Revised - February 2007

BABAR-PUB-06/061
SLAC-PUB-12170
hep-ex/0610067

Search for Lepton Flavor Violating Decays $\tau^\pm \to \ell^\pm\pi^0, \ell^\pm\eta, \ell^\pm\eta'$

B. Aubert,[1] M. Bona,[1] D. Boutigny,[1] F. Couderc,[1] Y. Karyotakis,[1] J. P. Lees,[1] V. Poireau,[1] V. Tisserand,[1] A. Zghiche,[1] E. Grauges,[2] A. Palano,[3] J. C. Chen,[4] N. D. Qi,[4] G. Rong,[4] P. Wang,[4] Y. S. Zhu,[4] G. Eigen,[5] I. Ofte,[5] B. Stugu,[5] G. S. Abrams,[6] M. Battaglia,[6] D. N. Brown,[6] J. Button-Shafer,[6] R. N. Cahn,[6] E. Charles,[6] M. S. Gill,[6] Y. Groysman,[6] R. G. Jacobsen,[6] J. A. Kadyk,[6] L. T. Kerth,[6] Yu. G. Kolomensky,[6] G. Kukartsev,[6] D. Lopes Pegna,[6] G. Lynch,[6] L. M. Mir,[6] T. J. Orimoto,[6] M. Pripstein,[6] N. A. Roe,[6] M. T. Ronan,[6] W. A. Wenzel,[6] P. del Amo Sanchez,[7] M. Barrett,[7] K. E. Ford,[7] T. J. Harrison,[7] A. J. Hart,[7] C. M. Hawkes,[7] A. T. Watson,[7] T. Held,[8] H. Koch,[8] B. Lewandowski,[8] M. Pelizaeus,[8] K. Peters,[8] T. Schroeder,[8] M. Steinke,[8] J. T. Boyd,[9] J. P. Burke,[9] W. N. Cottingham,[9] D. Walker,[9] D. J. Asgeirsson,[10] T. Cuhadar-Donszelmann,[10] B. G. Fulsom,[10] C. Hearty,[10] N. S. Knecht,[10] T. S. Mattison,[10] J. A. McKenna,[10] A. Khan,[11] P. Kyberd,[11] M. Saleem,[11] D. J. Sherwood,[11] L. Teodorescu,[11] V. E. Blinov,[12] A. D. Bukin,[12] V. P. Druzhinin,[12] V. B. Golubev,[12] A. P. Onuchin,[12] S. I. Serednyakov,[12] Yu. I. Skovpen,[12] E. P. Solodov,[12] K. Yu Todyshev,[12] D. S. Best,[13] M. Bondioli,[13] M. Bruinsma,[13] M. Chao,[13] S. Curry,[13] I. Eschrich,[13] D. Kirkby,[13] A. J. Lankford,[13] P. Lund,[13] M. Mandelkern,[13] W. Roethel,[13] D. P. Stoker,[13] S. Abachi,[14] C. Buchanan,[14] S. D. Foulkes,[15] J. W. Gary,[15] O. Long,[15] B. C. Shen,[15] K. Wang,[15] L. Zhang,[15] H. K. Hadavand,[16] E. J. Hill,[16] H. P. Paar,[16] S. Rahatlou,[16] V. Sharma,[16] J. W. Berryhill,[17] C. Campagnari,[17] A. Cunha,[17] B. Dahmes,[17] T. M. Hong,[17] D. Kovalskyi,[17] J. D. Richman,[17] T. W. Beck,[18] A. M. Eisner,[18] C. J. Flacco,[18] C. A. Heusch,[18] J. Kroseberg,[18] W. S. Lockman,[18] G. Nesom,[18] T. Schalk,[18] B. A. Schumm,[18] A. Seiden,[18] P. Spradlin,[18] D. C. Williams,[18] M. G. Wilson,[18] J. Albert,[19] E. Chen,[19] C. H. Cheng,[19] A. Dvoretskii,[19] F. Fang,[19] D. G. Hitlin,[19] I. Narsky,[19] T. Piatenko,[19] F. C. Porter,[19] G. Mancinelli,[20] B. T. Meadows,[20] K. Mishra,[20] M. D. Sokoloff,[20] F. Blanc,[21] P. C. Bloom,[21] S. Chen,[21] W. T. Ford,[21] J. F. Hirschauer,[21] A. Kreisel,[21] M. Nagel,[21] U. Nauenberg,[21] A. Olivas,[21] W. O. Ruddick,[21] J. G. Smith,[21] K. A. Ulmer,[21] S. R. Wagner,[21] J. Zhang,[21] A. Chen,[22] E. A. Eckhart,[22] A. Soffer,[22] W. H. Toki,[22] R. J. Wilson,[22] F. Winklmeier,[22] Q. Zeng,[22] D. D. Altenburg,[23] E. Feltresi,[23] A. Hauke,[23] H. Jasper,[23] J. Merkel,[23] A. Petzold,[23] B. Spaan,[23] T. Brandt,[24] V. Klose,[24] H. M. Lacker,[24] W. F. Mader,[24] R. Nogowski,[24] J. Schubert,[24] K. R. Schubert,[24] R. Schwierz,[24] J. E. Sundermann,[24] A. Volk,[24] D. Bernard,[25] G. R. Bonneaud,[25] E. Latour,[25] Ch. Thiebaux,[25] M. Verderi,[25] P. J. Clark,[26] W. Gradl,[26] F. Muheim,[26] S. Playfer,[26] A. I. Robertson,[26] Y. Xie,[26] M. Andreotti,[27] D. Bettoni,[27] C. Bozzi,[27] R. Calabrese,[27] G. Cibinetto,[27] E. Luppi,[27] M. Negrini,[27] A. Petrella,[27] L. Piemontese,[27] E. Prencipe,[27] F. Anulli,[28] R. Baldini-Ferroli,[28] A. Calcaterra,[28] R. de Sangro,[28] G. Finocchiaro,[28] S. Pacetti,[28] P. Patteri,[28] I. M. Peruzzi,[28,*] M. Piccolo,[28] M. Rama,[28] A. Zallo,[28] A. Buzzo,[29] R. Contri,[29] M. Lo Vetere,[29] M. M. Macri,[29] M. R. Monge,[29] S. Passaggio,[29] C. Patrignani,[29] E. Robutti,[29] A. Santroni,[29] S. Tosi,[29] G. Brandenburg,[30] K. S. Chaisanguanthum,[30] C. L. Lee,[30] M. Morii,[30] J. Wu,[30] R. S. Dubitzky,[31] J. Marks,[31] S. Schenk,[31] U. Uwer,[31] D. J. Bard,[32] W. Bhimji,[32] D. A. Bowerman,[32] P. D. Dauncey,[32] U. Egede,[32] R. L. Flack,[32] J. A. Nash,[32] M. B. Nikolich,[32] W. Panduro Vazquez,[32] P. K. Behera,[33] X. Chai,[33] M. J. Charles,[33] U. Mallik,[33] N. T. Meyer,[33] V. Ziegler,[33] J. Cochran,[34] H. B. Crawley,[34] L. Dong,[34] V. Eyges,[34] W. T. Meyer,[34] S. Prell,[34] E. I. Rosenberg,[34] A. E. Rubin,[34] A. V. Gritsan,[35] A. G. Denig,[36] M. Fritsch,[36] G. Schott,[36] N. Arnaud,[37] M. Davier,[37] G. Grosdidier,[37] A. Höcker,[37] V. Lepeltier,[37] F. Le Diberder,[37] A. M. Lutz,[37] A. Oyanguren,[37] S. Pruvot,[37] S. Rodier,[37] P. Roudeau,[37] M. H. Schune,[37] J. Serrano,[37] A. Stocchi,[37] W. F. Wang,[37] G. Wormser,[37] D. J. Lange,[38] D. M. Wright,[38] C. A. Chavez,[39] I. J. Forster,[39] J. R. Fry,[39] E. Gabathuler,[39] R. Gamet,[39] K. A. George,[39] D. E. Hutchcroft,[39] D. J. Payne,[39] K. C. Schofield,[39] C. Touramanis,[39] A. J. Bevan,[40] C. K. Clarke,[40] F. Di Lodovico,[40] W. Menges,[40] R. Sacco,[40] G. Cowan,[41] H. U. Flaecher,[41] D. A. Hopkins,[41] P. S. Jackson,[41] T. R. McMahon,[41] F. Salvatore,[41] A. C. Wren,[41] D. N. Brown,[42] C. L. Davis,[42] J. Allison,[43] N. R. Barlow,[43] R. J. Barlow,[43] Y. M. Chia,[43] C. L. Edgar,[43] G. D. Lafferty,[43] M. T. Naisbit,[43] J. C. Williams,[43] J. I. Yi,[43] C. Chen,[44] W. D. Hulsbergen,[44] A. Jawahery,[44] C. K. Lae,[44] D. A. Roberts,[44] G. Simi,[44] G. Blaylock,[45] C. Dallapiccola,[45] S. S. Hertzbach,[45] X. Li,[45] T. B. Moore,[45] S. Saremi,[45] H. Staengle,[45] R. Cowan,[46] G. Sciolla,[46] S. J. Sekula,[46] M. Spitznagel,[46] F. Taylor,[46] R. K. Yamamoto,[46] H. Kim,[47] S. E. Mclachlin,[47] P. M. Patel,[47]

Submitted to Physical Review Letters

Work supported in part by the US Department of Energy contract DE-AC02-76SF00515

S. H. Robertson,[47] A. Lazzaro,[48] V. Lombardo,[48] F. Palombo,[48] J. M. Bauer,[49] L. Cremaldi,[49] V. Eschenburg,[49] R. Godang,[49] R. Kroeger,[49] D. A. Sanders,[49] D. J. Summers,[49] H. W. Zhao,[49] S. Brunet,[50] D. Côté,[50] M. Simard,[50] P. Taras,[50] F. B. Viaud,[50] H. Nicholson,[51] N. Cavallo,[52,†] G. De Nardo,[52] F. Fabozzi,[52,†] C. Gatto,[52] L. Lista,[52] D. Monorchio,[52] P. Paolucci,[52] D. Piccolo,[52] C. Sciacca,[52] M. A. Baak,[53] G. Raven,[53] H. L. Snoek,[53] C. P. Jessop,[54] J. M. LoSecco,[54] G. Benelli,[55] L. A. Corwin,[55] K. K. Gan,[55] K. Honscheid,[55] D. Hufnagel,[55] P. D. Jackson,[55] H. Kagan,[55] R. Kass,[55] A. M. Rahimi,[55] J. J. Regensburger,[55] R. Ter-Antonyan,[55] Q. K. Wong,[55] N. L. Blount,[56] J. Brau,[56] R. Frey,[56] O. Igonkina,[56] J. A. Kolb,[56] M. Lu,[56] C. T. Potter,[56] R. Rahmat,[56] N. B. Sinev,[56] D. Strom,[56] J. Strube,[56] E. Torrence,[56] A. Gaz,[57] M. Margoni,[57] M. Morandin,[57] A. Pompili,[57] M. Posocco,[57] M. Rotondo,[57] F. Simonetto,[57] R. Stroili,[57] C. Voci,[57] M. Benayoun,[58] H. Briand,[58] J. Chauveau,[58] P. David,[58] L. Del Buono,[58] Ch. de la Vaissière,[58] O. Hamon,[58] B. L. Hartfiel,[58] Ph. Leruste,[58] J. Malclès,[58] J. Ocariz,[58] L. Roos,[58] G. Therin,[58] L. Gladney,[59] M. Biasini,[60] R. Covarelli,[60] C. Angelini,[61] G. Batignani,[61] S. Bettarini,[61] F. Bucci,[61] G. Calderini,[61] M. Carpinelli,[61] R. Cenci,[61] F. Forti,[61] M. A. Giorgi,[61] A. Lusiani,[61] G. Marchiori,[61] M. A. Mazur,[61] M. Morganti,[61] N. Neri,[61] E. Paoloni,[61] G. Rizzo,[61] J. J. Walsh,[61] M. Haire,[62] D. Judd,[62] D. E. Wagoner,[62] J. Biesiada,[63] N. Danielson,[63] P. Elmer,[63] Y. P. Lau,[63] C. Lu,[63] J. Olsen,[63] A. J. S. Smith,[63] A. V. Telnov,[63] F. Bellini,[64] G. Cavoto,[64] A. D'Orazio,[64] D. del Re,[64] E. Di Marco,[64] R. Faccini,[64] F. Ferrarotto,[64] F. Ferroni,[64] M. Gaspero,[64] L. Li Gioi,[64] M. A. Mazzoni,[64] S. Morganti,[64] G. Piredda,[64] F. Polci,[64] F. Safai Tehrani,[64] C. Voena,[64] M. Ebert,[65] H. Schröder,[65] R. Waldi,[65] T. Adye,[66] B. Franek,[66] E. O. Olaiya,[66] S. Ricciardi,[66] F. F. Wilson,[66] R. Aleksan,[67] S. Emery,[67] A. Gaidot,[67] S. F. Ganzhur,[67] G. Hamel de Monchenault,[67] W. Kozanecki,[67] M. Legendre,[67] G. Vasseur,[67] Ch. Yèche,[67] M. Zito,[67] X. R. Chen,[68] H. Liu,[68] W. Park,[68] M. V. Purohit,[68] J. R. Wilson,[68] M. T. Allen,[69] D. Aston,[69] R. Bartoldus,[69] P. Bechtle,[69] N. Berger,[69] R. Claus,[69] J. P. Coleman,[69] M. R. Convery,[69] J. C. Dingfelder,[69] J. Dorfan,[69] G. P. Dubois-Felsmann,[69] D. Dujmic,[69] W. Dunwoodie,[69] R. C. Field,[69] T. Glanzman,[69] S. J. Gowdy,[69] M. T. Graham,[69] P. Grenier,[69] V. Halyo,[69] C. Hast,[69] T. Hryn'ova,[69] W. R. Innes,[69] M. H. Kelsey,[69] P. Kim,[69] D. W. G. S. Leith,[69] S. Li,[69] S. Luitz,[69] V. Luth,[69] H. L. Lynch,[69] D. B. MacFarlane,[69] H. Marsiske,[69] R. Messner,[69] D. R. Muller,[69] C. P. O'Grady,[69] V. E. Ozcan,[69] A. Perazzo,[69] M. Perl,[69] T. Pulliam,[69] B. N. Ratcliff,[69] A. Roodman,[69] A. A. Salnikov,[69] R. H. Schindler,[69] J. Schwiening,[69] A. Snyder,[69] J. Stelzer,[69] D. Su,[69] M. K. Sullivan,[69] K. Suzuki,[69] S. K. Swain,[69] J. M. Thompson,[69] J. Va'vra,[69] N. van Bakel,[69] A. P. Wagner,[69] M. Weaver,[69] A. J. R. Weinstein,[69] W. J. Wisniewski,[69] M. Wittgen,[69] D. H. Wright,[69] H. W. Wulsin,[69] A. K. Yarritu,[69] K. Yi,[69] C. C. Young,[69] P. R. Burchat,[70] A. J. Edwards,[70] S. A. Majewski,[70] B. A. Petersen,[70] L. Wilden,[70] S. Ahmed,[71] M. S. Alam,[71] R. Bula,[71] J. A. Ernst,[71] V. Jain,[71] B. Pan,[71] M. A. Saeed,[71] F. R. Wappler,[71] S. B. Zain,[71] W. Bugg,[72] M. Krishnamurthy,[72] S. M. Spanier,[72] R. Eckmann,[73] J. L. Ritchie,[73] A. Satpathy,[73] C. J. Schilling,[73] R. F. Schwitters,[73] J. M. Izen,[74] X. C. Lou,[74] S. Ye,[74] F. Bianchi,[75] F. Gallo,[75] D. Gamba,[75] M. Bomben,[76] L. Bosisio,[76] C. Cartaro,[76] F. Cossutti,[76] G. Della Ricca,[76] S. Dittongo,[76] L. Lanceri,[76] L. Vitale,[76] V. Azzolini,[77] N. Lopez-March,[77] F. Martinez-Vidal,[77] Sw. Banerjee,[78] B. Bhuyan,[78] C. M. Brown,[78] D. Fortin,[78] K. Hamano,[78] R. Kowalewski,[78] I. M. Nugent,[78] J. M. Roney,[78] R. J. Sobie,[78] J. J. Back,[79] P. F. Harrison,[79] T. E. Latham,[79] G. B. Mohanty,[79] M. Pappagallo,[79,‡] H. R. Band,[80] X. Chen,[80] B. Cheng,[80] S. Dasu,[80] M. Datta,[80] K. T. Flood,[80] J. J. Hollar,[80] P. E. Kutter,[80] B. Mellado,[80] A. Mihalyi,[80] Y. Pan,[80] M. Pierini,[80] R. Prepost,[80] S. L. Wu,[80] Z. Yu,[80] and H. Neal[81]

(The *BABAR* Collaboration)

[1]*Laboratoire de Physique des Particules, IN2P3/CNRS et Université de Savoie, F-74941 Annecy-Le-Vieux, France*
[2]*Universitat de Barcelona, Facultat de Fisica, Departament ECM, E-08028 Barcelona, Spain*
[3]*Università di Bari, Dipartimento di Fisica and INFN, I-70126 Bari, Italy*
[4]*Institute of High Energy Physics, Beijing 100039, China*
[5]*University of Bergen, Institute of Physics, N-5007 Bergen, Norway*
[6]*Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA*
[7]*University of Birmingham, Birmingham, B15 2TT, United Kingdom*
[8]*Ruhr Universität Bochum, Institut für Experimentalphysik 1, D-44780 Bochum, Germany*
[9]*University of Bristol, Bristol BS8 1TL, United Kingdom*
[10]*University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1*
[11]*Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom*
[12]*Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia*
[13]*University of California at Irvine, Irvine, California 92697, USA*
[14]*University of California at Los Angeles, Los Angeles, California 90024, USA*
[15]*University of California at Riverside, Riverside, California 92521, USA*
[16]*University of California at San Diego, La Jolla, California 92093, USA*

[17]University of California at Santa Barbara, Santa Barbara, California 93106, USA
[18]University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA
[19]California Institute of Technology, Pasadena, California 91125, USA
[20]University of Cincinnati, Cincinnati, Ohio 45221, USA
[21]University of Colorado, Boulder, Colorado 80309, USA
[22]Colorado State University, Fort Collins, Colorado 80523, USA
[23]Universität Dortmund, Institut für Physik, D-44221 Dortmund, Germany
[24]Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany
[25]Laboratoire Leprince-Ringuet, CNRS/IN2P3, Ecole Polytechnique, F-91128 Palaiseau, France
[26]University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom
[27]Università di Ferrara, Dipartimento di Fisica and INFN, I-44100 Ferrara, Italy
[28]Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy
[29]Università di Genova, Dipartimento di Fisica and INFN, I-16146 Genova, Italy
[30]Harvard University, Cambridge, Massachusetts 02138, USA
[31]Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany
[32]Imperial College London, London, SW7 2AZ, United Kingdom
[33]University of Iowa, Iowa City, Iowa 52242, USA
[34]Iowa State University, Ames, Iowa 50011-3160, USA
[35]Johns Hopkins University, Baltimore, Maryland 21218, USA
[36]Universität Karlsruhe, Institut für Experimentelle Kernphysik, D-76021 Karlsruhe, Germany
[37]Laboratoire de l'Accélérateur Linéaire, IN2P3/CNRS et Université Paris-Sud 11,
Centre Scientifique d'Orsay, B. P. 34, F-91898 ORSAY Cedex, France
[38]Lawrence Livermore National Laboratory, Livermore, California 94550, USA
[39]University of Liverpool, Liverpool L69 7ZE, United Kingdom
[40]Queen Mary, University of London, E1 4NS, United Kingdom
[41]University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom
[42]University of Louisville, Louisville, Kentucky 40292, USA
[43]University of Manchester, Manchester M13 9PL, United Kingdom
[44]University of Maryland, College Park, Maryland 20742, USA
[45]University of Massachusetts, Amherst, Massachusetts 01003, USA
[46]Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Massachusetts 02139, USA
[47]McGill University, Montréal, Québec, Canada H3A 2T8
[48]Università di Milano, Dipartimento di Fisica and INFN, I-20133 Milano, Italy
[49]University of Mississippi, University, Mississippi 38677, USA
[50]Université de Montréal, Physique des Particules, Montréal, Québec, Canada H3C 3J7
[51]Mount Holyoke College, South Hadley, Massachusetts 01075, USA
[52]Università di Napoli Federico II, Dipartimento di Scienze Fisiche and INFN, I-80126, Napoli, Italy
[53]NIKHEF, National Institute for Nuclear Physics and High Energy Physics, NL-1009 DB Amsterdam, The Netherlands
[54]University of Notre Dame, Notre Dame, Indiana 46556, USA
[55]Ohio State University, Columbus, Ohio 43210, USA
[56]University of Oregon, Eugene, Oregon 97403, USA
[57]Università di Padova, Dipartimento di Fisica and INFN, I-35131 Padova, Italy
[58]Laboratoire de Physique Nucléaire et de Hautes Energies,
IN2P3/CNRS, Université Pierre et Marie Curie-Paris6,
Université Denis Diderot-Paris7, F-75252 Paris, France
[59]University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA
[60]Università di Perugia, Dipartimento di Fisica and INFN, I-06100 Perugia, Italy
[61]Università di Pisa, Dipartimento di Fisica, Scuola Normale Superiore and INFN, I-56127 Pisa, Italy
[62]Prairie View A&M University, Prairie View, Texas 77446, USA
[63]Princeton University, Princeton, New Jersey 08544, USA
[64]Università di Roma La Sapienza, Dipartimento di Fisica and INFN, I-00185 Roma, Italy
[65]Universität Rostock, D-18051 Rostock, Germany
[66]Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom
[67]DSM/Dapnia, CEA/Saclay, F-91191 Gif-sur-Yvette, France
[68]University of South Carolina, Columbia, South Carolina 29208, USA
[69]Stanford Linear Accelerator Center, Stanford, California 94309, USA
[70]Stanford University, Stanford, California 94305-4060, USA
[71]State University of New York, Albany, New York 12222, USA
[72]University of Tennessee, Knoxville, Tennessee 37996, USA
[73]University of Texas at Austin, Austin, Texas 78712, USA
[74]University of Texas at Dallas, Richardson, Texas 75083, USA
[75]Università di Torino, Dipartimento di Fisica Sperimentale and INFN, I-10125 Torino, Italy
[76]Università di Trieste, Dipartimento di Fisica and INFN, I-34127 Trieste, Italy
[77]IFIC, Universitat de Valencia-CSIC, E-46071 Valencia, Spain

[78] University of Victoria, Victoria, British Columbia, Canada V8W 3P6
[79] Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom
[80] University of Wisconsin, Madison, Wisconsin 53706, USA
[81] Yale University, New Haven, Connecticut 06511, USA
(Dated: February 9, 2007)

A search for lepton flavor violating decays of the τ lepton to a lighter mass lepton and a pseudoscalar meson has been performed using $339\,\mathrm{fb}^{-1}$ of e^+e^- annihilation data collected at a center-of-mass energy near 10.58 GeV by the *BABAR* detector at the SLAC PEP-II storage ring. No evidence of signal has been found, and upper limits on the branching fractions are set at 10^{-7} level.

PACS numbers: 13.35.Dx, 14.60.Fg, 11.30.Hv

The recent discovery of large neutrino mixing [1] suggests that lepton flavor violation (LFV) occurs. Charged LFV decays have not yet been observed, although they have long been identified as unambiguous signature of new physics. Neutrinoless decays like $\tau^\pm \to \ell^\pm P^0$, where $\ell = e, \mu$ and $P^0 = \pi^0, \eta, \eta'$, are likely candidates for LFV [2, 3], which could be induced by potentially large mixing between the supersymmetric partners of the leptons and is further enhanced by color factors associated with these semi-leptonic decays. Some models with heavy Dirac neutrinos [4, 5], two Higgs doublet models, R-parity violating supersymmetric models, and flavor changing Z' models with non-universal couplings [6] allow for observable parameter space of new physics [7], while respecting the existing experimental bounds [8].

The results presented here use an integrated luminosity Ł= $339\,\mathrm{fb}^{-1}$ collected at a center-of-mass (CM) energy, $\sqrt{s}$, near 10.58 GeV by the *BABAR* detector at the SLAC PEP-II e^+e^- asymmetric-energy storage ring. Details of the *BABAR* detector are described elsewhere [9].

The signature of the signal process is the presence of an ℓP^0 pair having an invariant mass consistent with $m_\tau = 1.777\,\mathrm{GeV}/c^2$ [10] and a total energy equal to $\sqrt{s}/2$ in the CM frame, along with other particles in $e^+e^- \to \tau^+\tau^-$ events having properties consistent with a τ lepton decay. Two neutral decay modes ($\pi^0 \to \gamma\gamma$ and $\eta \to \gamma\gamma$) and three charged decay modes [$\eta \to \pi^+\pi^-\pi^0$ ($\pi^0 \to \gamma\gamma$), $\eta' \to \pi^+\pi^-\eta$ ($\eta \to \gamma\gamma$), and $\eta' \to \rho^0\gamma$] are reconstructed. Signal events are simulated with the `KK2F` [11] Monte Carlo (MC) program, where the $\tau^\pm \to \ell^\pm P^0$ decays according to two body phase space, while the other τ decays according to measured branching fractions [12] simulated with `TAUOLA` [13]. $\mu^+\mu^-$ and $\tau^+\tau^-$ background processes are generated using `KK2F` and `TAUOLA`, and $q\overline{q}$ processes are generated using `EVTGEN` [14] and `JETSET` [15]. Radiative corrections are simulated using `PHOTOS` [16]. The detector response is simulated with `GEANT4` [17]. The MC events are used for the optimization and systematic studies of the signal efficiencies, and for determination of the background shapes. Estimates of the rates for the backgrounds are derived directly from the data.

Events with two or four well reconstructed tracks and zero total charge are selected. Tracks are rejected if they are consistent with coming from photon conversions. An event is divided into two hemispheres ("signal"- and "tag"- sides) in the CM frame by a plane perpendicular to the thrust axis [18], calculated using all observed particles.

The signal-side hemisphere is required to contain one or three tracks and two photon candidates with energy $E_\gamma > 50\,\mathrm{MeV}$ for the $\pi^0 \to \gamma\gamma$, $\eta \to \pi^+\pi^-\pi^0$ ($\pi^0 \to \gamma\gamma$) and $\eta' \to \pi^+\pi^-\eta$ ($\eta \to \gamma\gamma$) channels, and $E_\gamma > 100\,\mathrm{MeV}$ for the $\eta \to \gamma\gamma$ channel. For the $\eta' \to \rho^0\gamma$ channel, the single photon candidate is required to have $E_\gamma > 100\,\mathrm{MeV}$. Events with additional photon candidates in the signal hemisphere with $E_\gamma > 100\,\mathrm{MeV}$ are rejected.

The P^0 candidates are reconstructed in the following mass windows: $m(\pi^0 \to \gamma\gamma) \in [0.115,\ 0.150]\ \mathrm{GeV}/c^2$, $m(\eta \to \gamma\gamma) \in [0.515,\ 0.565]\ \mathrm{GeV}/c^2$, $m(\eta \to \pi^+\pi^-\pi^0) \in [0.537,\ 0.558]\ \mathrm{GeV}/c^2$, $m(\eta' \to \pi^+\pi^-\eta) \in [0.950,\ 0.965]\ \mathrm{GeV}/c^2$, $m(\eta' \to \rho^0\gamma) \in [0.940,\ 0.970]\ \mathrm{GeV}/c^2$, and $m(\rho^0 \to \pi^+\pi^-) \in [0.600,\ 0.900]\ \mathrm{GeV}/c^2$. To reduce combinatorial backgrounds, the momentum of P^0 is required to satisfy: $p_{\pi^0} > 0.5\,\mathrm{GeV}/c$ for $\tau^\pm \to e^\pm\pi^0$, $p_{\pi^0} > 1.5\,\mathrm{GeV}/c$ for $\tau^\pm \to \mu^\pm\pi^0$, $p_\eta > 1.0\,\mathrm{GeV}/c$ for $\tau^\pm \to e^\pm\eta$ ($\eta \to \gamma\gamma$), $p_\eta > 1.4\,\mathrm{GeV}/c$ for $\tau^\pm \to \mu^\pm\eta$ ($\eta \to \gamma\gamma$), $p_\eta > 1.2\,\mathrm{GeV}/c$ for $\tau^\pm \to \mu^\pm\eta$ ($\eta \to \pi^+\pi^-\pi^0$, $\pi^0 \to \gamma\gamma$) and $p_{\eta'} > 1.3\,\mathrm{GeV}/c$ for $\tau^\pm \to \mu^\pm\eta'$ ($\eta' \to \rho^0\gamma$) decays.

The track unassociated with any of the P^0 daughters is required to have a momentum $> 0.5\,\mathrm{GeV}/c$ and is identified as an electron or muon, but not as a kaon, using standard *BABAR* particle identification techniques [19]. In the case of a charged P^0 decay, this criteria is applied on the track that combines with the one having opposite-sign charge and the photon candidate(s) to give an invariant mass farthest from the nominal P^0 mass [12]. This provides the correct pairing for $> 99.7\%$ of selected signal MC events after particle-identification requirements.

The origin of the photon(s) is assigned to the point of closest approach of the lepton track to the e^+e^- collision axis for neutral P^0 decays, or to the common vertex in the signal-side hemisphere for the charged P^0 decays. The P^0 momentum is kinematically fitted with its respective mass constraints, and combined with the lepton track to form the signal τ candidate. An event is accepted based upon the closeness of the signal τ candidate to m_τ.

Signal decays are identified by two kinematic variables: the beam-energy constrained τ mass m_{EC} and

$\Delta E \equiv E_\ell + E_{P^0} - \sqrt{s}/2$, where E_ℓ and E_{P^0} are the respective energies in the CM frame. These two variables are independent apart from small correlations arising from initial and final state radiation. For signal events, the reconstructed peak positions of the $m_{\rm EC}$ distribution agree very well with m_τ, while those of ΔE vary between -5 to -23 MeV. The shift from zero in the ΔE peak comes from mis-calibration of the measured photon energy. The resolutions of the $m_{\rm EC}$ and ΔE distributions for the signal events are presented in Table I. Events in the data within a $\pm 3\sigma$ rectangular box centered around the signal MC peak positions are excluded until all optimization and systematic studies of the selection criteria have been completed. The selection is optimized to yield the smallest expected upper limit [20] in a background-only hypothesis for observing events inside the $\pm 2\sigma$ rectangular signal box around the signal MC peak positions shown in Fig. 1.

The dominant backgrounds are from $\tau \to e\nu\overline{\nu}\gamma$ or $\tau \to \rho\nu$ decays in $\tau^+\tau^-$ events, with additional contributions from Bhabha, di-muon and $q\overline{q}$ processes. The backgrounds are higher for searches with muons, due to misidentification of a π track as a μ candidate. Another source of background is the mis-reconstruction of η and π^0 candidates.

Non-τ backgrounds with radiation along the beam directions are suppressed by requiring the polar angle of the missing momentum to lie between -0.76 and 0.92. The total CM momentum of all tracks and photon candidates on the tag-side is required to be less than 4.75 GeV/c.

A tag-side hemisphere containing a single track is classified as e-tag, μ-tag or h-tag if the track is exclusively identified as an electron, muon, or neither, respectively. For these tags, the total neutral CM energy in the hemisphere ΣE_γ^{CM} is required to be less than 0.2 GeV, and the invariant mass $m_{\rm tag}$, calculated using all observed charged and neutral particles, to be less than 0.4 GeV/c^2. For $\tau^\pm \to e^\pm P^0$ channels, the data events in e-tag are used as a control sample to estimate the Bhabha background, and are not included in the final selection. If the track is neither an electron nor a muon, $\Sigma E_\gamma^{CM} > 0.2$ GeV and $m_{\rm tag} \in [0.6,\, 1.3]$ GeV/c^2, the event is classified as a ρ-tag. For searches of neutral P^0 decay modes, events with three tracks in the tag-side with $m_{\rm tag} \in [0.9,\, 1.6]$ GeV/c^2 are also allowed.

Taking the direction of the tag-side τ to be opposite the signal candidate, all tracks and photon candidates in the tag-side hemisphere are used to calculate the invariant mass squared of the tag-side missing momentum (m_ν^2). To reduce non-τ backgrounds for $\tau^\pm \to e^\pm\pi^0$, $\tau^\pm \to e^\pm\eta$ ($\eta \to \gamma\gamma$) searches, $(m_\nu^2/1.8\,{\rm GeV}^2/c^4) - \ln(2\times p^T_{\rm miss}/\sqrt{s})/2.0$ is required to be less than unity [21], where p^T_{miss} is the component of the missing momentum transverse to the collision axis. For the other searches, $-\ln(2\times p^T_{\rm miss}/\sqrt{s})$ is required to be less than 2.5, except for $\tau^\pm \to e^\pm\eta$ ($\eta \to \pi^+\pi^-\pi^0$) and $\tau^\pm \to \mu^\pm\eta'$ ($\eta' \to \pi^+\pi^-\eta$) searches, where very few events are expected.

To focus on selected signal-like events, a Grand Side Band (GSB) is defined in the $m_{\rm EC}$ vs. ΔE plane as: $m_{\rm EC} \in [1.5, 2.0]$ GeV/c^2 and $\Delta E \in [-0.8, 0.4]$ GeV. With electrons as the lepton track, 22, 18, 4, 1 and 30 events survive in the GSB for $\pi^0 \to \gamma\gamma$, $\eta \to \gamma\gamma$, $\eta \to \pi^+\pi^-\pi^0$, $\eta' \to \pi^+\pi^-\eta$ and $\eta' \to \rho^0\gamma$ channels, and 311, 69, 24, 24 and 285 events survive for the corresponding channels with muons as the lepton track, as shown by dots in Fig. 1. Also shown are the shaded regions containing 68% of the selected signal MC events inside the GSB.

The number of expected background events in the signal box is extracted from an unbinned maximum likelihood fit to the distributions of $m_{\rm EC}$ and ΔE in data inside the non-blinded parts of the GSB, using two-dimensional probability density functions (PDF) for e^+e^-, $\mu^+\mu^-$, $\tau^+\tau^-$ and $q\overline{q}$ backgrounds. The kernel of the PDFs are estimated [22] from the data control samples for e^+e^-, and respective MC events for the others.

The dominant contribution to the uncertainty in background estimation arises from the statistical precision on the selected data sample inside the non-blinded parts of the GSB, or from the variation of background components within $\pm 1\sigma$ from their fitted values. The observed and expected events from the fit to the data inside the $\pm 3\sigma$ to $\pm 11\sigma$ annular boxes and the signal boxes are shown in Table I, which confirm good modeling of the backgrounds in data and show no evidence of signal.

The largest systematic uncertainties in the signal reconstruction efficiency are due to the signal track momentum and the photon energy scale and resolution, estimated by varying the peak position and resolution of the $m_{\rm EC}$ and ΔE distributions. The errors associated with the modeling of each selection variable are estimated from the relative change in signal efficiency when varying the selection criteria by the difference between the data and MC events in the mean of that variable. Other sources of systematic uncertainties include those arising from trigger inefficiencies, tracking and neutral energy reconstruction efficiencies, the signal lepton identification, beam-energy scale and spread, luminosity estimation and $e^+e^- \to \tau^+\tau^-$ cross-section ($\sigma_{\tau\tau} = 0.89 \pm 0.02$ nb) [23]. About 2.4 million MC events are used per channel, resulting in a negligible systematic uncertainty due to MC statistics. Although the signal MC events have been modeled using a two body phase space model, the results obtained in this analysis are insensitive to this assumption as demonstrated by considering the two extreme cases of a $V-A$ and a $V+A$ form of interaction.

The upper limits for $\tau^\pm \to \ell^\pm P^0$ decays are calculated using $\mathcal{B}^{90}_{UL} = N^{90}_{UL}/(2Ł\sigma_{\tau\tau}\mathcal{B}\varepsilon)$, where N^{90}_{UL} is the 90% confidence level (C.L.) upper limit on the number of signal events inside the signal box, $\mathcal{B}$ and ε are the branching fraction [12] and reconstruction efficiency of the signal decay mode under consideration. To obtain a combined

FIG. 1: Selected data (dots) and 68% of signal MC events (shaded region) inside the GSB region, and the ±2σ signal box.

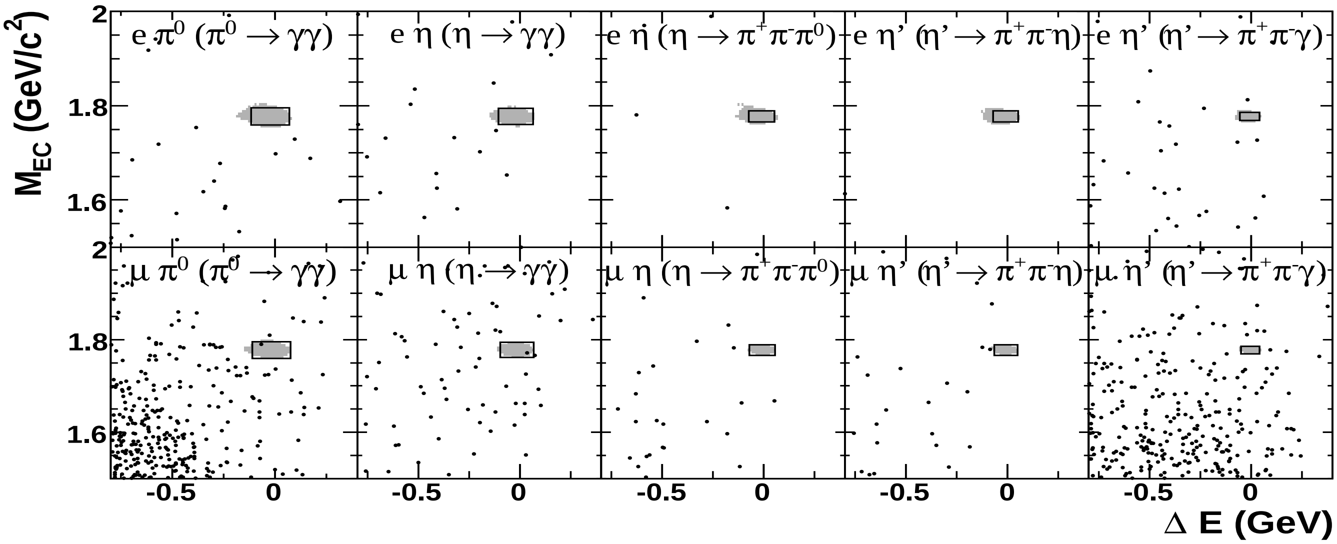


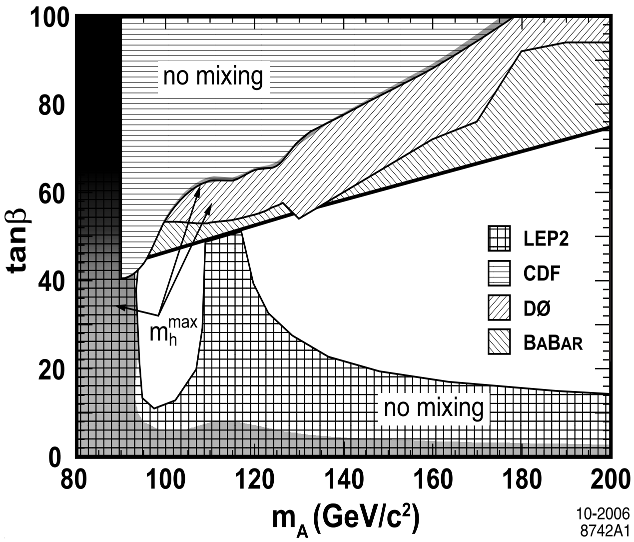
TABLE I: The $m_{\rm EC}$ and ΔE resolutions for the signal MC events, the number of observed (obs.) and expected (exp.) events inside $\pm3\sigma$ to $\pm11\sigma$ boxes and $\pm2\sigma$ box, the branching fractions ($\mathcal{B}$), the efficiencies (ε), and the 90% C.L. upper limits (UL).

Decay modes	$\sigma(m_{\rm EC})$	$\sigma(\Delta E)$	$\pm3\sigma$ to $\pm11\sigma$ box		$\pm2\sigma$ box		$\mathcal{B}$	ε	UL ($\times10^{-7}$)	
	MeV/c^2	MeV	obs.	exp.	obs.	exp.	(%)	(%)	obs.	exp.
$\tau^\pm\to e^\pm\pi^0$ ($\pi^0\to\gamma\gamma$)	9.1	46.4	4	5.37±1.14	0	0.17±0.04	98.80±0.03	2.83±0.25	1.3	1.4
$\tau^\pm\to\mu^\pm\pi^0$ ($\pi^0\to\gamma\gamma$)	9.0	46.4	43	40.68±4.32	1	1.33±0.15	98.80±0.03	4.75±0.37	1.1	1.1
$\tau^\pm\to e^\pm\eta$ ($\eta\to\gamma\gamma$)	8.5	42.6	4	4.99±1.18	0	0.20±0.05	39.38±0.26	3.59±0.24	2.5	2.8
$\tau^\pm\to e^\pm\eta$ ($\eta\to\pi^+\pi^-\pi^0$)	5.9	31.4	0	0.64±0.32	0	0.02±0.01	22.43±0.40	3.17±0.32	5.4	5.5
$\tau^\pm\to e^\pm\eta$					0	0.22±0.05	$\mathcal{B}\varepsilon$ = 2.12±0.20 (%)		1.6	1.9
$\tau^\pm\to\mu^\pm\eta$ ($\eta\to\gamma\gamma$)	8.3	40.8	20	17.36±2.12	1	0.67±0.08	39.38±0.26	7.03±0.53	1.9	1.6
$\tau^\pm\to\mu^\pm\eta$ ($\eta\to\pi^+\pi^-\pi^0$)	5.6	31.0	3	2.01±0.41	0	0.08±0.02	22.43±0.40	3.67±0.32	4.5	4.8
$\tau^\pm\to\mu^\pm\eta$					1	0.75±0.08	$\mathcal{B}\varepsilon$ = 3.59±0.41 (%)		1.5	1.3
$\tau^\pm\to e^\pm\eta'$ ($\eta'\to\pi^+\pi^-\eta$)	5.9	31.0	0	0.14±0.14	0	0.01±0.01	17.52±0.56	3.75±0.27	5.8	5.9
$\tau^\pm\to e^\pm\eta'$ ($\eta'\to\rho^0\gamma$)	4.4	24.3	2	2.97±0.54	0	0.11±0.03	29.40±0.90	2.98±0.28	4.2	4.5
$\tau^\pm\to e^\pm\eta'$					0	0.12±0.03	$\mathcal{B}\varepsilon$ = 1.53±0.16 (%)		2.4	2.6
$\tau^\pm\to\mu^\pm\eta'$ ($\eta'\to\pi^+\pi^-\eta$)	5.6	29.1	1	2.42±0.47	0	0.07±0.02	17.52±0.56	5.87±0.46	3.6	3.8
$\tau^\pm\to\mu^\pm\eta'$ ($\eta'\to\rho^0\gamma$)	4.1	23.1	13	11.06±0.65	0	0.42±0.03	29.40±0.90	3.90±0.46	2.7	3.7
$\tau^\pm\to\mu^\pm\eta'$					0	0.49±0.04	$\mathcal{B}\varepsilon$ = 2.18±0.26 (%)		1.4	2.0

upper limit with η and η' decays, the observed and expected background events and the signal efficiencies are added using $\mathcal{B}\varepsilon = (\mathcal{B}_1\times\varepsilon_1+\mathcal{B}_2\times\varepsilon_2)$, where $\mathcal{B}_1$, $\mathcal{B}_2$ are the respective branching fractions and ε_1 and ε_2 are the corresponding efficiencies. This combination takes into account correlated uncertainties from the track and neutral cluster reconstruction efficiency and the signal lepton identification. The observed and the expected upper limits at 90% C.L. are presented in Table I including all contributions from systematic uncertainties [24, 25]. These limits present up to a factor of four improvement over the previously published results [8], except for $\tau^\pm\to\mu^\pm\eta$ search, where the limit is similar.

Mixing between left-handed smuons and staus allows one to translate the $\tau^\pm\to\mu^\pm\eta$ limit to an exclusion plot in the $\tan\beta$ vs. m_A plane [3], where $\tan\beta$ is the ratio of the vacuum expectation values of the two Higgs doublets and m_A is the mass of the pseudoscalar Higgs. The excluded regions at 95% C.L. from this $\tau^\pm\to\mu^\pm\eta$ search ($< 1.9\times10^{-7}$) with right-handed neutrino mass $= 10^{14}$ GeV/c^2 introduced via the seesaw mechanism are shown in Fig. 2. This result is competitive with those obtained from the direct searches for Higgs $\to b\bar{b}$, $\tau^+\tau^-$ decays by CDF [26] and D0 [27], and complementary

FIG. 2: Excluded regions in $\tan\beta$ vs. m_A plane (see text).



to the region excluded by the LEP experiments with a top quark mass of 174.3 GeV/c^2 [28], for two common scenarios of stop-mixing benchmark models [29]: $m_h^{\max}$ and no-mixing obtained with the Higgs mass parameter $\mu = -200\,\mathrm{GeV}/c^2$ shown by darker and lighter shaded regions respectively.

We are grateful for the excellent luminosity and machine conditions provided by our PEP-II colleagues, and for the substantial dedicated effort from the computing organizations that support *BABAR*. The collaborating institutions wish to thank SLAC for its support and kind hospitality. This work is supported by DOE and NSF (USA), NSERC (Canada), IHEP (China), CEA and CNRS-IN2P3 (France), BMBF and DFG (Germany), INFN (Italy), FOM (The Netherlands), NFR (Norway), MIST (Russia), MEC (Spain), and PPARC (United Kingdom). Individuals have received support from the Marie Curie EIF (European Union) and the A. P. Sloan Foundation.

---

* Also with Università di Perugia, Dipartimento di Fisica, Perugia, Italy
† Also with Università della Basilicata, Potenza, Italy
‡ Also with IPPP, Physics Department, Durham University, Durham DH1 3LE, United Kingdom

[1] B. T. Cleveland *et al.*, Astrophys. J. **496**, 505 (1998); Y. Fukuda *et al.* [Super-Kamiokande Collab.], Phys. Rev. Lett. **81**, 1562 (1998); Q. R. Ahmad *et al.* [SNO Collab.], Phys. Rev. Lett. **89**, 011301 (2002); M. H. Ahn *et al.* [K2K Collab.], Phys. Rev. Lett. **90**, 041801 (2003).
[2] I. Hinchliffe and F. E. Paige, Phys. Rev. D **63**, 115006 (2001); J. Hisano, T. Moroi, K. Tobe and M. Yamaguchi, Phys. Rev. D **53**, 2442 (1996).
[3] M. Sher, Phys. Rev. D **66**, 057301 (2002).
[4] M. C. Gonzalez-Garcia and J. W. F. Valle, Mod. Phys. Lett. A **7**, 477 (1992).
[5] A. Ilakovac, Phys. Rev. D **62**, 036010 (2000).
[6] W. j. Li, Y. d. Yang and X. d. Zhang, Phys. Rev. D **73**, 073005 (2006).
[7] D. Black, T. Han, H. J. He and M. Sher, Phys. Rev. D **66**, 053002 (2002).
[8] Y. Enari *et al.* [Belle Collab.], Phys. Rev. Lett. **93**, 081803 (2004); Y. Enari *et al.* [Belle Collab.], Phys. Lett. B **622**, 218 (2005).
[9] B. Aubert *et al.* [*BABAR* Collab.], Nucl. Instrum. Methods Phys. Res., Sect. A **479**, 1 (2002).
[10] J. Z. Bai *et al.* [BES Collab.], Phys. Rev. D **53**, 20 (1996).
[11] B. F. Ward, S. Jadach, and Z. Was, Nucl. Phys. Proc. Suppl. **116**, 73 (2003).
[12] W. M. Yao *et al.* [Particle Data Group], J. Phys. G **33** (2006) 1.
[13] S. Jadach, Z. Was, R. Decker, and J. H. Kuhn, Comput. Phys. Commun. **76**, 361 (1993).
[14] D. J. Lange, Nucl. Instrum. Methods Phys. Res., Sect. A **462**, 152 (2001).
[15] T. Sjöstrand, Comput. Phys. Commun. **82**, 74 (1994).
[16] P. Golonka and Z. Was, Eur. Phys. J. C **45**, 97 (2006).
[17] S. Agostinelli *et al.* [GEANT4 Collab.], Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).
[18] S. Brandt *et al.*, Phys. Lett. **12** 57 (1964); E. Farhi, Phys. Rev. Lett. **39** 1587 (1977).
[19] B. Aubert *et al.* [*BABAR* Collab.], Phys. Rev. D **66**, 032003 (2002).
[20] G. J. Feldman and R. D. Cousins, Phys. Rev. D **57**, 3873 (1998).
[21] B. Aubert *et al.* [*BABAR* Collab.], Phys. Rev. Lett. **96**, 041801 (2006).
[22] K. Cranmer, Comput. Phys. Commun. **136**, 198 (2001).
[23] A 0.02 nb uncertainty is estimated by comparisons of the cross section between the generators `KK2F` [11] and `KORALB`: S. Jadach and Z. Was, Comput. Phys. Commun. **85**, 453 (1995).
[24] R. D. Cousins and V. L. Highland, Nucl. Instrum. Methods Phys. Res., Sect. A **320**, 331 (1992).
[25] R. Barlow, Comput. Phys. Commun. **149**, 97 (2002).
[26] A. A. Affolder *et al.* [CDF Collab.], Phys. Rev. Lett. **86**, 4472 (2001); A. Abulencia *et al.* [CDF Collab.], Phys. Rev. Lett. **96**, 011802 (2006).
[27] V. M. Abazov *et al.* [D0 Collab.], Phys. Rev. Lett. **95**, 151801 (2005); V. M. Abazov *et al.* [D0 Collab.], Phys. Rev. Lett. **97**, 121802 (2006).
[28] S. Schael *et al.* [ALEPH, DELPHI, L3 and OPAL Collab.], Eur. Phys. J. C **47**, 547 (2006).
[29] M. Carena, S. Heinemeyer, C. E. M. Wagner and G. Weiglein, hep-ph/9912223, *idem.* Eur. Phys. Journ. **C26**, 601 (2003).