothesis of the SM background only and the hypothesis of signal plus background. The systematic uncertainties for both signal and background, described below, enter the fit as Gaussian-constrained nuisance parameters. The uncertainties due to kinematic mis-modeling are taken into account by allowing the reconstructed mass distributions to change according to the values of the nuisance parameters [26].

Imperfect knowledge of various experimental and theoretical parameters leads to systematic uncertainties that degrade our sensitivity to  $\tilde{t}_1\bar{\tilde{t}}_1$  signal. The dominant systematic effect is due to the uncertainties in the NLO the-

Events per  $2.7 \text{ fb}^{-1}$  in the signal region.

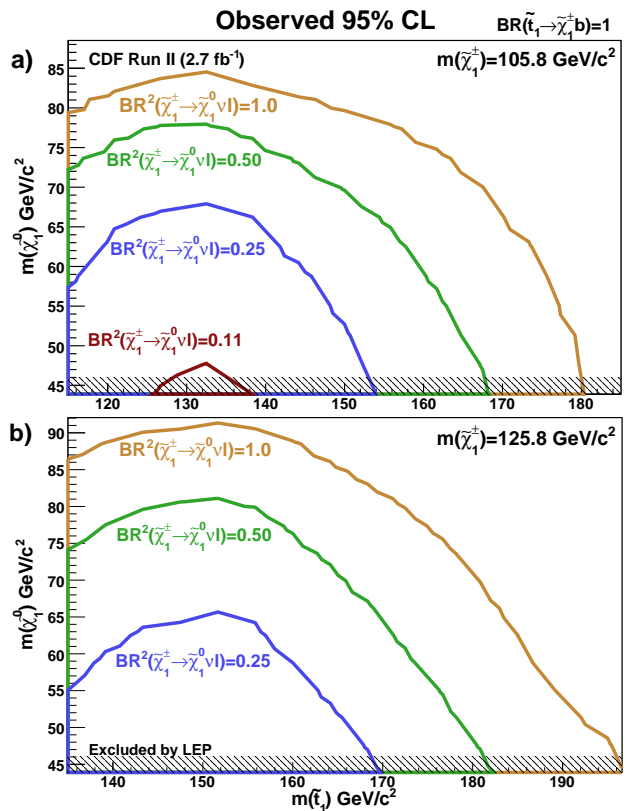
	Top	$Z/\gamma^* + \text{jets}$	Diboson	$W + \text{jets}$	Total	Data
$b$ -tag	$49.0 \pm 6.9$	$4.0 \pm 0.4$	$0.5 \pm 0.1$	$2.8 \pm 0.9$	$56.4 \pm 7.2$	57
no tag	$25.2 \pm 3.3$	$25.0 \pm 5.6$	$6.0 \pm 1.3$	$9.8 \pm 2.9$	$65.9 \pm 9.8$	65

TABLE I: The expected event yields from SM processes with the total uncertainties and the observed numbers of events in the signal region.

FIG. 1: The reconstructed stop mass distribution in the  $b$ -tagged channel. The contribution from stop events corresponds to an example point in the SUSY parameter space that is excluded at 95% C.L.

oretical cross sections for  $\tilde{t}_1 \tilde{t}_1^*$  and  $t\bar{t}$  production. These uncertainties come from two sources: the renormalization and factorization scale (11% and 7% for  $\tilde{t}_1 \tilde{t}_1^*$  and  $t\bar{t}$ , respectively) and PDFs (14% and 7%) [4, 5]. We assume that the scale uncertainty is uncorrelated for  $\tilde{t}_1 \tilde{t}_1^*$  and  $t\bar{t}$  processes, while the PDF uncertainty is fully correlated. The theoretical uncertainty of the diboson cross sections is 10% [20], and assumed to be uncorrelated with other systematic uncertainties. The experimental uncertainties applied to MC-based background estimates include those due to jet energy scale (3%),  $b$ -tagging probability (5%), lepton ID and trigger efficiencies (1%), initial and final state radiation (2%), and the integrated luminosity (6%). The uncertainty on  $W + \text{jets}$  is dominated by the uncertainties in the rate to misidentify jets as leptons (30%), while the uncertainty on  $Z/\gamma^* + \text{jets}$  comes from MC mis-modeling of the high- $\cancel{E}_T$  tail, jet multiplicity distribution and  $Z/\gamma^* + \text{heavy-flavor}$  contribution (16%).

Prior to looking at data in the signal sample we study the sensitivity of the search, taking into account all systematic effects, for various event selection criteria imposed separately for the  $b$ -tagged and the non- $b$ -tagged channels. An algorithm based on biological evolution (a so-called genetic algorithm) [27] is employed to determine the most sensitive selection criteria. Requirements

FIG. 2: The observed 95% C.L. exclusion regions in the  $m_{\tilde{\chi}_1^0}$  and  $m_{\tilde{t}_1}$  mass plane for several values of  $\mathcal{B}(\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0 \ell^\pm \nu)$  and  $m_{\tilde{\chi}_1^\pm}$ . The excluded region corresponds to the area below the lines. Universality of  $e$ ,  $\mu$ , and  $\tau$  in the  $\tilde{\chi}_1^\pm$  decays is assumed.

yielding poorer expected 95% C.L. limit are culled, while those improving the limit are bred together until reaching a plateau. This procedure optimizes the event selection criteria directly to produce the best expected 95% C.L. limit in the no-signal hypothesis.

In the  $b$ -tagged (non- $b$ -tagged) channel the optimization procedure yields the following event selection criteria: the leading jet  $E_T$  is required to be greater than 15 (20) GeV, and the sub-leading jet  $E_T$  must be greater than 12 (20) GeV. In both channels we require  $\cancel{E}_T > 20$  GeV, while this requirement is tightened to 50 GeV in the non- $b$ -tagged channel if there is a lepton or jet within an azimuthal angle of  $20^\circ$  from the  $\cancel{E}_T$  direction. Due to the fact that the stop quark is a scalar particle, and the top quark is a fermion, the angular distributions of their final decay products are very distinct. Therefore we implement an additional topological cut in both the  $b$ -tagged and non- $b$ -tagged channels to suppress  $t\bar{t}$  events:

$$\sum p_T < \left( \frac{\Delta\phi_{jj} \times \Delta\phi_{\ell\ell}}{\pi^2} \times 325 + 215 \right) \text{ GeV}/c, \quad (2)$$

where  $\sum p_T$  is the scalar sum of transverse momenta of

the leptons, jets and the  $\cancel{E}_T$ , and the  $\Delta\phi_{jj}$  and  $\Delta\phi_{\ell\ell}$  are the azimuthal angles between the jets and leptons, respectively. This requirement rejects about 50% of  $t\bar{t}$  events and only about 10% of stop events.

After applying these event selection requirements we obtain the numbers of predicted and observed events listed in Table I. The data distribution of the reconstructed stop mass in the  $b$ -tagged channel is shown in Fig. 1, together with the expectations from SM processes and an example of stop signal. The data are consistent with the SM alone and there is no evidence of  $\tilde{t}_1\tilde{t}_1$  production. We use these results to calculate the 95% C.L. exclusion limits in the  $m_{\tilde{\chi}_1^0}$  vs  $m_{\tilde{t}_1}$  plane for several values of the branching ratio  $\mathcal{B}(\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0\ell^\pm\nu)$  and  $m_{\tilde{\chi}_1^\pm}$ , assuming equal branching ratios into different lepton flavors and  $\mathcal{B}(\tilde{t}_1 \rightarrow \tilde{\chi}_1^\pm b) = 100\%$ . The limits for two different values of chargino mass are presented in Fig. 2. For a given branching ratio of the pair of stops decaying into leptons, equal to  $\mathcal{B}^2(\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0\ell^\pm\nu)$ , we exclude the stop and neutralino masses below the respective curve shown in the plot. The values  $\mathcal{B}^2(\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0\ell^\pm\nu)$  are expected to range from almost 100%, corresponding to the scenario with light sleptons and sneutrinos ( $m_{\tilde{\ell}}, m_{\tilde{\nu}} \gtrsim m_{\tilde{t}_1}$ ), where the leptonic decay of the chargino goes mostly through virtual sleptons and sneutrinos, down to 11%, where sleptons and sneutrinos are heavy ( $m_{\tilde{\ell}}, m_{\tilde{\nu}} \gg m_W$ ) and the chargino decay through a virtual  $W$  is dominant. For the scenario corresponding to the case in which the masses of the chargino and neutralino are near the current lower LEP exclusion limits,  $m_{\tilde{\chi}_1^\pm} = 105.8 \text{ GeV}/c^2$ ,  $m_{\tilde{\chi}_1^0} = 47.6 \text{ GeV}/c^2$  [28], we exclude a stop quark with masses between 128 and 135  $\text{GeV}/c^2$  at 95% C.L. independent of the value of  $\mathcal{B}^2(\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0\ell^\pm\nu)$ . The limits obtained are applicable to any R-parity conserving SUSY scenario where the neutralino is the LSP and the stop decays exclusively into  $\tilde{\chi}_1^\pm b$ , and are the first lower limits on stop mass in this mode.

In conclusion, we have presented the results of a search for pair production of supersymmetric top quarks decaying via  $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm \rightarrow b\tilde{\chi}_1^0\ell^\pm\nu$  using a data sample corresponding to  $2.7 \text{ fb}^{-1}$  of integrated luminosity in 1.96 TeV  $p\bar{p}$  collisions. Our fit to the observed  $m_{\tilde{t}_1}^{rec}$  distribution reveals no evidence for  $\tilde{t}_1\tilde{t}_1$  production, and we place the world's first limits on the masses of  $\tilde{t}_1$  and  $\tilde{\chi}_1^0$  for several values of  $m_{\tilde{\chi}_1^\pm}$  and branching ratio of  $\mathcal{B}(\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0\ell^\pm\nu)$  in this mode.

We thank the Fermilab staff and the technical staffs of the participating institutions for their vital contributions. This work was supported by the U.S. Department of Energy and National Science Foundation; the Italian Istituto Nazionale di Fisica Nucleare; the Ministry of Education, Culture, Sports, Science and Technology of Japan; the Natural Sciences and Engineering Research Council of Canada; the National Science Council of the Republic of China; the Swiss National Science Founda-

tion; the A.P. Sloan Foundation; the Bundesministerium für Bildung und Forschung, Germany; the World Class University Program, the National Research Foundation of Korea; the Science and Technology Facilities Council and the Royal Society, UK; the Institut National de Physique Nucleaire et Physique des Particules/CNRS; the Russian Foundation for Basic Research; the Ministerio de Ciencia e Innovación, and Programa Consolider-Ingénio 2010, Spain; the Slovak R&D Agency; and the Academy of Finland.

- 
- [1] H. E. Haber and G. L. Kane, Phys. Rep. **117**, 75 (1985).
  - [2] J. Ellis and S. Rudaz, Phys. Lett. B **128**, 248 (1983).
  - [3] C. Balazs, M. Carena, and C. Wagner, Phys. Rev. D **70** (2004) 015007.
  - [4] W. Beenakker *et al.*, Nucl. Phys. **B515**, 3 (1998).
  - [5] M. Cacciari *et al.*, J. High Energy Phys. 04 (2004) 068.
  - [6] F. Canelli *et al.*, Fermilab-TM-2380-E, TEVEWWG/top 2007/01.
  - [7] T. Affolder *et al.*, (CDF Collaboration) Phys. Rev. Lett. **84** (2000) 5273; V. Abazov *et al.*, (D0 Collaboration) Phys. Lett. B **674** (2009) 4.
  - [8] D. Acosta *et al.*, Phys. Rev. D **71**, 032001 (2005).
  - [9] CDF uses a cylindrical coordinate system with the  $z$  axis along the proton beam axis.  $\theta$  is the polar angle relative to the proton beam direction, and  $\phi$  is the azimuthal angle. Pseudorapidity is defined as  $\eta \equiv -\ln(\tan \frac{\theta}{2})$ , while transverse momenta and energies of particles are defined as  $p_T = |p| \sin \theta$  and  $E_T = E \sin \theta$  respectively.
  - [10] D. Acosta *et al.*, Phys. Rev. D **94**, 091803 (2005).
  - [11] The missing transverse energy is defined as  $\cancel{E}_T = |\vec{\cancel{E}}_T| = |-\sum_i E_T^i \vec{n}_i|$  where  $\vec{n}_i$  is a unit vector in the plane transverse to the beam direction and that points from the event vertex to the  $i$ -th calorimeter tower. The missing transverse energy is corrected for the escaping muon momenta when muon candidates are present.
  - [12] A. Bhatti *et al.*, Nucl. Instrum. Methods Phys. Res. A **566**, 375 (2006).
  - [13] D. Acosta *et al.*, Phys. Rev. D **71**, 052003 (2005).
  - [14] The lepton is defined as isolated, if the energy deposit within  $R = 0.4$  cone of the lepton momentum  $p_T$  is less than 10% of the lepton  $p_T$ .
  - [15] The missing transverse energy significance is defined as  $\cancel{E}_T^{sig} = \cancel{E}_T / \sqrt{\sum E_T}$ , where  $\sum E_T$  is the scalar transverse energy sum over all calorimeter towers.  $\sum E_T$  is corrected for muons and other effects in an identical manner to the  $\cancel{E}_T$ .
  - [16] T. Sjöstrand *et al.*, Comput. Phys. Commun. **135**, 238 (2001).
  - [17] W. Beenakker *et al.*, Phys. Rev. Lett. **83** 3780 (1999).
  - [18] J. Pumplin *et al.*, J. High Energy Phys. 07 (2002) 012.
  - [19] D. Glenzinski *et al.*, Fermilab-TM-2103-E, TEVEWWG/top 2008/01.
  - [20] J. M. Campbell and R. K. Ellis, Phys. Rev. D **60**, 113006 (1999).
  - [21] M. L. Mangano *et al.*, J. High Energy Phys. 01 (2001) 10.
  - [22] E. Gerchtein and M. Paulini, eConf C0303241, TUMT005

- (2003).
- [23] F. James and M. Roos, *Comput. Phys. Commun.* **10**, 343 (1975).
- [24] W. Johnson, Ph.D. thesis, University of California, Davis, 2009.
- [25] T. Junk, *Nucl. Instrum. Methods A* **434** (1999).
- [26] A.L. Read, *J. Phys. G* **28**, 2693 (2002).
- [27] D. E. Goldberg, *Genetic Algorithms in Search, Optimization and Machine Learning*, Reading Addison Wesley (1989).
- [28] LEP SUSY Working Group (ALEPH, DELPHI, L3, and OPAL experiments), notes LEPSUSYWG/01-03.1, LEPSUSYWG/02-06.2.