BABAR-CONF-07/004
SLAC-PUB-12675
arXiv:0707.2758
July 2007

Measurement of the Semileptonic Decays $B \to D\tau^-\overline{\nu}_\tau$ and $B \to D^*\tau^-\overline{\nu}_\tau$

B. Aubert,[1] M. Bona,[1] D. Boutigny,[1] Y. Karyotakis,[1] J. P. Lees,[1] V. Poireau,[1] X. Prudent,[1] V. Tisserand,[1] A. Zghiche,[1] J. Garra Tico,[2] E. Grauges,[2] L. Lopez,[3] A. Palano,[3] M. Pappagallo,[3] G. Eigen,[4] B. Stugu,[4] L. Sun,[4] G. S. Abrams,[5] M. Battaglia,[5] D. N. Brown,[5] J. Button-Shafer,[5] R. N. Cahn,[5] Y. Groysman,[5] R. G. Jacobsen,[5] J. A. Kadyk,[5] L. T. Kerth,[5] Yu. G. Kolomensky,[5] G. Kukartsev,[5] D. Lopes Pegna,[5] G. Lynch,[5] L. M. Mir,[5] T. J. Orimoto,[5] I. L. Osipenkov,[5] M. T. Ronan,[5, *] K. Tackmann,[5] T. Tanabe,[5] W. A. Wenzel,[5] P. del Amo Sanchez,[6] C. M. Hawkes,[6] A. T. Watson,[6] T. Held,[7] H. Koch,[7] M. Pelizaeus,[7] T. Schroeder,[7] M. Steinke,[7] D. Walker,[8] D. J. Asgeirsson,[9] T. Cuhadar-Donszelmann,[9] B. G. Fulsom,[9] C. Hearty,[9] T. S. Mattison,[9] J. A. McKenna,[9] A. Khan,[10] M. Saleem,[10] L. Teodorescu,[10] V. E. Blinov,[11] A. D. Bukin,[11] V. P. Druzhinin,[11] V. B. Golubev,[11] A. P. Onuchin,[11] S. I. Serednyakov,[11] Yu. I. Skovpen,[11] E. P. Solodov,[11] K. Yu. Todyshev,[11] M. Bondioli,[12] S. Curry,[12] I. Eschrich,[12] D. Kirkby,[12] A. J. Lankford,[12] P. Lund,[12] M. Mandelkern,[12] E. C. Martin,[12] D. P. Stoker,[12] S. Abachi,[13] C. Buchanan,[13] S. D. Foulkes,[14] J. W. Gary,[14] F. Liu,[14] O. Long,[14] B. C. Shen,[14] L. Zhang,[14] H. P. Paar,[15] S. Rahatlou,[15] V. Sharma,[15] J. W. Berryhill,[16] C. Campagnari,[16] A. Cunha,[16] B. Dahmes,[16] T. M. Hong,[16] D. Kovalskyi,[16] J. D. Richman,[16] T. W. Beck,[17] A. M. Eisner,[17] C. J. Flacco,[17] C. A. Heusch,[17] J. Kroseberg,[17] W. S. Lockman,[17] T. Schalk,[17] B. A. Schumm,[17] A. Seiden,[17] M. G. Wilson,[17] L. O. Winstrom,[17] E. Chen,[18] C. H. Cheng,[18] F. Fang,[18] D. G. Hitlin,[18] I. Narsky,[18] T. Piatenko,[18] F. C. Porter,[18] R. Andreassen,[19] G. Mancinelli,[19] B. T. Meadows,[19] K. Mishra,[19] M. D. Sokoloff,[19] F. Blanc,[20] P. C. Bloom,[20] S. Chen,[20] W. T. Ford,[20] J. F. Hirschauer,[20] A. Kreisel,[20] M. Nagel,[20] U. Nauenberg,[20] A. Olivas,[20] J. G. Smith,[20] K. A. Ulmer,[20] S. R. Wagner,[20] J. Zhang,[20] A. M. Gabareen,[21] A. Soffer,[21] W. H. Toki,[21] R. J. Wilson,[21] F. Winklmeier,[21] D. D. Altenburg,[22] E. Feltresi,[22] A. Hauke,[22] H. Jasper,[22] J. Merkel,[22] A. Petzold,[22] B. Spaan,[22] K. Wacker,[22] V. Klose,[23] M. J. Kobel,[23] H. M. Lacker,[23] W. F. Mader,[23] R. Nogowski,[23] J. Schubert,[23] K. R. Schubert,[23] R. Schwierz,[23] J. E. Sundermann,[23] A. Volk,[23] D. Bernard,[24] G. R. Bonneaud,[24] E. Latour,[24] V. Lombardo,[24] Ch. Thiebaux,[24] M. Verderi,[24] P. J. Clark,[25] W. Gradl,[25] F. Muheim,[25] S. Playfer,[25] A. I. Robertson,[25] J. E. Watson,[25] Y. Xie,[25] M. Andreotti,[26] D. Bettoni,[26] C. Bozzi,[26] R. Calabrese,[26] A. Cecchi,[26] G. Cibinetto,[26] P. Franchini,[26] E. Luppi,[26] M. Negrini,[26] A. Petrella,[26] L. Piemontese,[26] E. Prencipe,[26] V. Santoro,[26] F. Anulli,[27] R. Baldini-Ferroli,[27] A. Calcaterra,[27] R. de Sangro,[27] G. Finocchiaro,[27] S. Pacetti,[27] P. Patteri,[27] I. M. Peruzzi,[27, †] M. Piccolo,[27] M. Rama,[27] A. Zallo,[27] A. Buzzo,[28] R. Contri,[28] M. Lo Vetere,[28] M. M. Macri,[28] M. R. Monge,[28] S. Passaggio,[28] C. Patrignani,[28] E. Robutti,[28] A. Santroni,[28] S. Tosi,[28] K. S. Chaisanguanthum,[29] M. Morii,[29] J. Wu,[29] R. S. Dubitzky,[30] J. Marks,[30] S. Schenk,[30] U. Uwer,[30] D. J. Bard,[31] P. D. Dauncey,[31] R. L. Flack,[31] J. A. Nash,[31] W. Panduro Vazquez,[31] M. Tibbetts,[31] P. K. Behera,[32] X. Chai,[32] M. J. Charles,[32] U. Mallik,[32] V. Ziegler,[32] J. Cochran,[33] H. B. Crawley,[33] L. Dong,[33] V. Eyges,[33] W. T. Meyer,[33] S. Prell,[33] E. I. Rosenberg,[33] A. E. Rubin,[33] Y. Y. Gao,[34] A. V. Gritsan,[34] Z. J. Guo,[34] C. K. Lae,[34] A. G. Denig,[35] M. Fritsch,[35] G. Schott,[35] N. Arnaud,[36] J. Béquilleux,[36] A. D'Orazio,[36] M. Davier,[36] G. Grosdidier,[36] A. Höcker,[36] V. Lepeltier,[36] F. Le Diberder,[36] A. M. Lutz,[36] S. Pruvot,[36] S. Rodier,[36] P. Roudeau,[36] M. H. Schune,[36] J. Serrano,[36] V. Sordini,[36] A. Stocchi,[36] W. F. Wang,[36] G. Wormser,[36] D. J. Lange,[37] D. M. Wright,[37] I. Bingham,[38] C. A. Chavez,[38] I. J. Forster,[38] J. R. Fry,[38] E. Gabathuler,[38] R. Gamet,[38] D. E. Hutchcroft,[38] D. J. Payne,[38] K. C. Schofield,[38] C. Touramanis,[38] A. J. Bevan,[39] K. A. George,[39] F. Di Lodovico,[39] W. Menges,[39] R. Sacco,[39] G. Cowan,[40] H. U. Flaecher,[40] D. A. Hopkins,[40] S. Paramesvaran,[40] F. Salvatore,[40] A. C. Wren,[40] D. N. Brown,[41] C. L. Davis,[41] J. Allison,[42] N. R. Barlow,[42] R. J. Barlow,[42] Y. M. Chia,[42] C. L. Edgar,[42] G. D. Lafferty,[42] T. J. West,[42] J. I. Yi,[42] J. Anderson,[43] C. Chen,[43] A. Jawahery,[43] D. A. Roberts,[43] G. Simi,[43] J. M. Tuggle,[43] G. Blaylock,[44] C. Dallapiccola,[44] S. S. Hertzbach,[44] X. Li,[44] T. B. Moore,[44] E. Salvati,[44] S. Saremi,[44] R. Cowan,[45] D. Dujmic,[45] P. H. Fisher,[45] K. Koeneke,[45] G. Sciolla,[45] S. J. Sekula,[45] M. Spitznagel,[45] F. Taylor,[45] R. K. Yamamoto,[45] M. Zhao,[45] Y. Zheng,[45] S. E. Mclachlin,[46, *] P. M. Patel,[46] S. H. Robertson,[46] A. Lazzaro,[47] F. Palombo,[47] J. M. Bauer,[48] L. Cremaldi,[48] V. Eschenburg,[48] R. Godang,[48] R. Kroeger,[48] D. A. Sanders,[48] D. J. Summers,[48] H. W. Zhao,[48] S. Brunet,[49] D. Côté,[49] M. Simard,[49] P. Taras,[49] F. B. Viaud,[49]

Contributed to International Europhysics Conference On High Energy Physics (EPS-HEP2007), 7/19/2007- 7/25/2007, Manchester, England, UK

Work supported in part by US Department of Energy contract DE-AC02-76SF00515
SLAC, Stanford University, Stanford, CA 94025

H. Nicholson,[50] G. De Nardo,[51] F. Fabozzi,[51, ‡] L. Lista,[51] D. Monorchio,[51] C. Sciacca,[51] M. A. Baak,[52] G. Raven,[52]
H. L. Snoek,[52] C. P. Jessop,[53] K. J. Knoepfel,[53] J. M. LoSecco,[53] G. Benelli,[54] L. A. Corwin,[54] K. Honscheid,[54]
H. Kagan,[54] R. Kass,[54] J. P. Morris,[54] A. M. Rahimi,[54] J. J. Regensburger,[54] Q. K. Wong,[54] N. L. Blount,[55]
J. Brau,[55] R. Frey,[55] O. Igonkina,[55] J. A. Kolb,[55] M. Lu,[55] R. Rahmat,[55] N. B. Sinev,[55] D. Strom,[55] J. Strube,[55]
E. Torrence,[55] N. Gagliardi,[56] A. Gaz,[56] M. Margoni,[56] M. Morandin,[56] A. Pompili,[56] M. Posocco,[56] M. Rotondo,[56]
F. Simonetto,[56] R. Stroili,[56] C. Voci,[56] E. Ben-Haim,[57] H. Briand,[57] G. Calderini,[57] J. Chauveau,[57] P. David,[57]
L. Del Buono,[57] Ch. de la Vaissière,[57] O. Hamon,[57] Ph. Leruste,[57] J. Malclès,[57] J. Ocariz,[57] A. Perez,[57]
J. Prendki,[57] L. Gladney,[58] M. Biasini,[59] R. Covarelli,[59] E. Manoni,[59] C. Angelini,[60] G. Batignani,[60] S. Bettarini,[60]
M. Carpinelli,[60] R. Cenci,[60] A. Cervelli,[60] F. Forti,[60] M. A. Giorgi,[60] A. Lusiani,[60] G. Marchiori,[60] M. A. Mazur,[60]
M. Morganti,[60] N. Neri,[60] E. Paoloni,[60] G. Rizzo,[60] J. J. Walsh,[60] M. Haire,[61] J. Biesiada,[62] P. Elmer,[62]
Y. P. Lau,[62] C. Lu,[62] J. Olsen,[62] A. J. S. Smith,[62] A. V. Telnov,[62] E. Baracchini,[63] F. Bellini,[63] G. Cavoto,[63]
D. del Re,[63] E. Di Marco,[63] R. Faccini,[63] F. Ferrarotto,[63] F. Ferroni,[63] M. Gaspero,[63] P. D. Jackson,[63] L. Li Gioi,[63]
M. A. Mazzoni,[63] S. Morganti,[63] G. Piredda,[63] F. Polci,[63] F. Renga,[63] C. Voena,[63] M. Ebert,[64] T. Hartmann,[64]
H. Schröder,[64] R. Waldi,[64] T. Adye,[65] G. Castelli,[65] B. Franek,[65] E. O. Olaiya,[65] S. Ricciardi,[65] W. Roethel,[65]
F. F. Wilson,[65] S. Emery,[66] M. Escalier,[66] A. Gaidot,[66] S. F. Ganzhur,[66] G. Hamel de Monchenault,[66]
W. Kozanecki,[66] G. Vasseur,[66] Ch. Yèche,[66] M. Zito,[66] X. R. Chen,[67] H. Liu,[67] W. Park,[67] M. V. Purohit,[67]
J. R. Wilson,[67] M. T. Allen,[68] D. Aston,[68] R. Bartoldus,[68] P. Bechtle,[68] N. Berger,[68] R. Claus,[68] J. P. Coleman,[68]
M. R. Convery,[68] J. C. Dingfelder,[68] J. Dorfan,[68] G. P. Dubois-Felsmann,[68] W. Dunwoodie,[68] R. C. Field,[68]
T. Glanzman,[68] S. J. Gowdy,[68] M. T. Graham,[68] P. Grenier,[68] C. Hast,[68] T. Hryn'ova,[68] W. R. Innes,[68]
J. Kaminski,[68] M. H. Kelsey,[68] H. Kim,[68] P. Kim,[68] M. L. Kocian,[68] D. W. G. S. Leith,[68] S. Li,[68] S. Luitz,[68]
V. Luth,[68] H. L. Lynch,[68] D. B. MacFarlane,[68] H. Marsiske,[68] R. Messner,[68] D. R. Muller,[68] C. P. O'Grady,[68]
I. Ofte,[68] A. Perazzo,[68] M. Perl,[68] T. Pulliam,[68] B. N. Ratcliff,[68] A. Roodman,[68] A. A. Salnikov,[68]
R. H. Schindler,[68] J. Schwiening,[68] A. Snyder,[68] J. Stelzer,[68] D. Su,[68] M. K. Sullivan,[68] K. Suzuki,[68] S. K. Swain,[68]
J. M. Thompson,[68] J. Va'vra,[68] N. van Bakel,[68] A. P. Wagner,[68] M. Weaver,[68] W. J. Wisniewski,[68] M. Wittgen,[68]
D. H. Wright,[68] A. K. Yarritu,[68] K. Yi,[68] C. C. Young,[68] P. R. Burchat,[69] A. J. Edwards,[69] S. A. Majewski,[69]
B. A. Petersen,[69] L. Wilden,[69] S. Ahmed,[70] M. S. Alam,[70] R. Bula,[70] J. A. Ernst,[70] V. Jain,[70] B. Pan,[70]
M. A. Saeed,[70] F. R. Wappler,[70] S. B. Zain,[70] M. Krishnamurthy,[71] S. M. Spanier,[71] R. Eckmann,[72] J. L. Ritchie,[72]
A. M. Ruland,[72] C. J. Schilling,[72] R. F. Schwitters,[72] J. M. Izen,[73] X. C. Lou,[73] S. Ye,[73] F. Bianchi,[74] F. Gallo,[74]
D. Gamba,[74] M. Pelliccioni,[74] M. Bomben,[75] L. Bosisio,[75] C. Cartaro,[75] F. Cossutti,[75] G. Della Ricca,[75]
L. Lanceri,[75] L. Vitale,[75] V. Azzolini,[76] N. Lopez-March,[76] F. Martinez-Vidal,[76, §] D. A. Milanes,[76] A. Oyanguren,[76]
J. Albert,[77] Sw. Banerjee,[77] B. Bhuyan,[77] K. Hamano,[77] R. Kowalewski,[77] I. M. Nugent,[77] J. M. Roney,[77]
R. J. Sobie,[77] P. F. Harrison,[78] J. Ilic,[78] T. E. Latham,[78] G. B. Mohanty,[78] H. R. Band,[79] X. Chen,[79] S. Dasu,[79]
K. T. Flood,[79] J. J. Hollar,[79] P. E. Kutter,[79] Y. Pan,[79] M. Pierini,[79] R. Prepost,[79] S. L. Wu,[79] and H. Neal[80]
(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]*University of Bergen, Institute of Physics, N-5007 Bergen, Norway*
[5]*Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA*
[6]*University of Birmingham, Birmingham, B15 2TT, United Kingdom*
[7]*Ruhr Universität Bochum, Institut für Experimentalphysik 1, D-44780 Bochum, Germany*
[8]*University of Bristol, Bristol BS8 1TL, United Kingdom*
[9]*University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1*
[10]*Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom*
[11]*Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia*
[12]*University of California at Irvine, Irvine, California 92697, USA*
[13]*University of California at Los Angeles, Los Angeles, California 90024, USA*
[14]*University of California at Riverside, Riverside, California 92521, USA*
[15]*University of California at San Diego, La Jolla, California 92093, USA*
[16]*University of California at Santa Barbara, Santa Barbara, California 93106, USA*
[17]*University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA*
[18]*California Institute of Technology, Pasadena, California 91125, USA*
[19]*University of Cincinnati, Cincinnati, Ohio 45221, USA*
[20]*University of Colorado, Boulder, Colorado 80309, USA*
[21]*Colorado State University, Fort Collins, Colorado 80523, USA*

[22]Universität Dortmund, Institut für Physik, D-44221 Dortmund, Germany
[23]Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany
[24]Laboratoire Leprince-Ringuet, CNRS/IN2P3, Ecole Polytechnique, F-91128 Palaiseau, France
[25]University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom
[26]Università di Ferrara, Dipartimento di Fisica and INFN, I-44100 Ferrara, Italy
[27]Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy
[28]Università di Genova, Dipartimento di Fisica and INFN, I-16146 Genova, Italy
[29]Harvard University, Cambridge, Massachusetts 02138, USA
[30]Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany
[31]Imperial College London, London, SW7 2AZ, United Kingdom
[32]University of Iowa, Iowa City, Iowa 52242, USA
[33]Iowa State University, Ames, Iowa 50011-3160, USA
[34]Johns Hopkins University, Baltimore, Maryland 21218, USA
[35]Universität Karlsruhe, Institut für Experimentelle Kernphysik, D-76021 Karlsruhe, Germany
[36]Laboratoire de l'Accélérateur Linéaire, IN2P3/CNRS et Université Paris-Sud 11,
Centre Scientifique d'Orsay, B. P. 34, F-91898 ORSAY Cedex, France
[37]Lawrence Livermore National Laboratory, Livermore, California 94550, USA
[38]University of Liverpool, Liverpool L69 7ZE, United Kingdom
[39]Queen Mary, University of London, E1 4NS, United Kingdom
[40]University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom
[41]University of Louisville, Louisville, Kentucky 40292, USA
[42]University of Manchester, Manchester M13 9PL, United Kingdom
[43]University of Maryland, College Park, Maryland 20742, USA
[44]University of Massachusetts, Amherst, Massachusetts 01003, USA
[45]Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Massachusetts 02139, USA
[46]McGill University, Montréal, Québec, Canada H3A 2T8
[47]Università di Milano, Dipartimento di Fisica and INFN, I-20133 Milano, Italy
[48]University of Mississippi, University, Mississippi 38677, USA
[49]Université de Montréal, Physique des Particules, Montréal, Québec, Canada H3C 3J7
[50]Mount Holyoke College, South Hadley, Massachusetts 01075, USA
[51]Università di Napoli Federico II, Dipartimento di Scienze Fisiche and INFN, I-80126, Napoli, Italy
[52]NIKHEF, National Institute for Nuclear Physics and High Energy Physics, NL-1009 DB Amsterdam, The Netherlands
[53]University of Notre Dame, Notre Dame, Indiana 46556, USA
[54]Ohio State University, Columbus, Ohio 43210, USA
[55]University of Oregon, Eugene, Oregon 97403, USA
[56]Università di Padova, Dipartimento di Fisica and INFN, I-35131 Padova, Italy
[57]Laboratoire de Physique Nucléaire et de Hautes Energies,
IN2P3/CNRS, Université Pierre et Marie Curie-Paris6,
Université Denis Diderot-Paris7, F-75252 Paris, France
[58]University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA
[59]Università di Perugia, Dipartimento di Fisica and INFN, I-06100 Perugia, Italy
[60]Università di Pisa, Dipartimento di Fisica, Scuola Normale Superiore and INFN, I-56127 Pisa, Italy
[61]Prairie View A&M University, Prairie View, Texas 77446, USA
[62]Princeton University, Princeton, New Jersey 08544, USA
[63]Università di Roma La Sapienza, Dipartimento di Fisica and INFN, I-00185 Roma, Italy
[64]Universität Rostock, D-18051 Rostock, Germany
[65]Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom
[66]DSM/Dapnia, CEA/Saclay, F-91191 Gif-sur-Yvette, France
[67]University of South Carolina, Columbia, South Carolina 29208, USA
[68]Stanford Linear Accelerator Center, Stanford, California 94309, USA
[69]Stanford University, Stanford, California 94305-4060, USA
[70]State University of New York, Albany, New York 12222, USA
[71]University of Tennessee, Knoxville, Tennessee 37996, USA
[72]University of Texas at Austin, Austin, Texas 78712, USA
[73]University of Texas at Dallas, Richardson, Texas 75083, USA
[74]Università di Torino, Dipartimento di Fisica Sperimentale and INFN, I-10125 Torino, Italy
[75]Università di Trieste, Dipartimento di Fisica and INFN, I-34127 Trieste, Italy
[76]IFIC, Universitat de Valencia-CSIC, E-46071 Valencia, Spain
[77]University of Victoria, Victoria, British Columbia, Canada V8W 3P6
[78]Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom
[79]University of Wisconsin, Madison, Wisconsin 53706, USA
[80]Yale University, New Haven, Connecticut 06511, USA

(Dated: July 18, 2007)

We present preliminary measurements of branching fractions for the semileptonic decays $B \to D\tau^-\overline{\nu}_\tau$ and $B \to D^*\tau^-\overline{\nu}_\tau$, which are potentially sensitive to non–Standard Model amplitudes. The data sample comprises 232×10^6 $\Upsilon(4S) \to B\overline{B}$ decays collected with the *BABAR* detector at the PEP-II e^+e^- storage ring. We obtain $\mathcal{B}(B^- \to D^0\tau^-\overline{\nu}_\tau) = (0.63 \pm 0.38 \pm 0.10 \pm 0.06)\%$, $\mathcal{B}(B^- \to D^{*0}\tau^-\overline{\nu}_\tau) = (2.35 \pm 0.49 \pm 0.22 \pm 0.18)\%$, $\mathcal{B}(\overline{B}^0 \to D^+\tau^-\overline{\nu}_\tau) = (1.03 \pm 0.35 \pm 0.14 \pm 0.10)\%$, and $\mathcal{B}(\overline{B}^0 \to D^{*+}\tau^-\overline{\nu}_\tau) = (1.15 \pm 0.33 \pm 0.04 \pm 0.04)\%$, where the uncertainties are statistical, systematic, and normalization, respectively. By combining B^- and $\overline{B}^0$ results, we also obtain the branching fractions $\mathcal{B}(B \to D\tau^-\overline{\nu}_\tau) = (0.90 \pm 0.26 \pm 0.11 \pm 0.06)\%$ and $\mathcal{B}(B \to D^*\tau^-\overline{\nu}_\tau) = (1.81 \pm 0.33 \pm 0.11 \pm 0.06)\%$ (quoted for the B^- lifetime), with significances of 3.5σ and 6.2σ.

Submitted to the 2007 Europhysics Conference on High Energy Physics, Manchester, England.

PACS numbers: 12.15.Hh, 13.20.-v, 13.20.He, 14.40.Nd, 14.80.Cp

Semileptonic decays of B mesons to the τ lepton—the heaviest of the three charged leptons—provide a new source of information on Standard Model (SM) processes [1–3], as well as a new window on physics beyond the SM [4–8]. In the SM, semileptonic decays occur at tree level and are mediated by the W^- boson, but the large mass of the τ lepton provides sensitivity to additional amplitudes, such as those mediated by a charged Higgs boson, H^-. Experimentally, $b \to c\tau^-\overline{\nu}_\tau$ decays are challenging to study because the final state contains not just one, but two or three neutrinos.

Branching fractions for semileptonic B decays to τ leptons are predicted to be smaller than those for $\ell = e$, μ [9], but are still substantial compared to most hadronic B decays. A recent SM-based calculation [8] predicts $\mathcal{B}(\overline{B}^0 \to D^+\tau^-\overline{\nu}_\tau) = (0.69 \pm 0.04)\%$ and $\mathcal{B}(\overline{B}^0 \to D^{*+}\tau^-\overline{\nu}_\tau) = (1.41 \pm 0.07)\%$; an inclusive calculation [2] gives $\mathcal{B}(B \to X_c\tau^-\overline{\nu}_\tau) = (2.3 \pm 0.25)\%$, where X_c represents all final states resulting from the $b \to c$ transition. Calculations [4–8] in supersymmetric models show that substantial departures from the SM decay rate could occur for $\mathcal{B}(B \to D\tau^-\overline{\nu}_\tau)$, but that those for $\mathcal{B}(B \to D^*\tau^-\overline{\nu}_\tau)$ are expected to be smaller. The interference with the SM amplitude can be constructive or destructive, depending on the value of $(\tan\beta)/m_H$, where $\tan\beta$ is the ratio of the vacuum expectation values for the two Higgs doublets and m_H is the H^- mass.

Theoretical predictions for semileptonic decays to exclusive final states require knowledge of the form factors, which parametrize the hadronic current as a function of $q^2 = (p_B - p_{D^{(*)}})^2$. For light leptons ($e$, μ), there is effectively one form factor for $B \to D\ell^-\overline{\nu}_\ell$, while there are three for $B \to D^*\ell^-\overline{\nu}_\ell$. If a τ lepton is produced instead, one additional form factor enters in each mode. The form factors for $B \to D^{(*)}\ell^-\overline{\nu}_\ell$ decays involving the light leptons have been measured [10] and have been discussed extensively in the theoretical literature. Heavy-quark-symmetry (HQS) relations [11] allow one to express the two additional form factors for $B \to D^{(*)}\tau^-\overline{\nu}_\tau$ in terms of the form factors measurable from decays with the light leptons. With sufficient data, one could probe the additional form factors and test the HQS relations.

The first measurements of semileptonic b-hadron decays to τ leptons were performed by the LEP experiments [12] operating at the Z^0 resonance, yielding an average [13] branching fraction $\mathcal{B}(b_{\rm had} \to X\tau^-\overline{\nu}_\tau) = (2.48 \pm 0.26)\%$, where $b_{\rm had}$ represents the mixture of b-hadrons produced in $Z^0 \to b\overline{b}$ decay.

We determine branching fractions of four exclusive decay modes [14]: $B^- \to D^0\tau^-\overline{\nu}_\tau$, $B^- \to D^{*0}\tau^-\overline{\nu}_\tau$, $\overline{B}^0 \to D^+\tau^-\overline{\nu}_\tau$, and $\overline{B}^0 \to D^{*+}\tau^-\overline{\nu}_\tau$, each of which is measured relative to the corresponding e and μ modes. To reconstruct the τ, we use the decays $\tau^- \to e^-\overline{\nu}_e\nu_\tau$ and $\tau^- \to \mu^-\overline{\nu}_\mu\nu_\tau$, which are experimentally most accessible. The main challenge of the measurement is to separate $B \to D^{(*)}\tau^-\overline{\nu}_\tau$ decays, which have three neutrinos, from $B \to D^{(*)}\ell^-\overline{\nu}_\ell$ decays, which have the same observable final-state particles but only one neutrino.

We analyze data collected with the *BABAR* detector [15], at the PEP-II e^+e^- storage ring at the Stanford Linear Accelerator Center. The data sample used in the analysis comprises 208.9 fb^{-1} recorded on the $\Upsilon(4S)$ resonance, yielding 232×10^6 $B\overline{B}$ decays. The measurement uses all of the major detector subsystems: a charged-particle tracking system consisting of a 5-layer silicon vertex tracker and a 40-layer He-gas drift chamber (DCH); a quartz-bar Cherenkov particle-identification system; a CsI(Tl) crystal electromagnetic calorimeter for electron identification and photon energy measurement; a 1.5 T superconducting magnet; and a muon identification system in the magnet flux return.

The analysis strategy is to reconstruct the decays of both B mesons in the $\Upsilon(4S) \to B\overline{B}$ event, providing powerful constraints on unobserved particles. One B meson, denoted $B_{\rm tag}$, is fully reconstructed in a purely hadronic decay chain. The remaining charged tracks and photons are required to be consistent with the products of a $b \to c$ semileptonic B decay: a hadronic system, either a D or D^* meson, and a lepton (e or μ), either primary or from $\tau^- \to \ell^-\overline{\nu}_\ell\nu_\tau$. Using the known total four-momentum of the e^+e^- collision, we calculate $p_{\rm miss} = [p(e^+e^-) - p_{\rm tag} - p_{D^{(*)}} - p_\ell]$ recoiling against the observed $B_{\rm tag} + D^{(*)}\ell$ system. A large peak at zero in $m^2_{\rm miss} = p^2_{\rm miss}$ corresponds to semileptonic decays with one neutrino, whereas signal events form a broad tail out to $m^2_{\rm miss} \sim 8$ (GeV/c^2)^2. To separate signal and background events, we perform a fit to the joint distribution of $m^2_{\rm miss}$ and the lepton momentum ($|\mathbf{p}^*_\ell|$), in the rest frame of the B meson. In a signal event, the observed lepton is the daughter of the τ and typically has a soft spectrum; for most background events, this lepton typically has higher momentum.

We reconstruct $B_{\rm tag}$ candidates [16] in 1114 final states $B_{\rm tag} \to D^{(*)}Y^{\pm}$. Tag-side $D^{(*)}$ candidates are reconstructed in 21 decay chains, and the $Y^{\pm}$ system can consist of up to six light hadrons ($\pi^{\pm}$, π^0, $K^{\pm}$, or K^0_S). $B_{\rm tag}$ candidates are identified using two kinematic variables, $m_{\rm ES} = \sqrt{s/4 - |\mathbf{p}_{\rm tag}|^2}$ and $\Delta E = E_{\rm tag} - \sqrt{s}/2$, where $\sqrt{s}$ is the total e^+e^- energy; $|\mathbf{p}_{\rm tag}|$ is the magnitude of the $B_{\rm tag}$ momentum; and $E_{\rm tag}$ is the $B_{\rm tag}$ energy, all defined in the e^+e^- center-of-mass frame. We require $m_{\rm ES} > 5.27$ GeV/c^2 and $|\Delta E| < 72$ MeV, corresponding to 4σ (standard deviations). We reconstruct $B_{\rm tag}$ candidates with an efficiency of approximately 0.3% to 0.5%.

For the B meson decaying semileptonically, we reconstruct $D^{(*)}$ candidates in the modes $D^0 \to K^-\pi^+$, $K^-\pi^+\pi^0$, $K^-\pi^+\pi^+\pi^-$, $K^0_S\pi^+\pi^-$; $D^+ \to K^-\pi^+\pi^+$, $K^-\pi^+\pi^+\pi^0$, $K^0_S\pi^+$, $K^-K^+\pi^+$; $D^{*0} \to D^0\pi^0$, $D^0\gamma$; and $D^{*+} \to D^0\pi^+$, $D^+\pi^0$. D (D^*) candidates are selected within 4σ of the D mass ($D^* - D$ mass difference), with σ typically 5–10 MeV/c^2 (1–2 MeV/c^2). To ensure well-measured momenta, identified electron and muon tracks are required to have at least 12 hits in the drift chamber and not to be near the acceptance edges. Electron candidates must have lab-frame momentum $|\mathbf{p}_e| > 0.3\,$GeV/c; muon candidates must have an appropriate signature in the muon detector system, effectively requiring $|\mathbf{p}_\mu| \gtrapprox 0.6\,$GeV/$c$. The energy of electron candidates is corrected for bremsstrahlung energy loss if photons are found close to the electron direction.

We require that there be no charged tracks not associated with the $B_{\rm tag}$, $D^{(*)}$, or ℓ candidates. We compute $E_{\rm extra}$, the sum of the energies of all photon candidates not associated with the $B_{\rm tag}$, $D^{(*)}$, or ℓ candidates, and we require $E_{\rm extra} < 150$–300 MeV, depending on the $D^{(*)}$ channel. We suppress hadronic events and combinatoric backgrounds by requiring $|\mathbf{p}_{\rm miss}| > 200$ MeV/c and $q^2 > 4$ (GeV/c^2)^2. If multiple candidates pass this selection, we select the candidate with the lowest value of $E_{\rm extra}$. To improve the $m^2_{\rm miss}$ resolution, we perform a kinematic fit to the event, constraining particle masses to known values and requiring tracks from B, D, and K^0_S mesons to originate from appropriate common vertices.

Figure 1 shows the distributions of $m^2_{\rm miss}$ for the four $D^{(*)}\ell$ channels, along with the projections of the maximum likelihood fit to be discussed below. The large peaks at $m^2_{\rm miss} \approx 0$ are mainly due to $B \to D^{(*)}\ell^-\overline{\nu}_\ell$, which serve as normalization modes. The structure of this background is shown in the inset figures, which expand the region $-0.4 < m^2_{\rm miss} < 1.4$ (GeV/c^2)^2. $B \to D^*\ell^-\overline{\nu}_\ell$ background is the dominant feature in the two $D^*\ell$ channels (Figs. 1a, c); the two $D\ell$ channels (Figs. 1b, d) are dominated by $B \to D\ell^-\overline{\nu}_\ell$ decays but also include substantial feed-down contributions from true D^* mesons where the low-momentum π^0 or photon from $D^* \to D\pi^0/\gamma$ is not reconstructed. This feed-down is clearly visible for $B \to D^*\ell^-\overline{\nu}_\ell$ background, but affects $B \to D^*\tau^-\overline{\nu}_\tau$ signal similarly, and both feed-down components (as well as smaller feed-up contributions from $B \to D(\ell^-/\tau^-)\overline{\nu}$ into the $D^*\ell$ channels) are included in the fit. Other sources of background include $B \to D^{**}(\ell^-/\tau^-)\overline{\nu}$ events (here D^{**} represents charm resonances heavier than the $D^*(2010)$, as well as non-resonant $D^{(*)}n\pi$ systems); charge-crossfeed (which occurs when a $B \to D^{(*)}\ell^-\overline{\nu}_\ell$ event is reconstructed with the wrong charge for the $B_{\rm tag}$ and $D^{(*)}$ meson, typically because a low-momentum $\pi^{\pm}$ is swapped between the $B_{\rm tag}$ and the $D^{(*)}$); and combinatoric background. This last background is dominated by hadronic B decays such as $B \to D^{(*)}D^{(*)}_s$, in which one of the charm mesons produces a secondary lepton, including τ leptons from D_s decay.

To constrain background from $B \to D^{**}(\ell^-/\tau^-)\overline{\nu}$ decays, we use four control samples (one for each signal channel) in which an extra π^0 meson is observed. Most of the D^{**} background in the signal channels occurs when the π^0 from $D^{**} \to D^{(*)}\pi^0$ is not reconstructed, so these control samples provide a good normalization of the background source. D^{**} decays in which a $\pi^{\pm}$ is lost do not have the correct charge correlation between the $B_{\rm tag}$ and $D^{(*)}$, and decays with two missing charged pions are rare. The feed-down probabilities for the $D^{**}(\ell^-/\tau^-)\overline{\nu}$ background are determined from simulation, with uncertainties in the D^{**} content treated as a systematic error. However, the control samples reduce our sensitivity to the details of this model.

We perform a relative measurement, extracting both signal $B \to D^{(*)}\tau^-\overline{\nu}_\tau$ and normalization $B \to D^{(*)}\ell^-\overline{\nu}_\ell$ yields from the fit to obtain the four branching ratios $R(D^0)$, $R(D^+)$, $R(D^{*0})$, and $R(D^{*+})$ where, for example, $R(D^{*0}) \equiv \mathcal{B}(B^- \to D^{*0}\tau^-\overline{\nu}_\tau)/\mathcal{B}(B^- \to D^{*0}\ell^-\overline{\nu}_\ell)$. Here, ℓ represents only one of e or μ; however, both light lepton species contribute statistically to the denominator. Signal and background yields are extracted using an extended, unbinned maximum likelihood fit to the joint ($m^2_{\rm miss}$, $|\mathbf{p}^*_\ell|$) distribution. The 18-parameter fit is performed simultaneously in the four signal channels and the four D^{**} control samples. In each of the four signal channels, we describe the data as the sum of seven components (shown in Fig. 1): $D\tau^-\overline{\nu}_\tau$, $D^*\tau^-\overline{\nu}_\tau$, $D\ell^-\overline{\nu}_\ell$, $D^*\ell^-\overline{\nu}_\ell$, $D^{**}(\ell^-/\tau^-)\overline{\nu}$, charge crossfeed, and combinatoric background. The four D^{**} control samples are described as the sum of five components: $D^{**}(\ell^-/\tau^-)\overline{\nu}$, $D\ell^-\overline{\nu}_\ell$, $D^*\ell^-\overline{\nu}_\ell$, charge crossfeed, and combinatoric background. Probability distribution functions (PDFs) are primarily determined from simulated event samples; however, the parameters describing the dominant feed-down component—D^* feed-down into

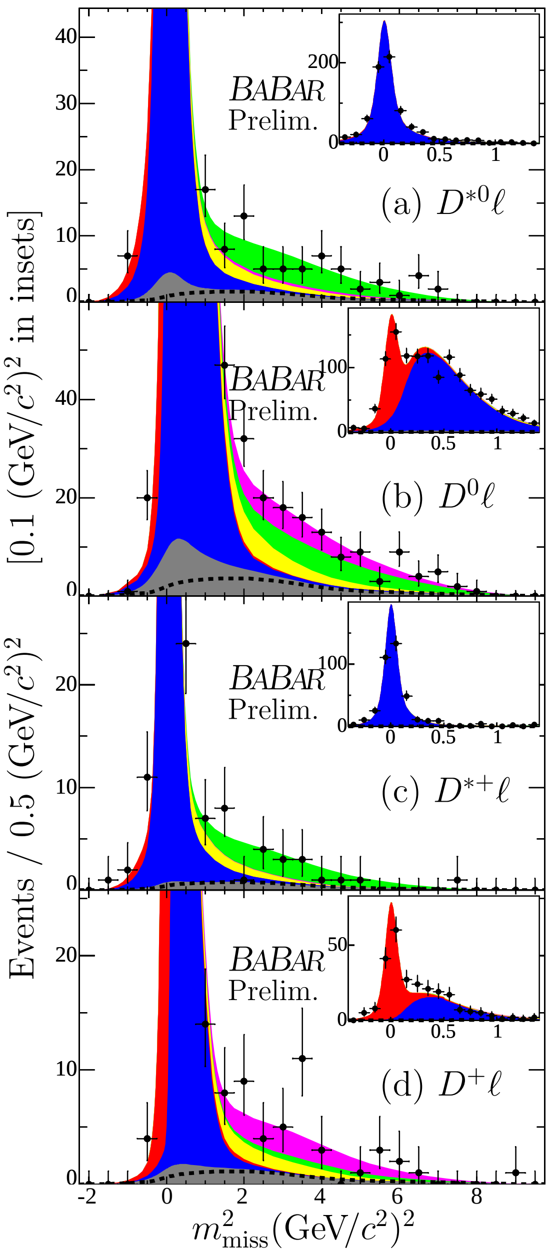

FIG. 1: Distributions of events and fit projections in m^2_{miss} for the four signal channels: $D^{*0}\ell$, $D^0\ell$, $D^{*+}\ell$, and $D^+\ell$. (The fit shown incorporates the B^-–$\overline{B}^0$ constraints.) The normalization region $m^2_{\mathrm{miss}} \sim 0$ is shown as an inset in each figure. The fit components are: $D^*\tau^-\overline{\nu}_\tau$ (green), $D\tau^-\overline{\nu}_\tau$ (purple), $D^*\ell^-\overline{\nu}_\ell$ (blue), $D\ell^-\overline{\nu}_\ell$ (red), $D^{**}(\ell^-/\tau^-)\overline{\nu}$ (yellow), combinatoric (grey, below dashed line), charge crossfeed (grey, above dashed line).

the $D\ell$ channels—are determined directly by the fit.

We perform two fits, one in which all four signal yields are allowed to float independently, and a second, B^-–$\overline{B}^0$ combined fit, in which we constrain [17] $R(D^+) = R(D^0)$ and $R(D^{*+}) = R(D^{*0})$. The fit results are summarized in Table I, and the m^2_{miss} projections of the constrained fit are shown in Fig. 1.

Systematic uncertainties on R associated with the fit are determined by running ensembles of fits in which input parameters are distributed according to our knowledge of the underlying source, and include the PDF parametrization (2% to 12%); the composition of combinatoric backgrounds (2% to 11%); the mixture of D^{**} states in $B \to D^{**}\ell^-\overline{\nu}_\ell$ decays (0.4% to 6%); the $B \to D^*\ell^-\overline{\nu}_\ell$ form factors (0.1% to 1.8%); and the π^0 efficiency, which affects the $D^* \to D$ feed-down rate (0.4% to 1.0%). Uncertainties on the m^2_{miss} resolution for $B \to D^*\ell^-\overline{\nu}_\ell$ events and on the $B \to D\ell^-\overline{\nu}_\ell$ form factors each contribute less than 1%. The net systematic uncertainty on R associated with fit yields is given by $(\Delta R/R)_{\mathrm{fit}}$ for each channel in Table I. Uncertainties on R propagated from the ratio of efficiencies for signal and normalization modes are typically small due to cancellations, and include the limited statistics in the simulation (1.1% to 1.5%) and systematic errors related to detector performance. The latter are determined by studying the efficiency of track and neutral reconstruction and particle identification performance in control samples in data and contribute less than 0.2% each, except for $e^\pm$ and $\mu^\pm$ identification, which contribute 0.5% to 0.7% each, and are larger because the lepton momentum spectrum differs between the signal and normalization processes. Finally, the uncertainty on $\mathcal{B}(\tau^- \to \ell^-\overline{\nu}_\ell\nu_\tau)$ [13] contributes 0.2% to all modes. The net systematic uncertainty on R due to the efficiencies is given by $(\Delta R/R)_\varepsilon$ in Table I.

These results are preliminary. We estimate that uncertainties in R due to modeling of bremsstrahlung radiation are at or below the 1% level, but they have not been explicitly included in the results. While $B \to D^{(*)}\ell^-\overline{\nu}_\ell$ decays are modeled with HQET-based form factors [19] including recent experimental measurements [10], we currently use ISGW2 [20] to model signal decays.

We determine the statistical significance of the signals from $\sqrt{2\Delta(\ln\mathcal{L})}$, where $\Delta(\ln\mathcal{L})$ is the change in log-likelihood between the nominal fit and the no-signal hypothesis. The total significance is determined in a similar manner, by modifying the likelihood function to take into account systematic uncertainties from the fit. Table I gives both significances for each channel.

We have presented preliminary measurements of the decays $B \to D\tau^-\overline{\nu}_\tau$ and $B \to D^*\tau^-\overline{\nu}_\tau$, relative to the corresponding decays involving light leptons. We obtain $R(B \to D\tau^-\overline{\nu}_\tau) = (40.7 \pm 12.0 \pm 4.9)\%$ and $R(B \to D^*\tau^-\overline{\nu}_\tau) = (31.0 \pm 5.7 \pm 1.8)\%$, where the first error is statistical and the second is systematic. Normalizing to known branching fractions [13], we obtain

$$\begin{aligned}\mathcal{B}(B \to D\tau^-\overline{\nu}_\tau) &= (0.90 \pm 0.26 \pm 0.11 \pm 0.06)\%\\ \mathcal{B}(B \to D^*\tau^-\overline{\nu}_\tau) &= (1.81 \pm 0.33 \pm 0.11 \pm 0.06)\%,\end{aligned}$$

where the third error is the uncertainty on the normaliza-

TABLE I: Preliminary results from fits to data and associated uncertainties: the columns are the signal yield ($N_{\rm sig}$), the yield of normalization $B \to D^{(*)}\ell^-\overline{\nu}_\ell$ events ($N_{\rm norm}$), the ratio of signal and normalization mode efficiencies ($\varepsilon_{\rm sig}/\varepsilon_{\rm norm}$), the relative systematic error due to the fit yields ($(\Delta R/R)_{\rm fit}$), the relative systematic error due to the efficiency ratios ($(\Delta R/R)_\varepsilon$), the branching fraction relative to the normalization mode (R), the absolute branching fraction ($\mathcal{B}$), and the total and statistical signal significances ($\sigma_{\rm tot}$ and $\sigma_{\rm stat}$). The first two errors on R and $\mathcal{B}$ are statistical and systematic, respectively; the third error on $\mathcal{B}$ represents the uncertainty on the normalization mode [18]. The last two rows show the results of the fit with the B^-–$\overline{B}^0$ constraint applied, where $\mathcal{B}$ is expressed for the B^-.

Mode	$N_{\rm sig}$	$N_{\rm norm}$	$\varepsilon_{\rm sig}/\varepsilon_{\rm norm}$	$(\Delta R/R)_{\rm fit}$ [%]	$(\Delta R/R)_\varepsilon$ [%]	R [%]	$\mathcal{B}$ [%]	$\sigma_{\rm tot}$ ($\sigma_{\rm stat}$)
$B^- \to D^0\tau^-\overline{\nu}_\tau$	33.1±19.6	346.7±23.0	1.85	15.2	1.5	29.5±17.4±4.5	0.63±0.38±0.10±0.06	1.7 (1.7)
$B^- \to D^{*0}\tau^-\overline{\nu}_\tau$	95.9±19.8	1628.6±63.5	0.98	9.4	1.4	36.2± 7.5±3.4	2.35±0.49±0.22±0.18	5.3 (5.8)
$\overline{B}^0 \to D^+\tau^-\overline{\nu}_\tau$	23.0±7.9	149.9±13.3	1.83	13.4	1.7	48.6±16.7±6.6	1.03±0.35±0.14±0.10	3.3 (3.5)
$\overline{B}^0 \to D^{*+}\tau^-\overline{\nu}_\tau$	16.2±7.3	481.8±25.5	0.93	3.4	1.5	21.4± 9.7±0.8	1.15±0.52±0.04±0.04	2.7 (2.7)
$B \to D\tau^-\overline{\nu}_\tau$	64.9±19.1	496.3±26.4	1.85	12.0	1.3	40.7±12.0±4.9	0.90±0.26±0.11±0.06	3.5 (3.8)
$B \to D^*\tau^-\overline{\nu}_\tau$	105.3±19.4	2109.4±68.0	0.93	5.7	1.2	31.0± 5.7±1.8	1.81±0.33±0.11±0.06	6.2 (6.5)

tion branching fraction, and where results are expressed for the B^- lifetime. The significances of the signals are 3.5σ and 6.2σ, respectively. The measurement of $B \to D^*\tau^-\overline{\nu}_\tau$ is consistent with a preliminary Belle measurement [21]; the measurement of $B \to D\tau^-\overline{\nu}_\tau$ is the first evidence for this mode. These results are about 1σ higher than predictions based on the Standard Model, but, given the size of the uncertainty, there is still room for a non-SM contribution.

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), CEA and CNRS-IN2P3 (France), BMBF and DFG (Germany), INFN (Italy), FOM (The Netherlands), NFR (Norway), MIST (Russia), MEC (Spain), and STFC (United Kingdom). Individuals have received support from the Marie Curie EIF (European Union) and the A. P. Sloan Foundation.

---

[*] Deceased

[†] Also with Università di Perugia, Dipartimento di Fisica, Perugia, Italy

[‡] Also with Università della Basilicata, Potenza, Italy

[§] Also with Universitat de Barcelona, Facultat de Fisica, Departament ECM, E-08028 Barcelona, Spain

[1] J.G. Körner and G.A. Schuler, Phys. Lett. B **231**, 306 (1989); Z. Phys. C **46**, 93 (1990).

[2] A.F. Falk *et al.*, Phys. Lett. B **326**, 145 (1994).

[3] D. S. Hwang, and D.-W. Kim, Eur. Phys. Jour. C **14**, 271 (2000).

[4] B. Grzadkowski and W.-S. Hou, Phys. Lett. B **283**, 427 (1992).

[5] M. Tanaka, Z. Phys. C **67**, 321 (1995).

[6] K. Kiers and A. Soni, Phys. Rev. D **56**, 5786 (1997).

[7] H. Itoh, S. Komine, and Y. Okada, Prog. Theor. Phys. **114** 179 (2005).

[8] C.-H. Chen and C.-Q. Geng, JHEP **0610**, 053 (2006).

[9] Throughout this letter, we use the symbol ℓ to refer only to the light charged leptons e and μ. The symbol $D^{(*)}$ refers either to a D or a D^* meson.

[10] CLEO Collab., J.E. Duboscq *et al.*, Phys. Rev. Lett. **76**, 3898 (1996); *BABAR* Collab., B. Aubert *et al.*, Phys. Rev. D **74**, 092004 (2006).

[11] N. Isgur and M.B. Wise, Phys. Lett. B **232**, 113 (1989); B **237**, 527 (1990).

[12] L3 Collab., M. Acciarri *et al.*, Phys. Lett. B **332**, 201 (1994); Z. Phys. C **71**, 379 (1996); ALEPH Collab., R. Barate *et al.*, Eur. Phys. Jour. C **6**, 555 (2001); OPAL Collab., G. Abbiendi *et al.*, Phys. Lett. B **520**, 1 (2001).

[13] Particle Data Group, W.-M. Yao *et al.*, J. Phys. G: Nucl. Part. Phys. **33**, 1 (2006).

[14] Throughout this letter, charge-conjugate modes are implied.

[15] *BABAR* Collab., B. Aubert *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **479**, 1 (2002).

[16] *BABAR* Collab., B. Aubert *et al.*, Phys. Rev. Lett. **92**, 071802 (2004).

[17] This constraint follows from isospin symmetry in both the signal and normalization modes, but is, in fact, slightly more general.

[18] We use [13] to normalize the four individual branching fractions. For the B^-–$\overline{B}^0$-constrained measurement, we use our own averages of the values in [13]: $\mathcal{B}(B^- \to D^0\ell^-\overline{\nu}_\ell) = (2.21 \pm 0.15)\%$ and $\mathcal{B}(B^- \to D^{*0}\ell^-\overline{\nu}_\ell) = (5.85 \pm 0.20)\%$.

[19] I. Caprini, L. Lellouch, and M. Neubert, Nucl. Phys. B **530** 153 (1998).

[20] D. Scora and N. Isgur, Phys. Rev. D **52** 2783 (1995).

[21] Belle Collab., A. Matyja *et al.*, arXiv:0706.4429v1.