BABAR-PUB-07/057
SLAC-PUB-13040
arXiv:0712.1516
December 2007

Search for decays of B^0 mesons into e^+e^- , $\mu^+\mu^-$, and $e^\pm\mu^\mp$ final states

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] H. Koch,[7] T. Schroeder,[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] M. Barrett,[10] 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] G. M. Vitug,[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] 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] J. P. Burke,[38] C. A. Chavez,[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] 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] D. Bailey,[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] 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]

Submitted to Physical Review D

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

H. W. Zhao,[48] S. Brunet,[49] D. Côté,[49] M. Simard,[49] P. Taras,[49] F. B. Viaud,[49] 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] S. J. Sekula,[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] J. Biesiada,[61] P. Elmer,[61] Y. P. Lau,[61] C. Lu,[61] J. Olsen,[61] A. J. S. Smith,[61] A. V. Telnov,[61] E. Baracchini,[62] F. Bellini,[62] G. Cavoto,[62] D. del Re,[62] E. Di Marco,[62] R. Faccini,[62] F. Ferrarotto,[62] F. Ferroni,[62] M. Gaspero,[62] P. D. Jackson,[62] L. Li Gioi,[62] M. A. Mazzoni,[62] S. Morganti,[62] G. Piredda,[62] F. Polci,[62] F. Renga,[62] C. Voena,[62] M. Ebert,[63] T. Hartmann,[63] H. Schröder,[63] R. Waldi,[63] T. Adye,[64] G. Castelli,[64] B. Franek,[64] E. O. Olaiya,[64] W. Roethel,[64] F. F. Wilson,[64] S. Emery,[65] M. Escalier,[65] A. Gaidot,[65] S. F. Ganzhur,[65] G. Hamel de Monchenault,[65] W. Kozanecki,[65] G. Vasseur,[65] Ch. Yèche,[65] M. Zito,[65] X. R. Chen,[66] H. Liu,[66] W. Park,[66] M. V. Purohit,[66] R. M. White,[66] J. R. Wilson,[66] M. T. Allen,[67] D. Aston,[67] R. Bartoldus,[67] P. Bechtle,[67] R. Claus,[67] J. P. Coleman,[67] M. R. Convery,[67] J. C. Dingfelder,[67] J. Dorfan,[67] G. P. Dubois-Felsmann,[67] W. Dunwoodie,[67] R. C. Field,[67] T. Glanzman,[67] S. J. Gowdy,[67] M. T. Graham,[67] P. Grenier,[67] C. Hast,[67] W. R. Innes,[67] J. Kaminski,[67] M. H. Kelsey,[67] H. Kim,[67] P. Kim,[67] M. L. Kocian,[67] D. W. G. S. Leith,[67] S. Li,[67] S. Luitz,[67] V. Luth,[67] H. L. Lynch,[67] D. B. MacFarlane,[67] H. Marsiske,[67] R. Messner,[67] D. R. Muller,[67] C. P. O'Grady,[67] I. Ofte,[67] A. Perazzo,[67] M. Perl,[67] T. Pulliam,[67] B. N. Ratcliff,[67] A. Roodman,[67] A. A. Salnikov,[67] R. H. Schindler,[67] J. Schwiening,[67] A. Snyder,[67] D. Su,[67] M. K. Sullivan,[67] K. Suzuki,[67] S. K. Swain,[67] J. M. Thompson,[67] J. Va'vra,[67] A. P. Wagner,[67] M. Weaver,[67] W. J. Wisniewski,[67] M. Wittgen,[67] D. H. Wright,[67] A. K. Yarritu,[67] K. Yi,[67] C. C. Young,[67] V. Ziegler,[67] P. R. Burchat,[68] A. J. Edwards,[68] S. A. Majewski,[68] T. S. Miyashita,[68] B. A. Petersen,[68] L. Wilden,[68] S. Ahmed,[69] M. S. Alam,[69] R. Bula,[69] J. A. Ernst,[69] V. Jain,[69] B. Pan,[69] M. A. Saeed,[69] F. R. Wappler,[69] S. B. Zain,[69] M. Krishnamurthy,[70] S. M. Spanier,[70] R. Eckmann,[71] J. L. Ritchie,[71] A. M. Ruland,[71] C. J. Schilling,[71] R. F. Schwitters,[71] J. M. Izen,[72] X. C. Lou,[72] S. Ye,[72] F. Bianchi,[73] F. Gallo,[73] D. Gamba,[73] M. Pelliccioni,[73] M. Bomben,[74] L. Bosisio,[74] C. Cartaro,[74] F. Cossutti,[74] G. Della Ricca,[74] L. Lanceri,[74] L. Vitale,[74] V. Azzolini,[75] N. Lopez-March,[75] F. Martinez-Vidal,[75, ¶] D. A. Milanes,[75] A. Oyanguren,[75] J. Albert,[76] Sw. Banerjee,[76] B. Bhuyan,[76] K. Hamano,[76] R. Kowalewski,[76] I. M. Nugent,[76] J. M. Roney,[76] R. J. Sobie,[76] P. F. Harrison,[77] J. Ilic,[77] T. E. Latham,[77] G. B. Mohanty,[77] H. R. Band,[78] X. Chen,[78] S. Dasu,[78] K. T. Flood,[78] J. J. Hollar,[78] P. E. Kutter,[78] Y. Pan,[78] M. Pierini,[78] R. Prepost,[78] S. L. Wu,[78] and H. Neal[79]

(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]Princeton University, Princeton, New Jersey 08544, USA
[62]Università di Roma La Sapienza, Dipartimento di Fisica and INFN, I-00185 Roma, Italy
[63]Universität Rostock, D-18051 Rostock, Germany
[64]Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom
[65]DSM/Dapnia, CEA/Saclay, F-91191 Gif-sur-Yvette, France
[66]University of South Carolina, Columbia, South Carolina 29208, USA
[67]Stanford Linear Accelerator Center, Stanford, California 94309, USA
[68]Stanford University, Stanford, California 94305-4060, USA
[69]State University of New York, Albany, New York 12222, USA
[70]University of Tennessee, Knoxville, Tennessee 37996, USA
[71]University of Texas at Austin, Austin, Texas 78712, USA
[72]University of Texas at Dallas, Richardson, Texas 75083, USA
[73]Università di Torino, Dipartimento di Fisica Sperimentale and INFN, I-10125 Torino, Italy
[74]Università di Trieste, Dipartimento di Fisica and INFN, I-34127 Trieste, Italy
[75]IFIC, Universitat de Valencia-CSIC, E-46071 Valencia, Spain
[76]University of Victoria, Victoria, British Columbia, Canada V8W 3P6
[77]Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom
[78]University of Wisconsin, Madison, Wisconsin 53706, USA
[79]Yale University, New Haven, Connecticut 06511, USA

(Dated: December 19, 2007)

We present a search for the decays $B^0 \to e^+e^-$, $B^0 \to \mu^+\mu^-$and $B^0 \to e^\pm\mu^\mp$using data collected with the *BABAR* detector at the PEP-II e^+e^- collider at SLAC. Using a dataset corresponding to 384×10^6 $B\overline{B}$ pairs, we do not find evidence of any of the three decay modes. We obtain upper limit on the branching fractions, at 90% confidence level, of $\mathcal{B}(B^0 \to e^+e^-) < 11.3 \times 10^{-8}$, $\mathcal{B}(B^0 \to \mu^+\mu^-) < 5.2 \times 10^{-8}$, and $\mathcal{B}(B^0 \to e^\pm\mu^\mp) < 9.2 \times 10^{-8}$.

PACS numbers: 13.20.He,14.40.Nd

The standard model (SM) of particle physics does not allow flavor changing neutral currents at tree-level, and decays of this kind are predicted to have very small branching fractions. This makes rare decays particularly interesting for the detection of possible new physics (NP) beyond the SM, such as supersymmetry [1] (SUSY): loop contributions from heavy partners of the SM particles predicted in these models might induce, for certain decay modes, branching fractions significantly larger than the values predicted by the SM.

The leptonic decays $B^0 \to l^+l'^-$ (where $l^+l'^-$ stands for e^+e^-, $\mu^+\mu^-$ or $e^\pm\mu^\mp$; charge conjugation is implied throughout) are particularly interesting among rare decays, since a prediction of the decay rate in the context of the SM can be obtained with a relatively small error, due to the limited impact of long-distance hadronic corrections [2]. In the SM, $B^0 \to l^+l^-$ decays proceed through diagrams such as those shown in Fig. 1. These contributions are highly suppressed since they involve a $b \to d$ transition and require an internal quark annihilation within the B meson. The decays are also helicity suppressed by factors of $(m_\ell/m_B)^2$, where m_ℓ is the mass of the lepton and m_B the mass of the B meson.

In addition, B^0 decays to leptons of two different flavors violate lepton flavor conservation, so they are forbidden in the SM. This feature provides a handle to discriminate among different NP models [4].

The $B^0 \to l^+l'^-$ decays are sensitive to NP also in a large set of models with Minimal Flavor Violation [5] (MFV), in which the NP Lagrangian is flavor blind at the typical mass scale of new heavy states, with reduced effects on flavor physics at the B mass scale [6]. In the context of MFV models, NP corrections to $B^0 \to l^+l'^-$ are characterized by interesting correlations with other rare decays for a particular choice of some fundamental parameters (as in the case of small [7] or large [8] $\tan\beta$ in SUSY models with MFV). A precise determination of the decay rate of $B^0 \to l^+l'^-$ would allow different NP scenarios to be disentangled.

As shown in Table I, the present experimental limits on $B^0 \to l^+l'^-$ are several orders of magnitude larger than SM expectations. Nevertheless, improved experimental bounds will restrict the allowed parameter space of several NP models.

The search for the $B^0 \to \tau^+\tau^-$ decay has been presented in a previous paper [3].

In this paper, we present a search for $B^0 \to l^+l'^-$ decay using data collected with the *BABAR* detector [13] at the PEP-II e^+e^- storage ring at SLAC. The collider is operated at the $\Upsilon(4S)$ resonance with asymmetric beam energies, producing a boost ($\beta\gamma \approx 0.56$) of the $\Upsilon(4S)$ along the collision axis.

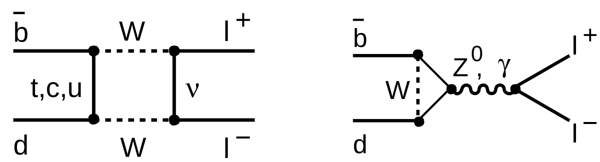

FIG. 1: Representative Feynman diagrams for $B^0 \to l^+l^-$ in the Standard Model.

TABLE I: The expected branching fractions in the Standard Model [2] and the available upper limits (UL) at 90% C.L.

Decay mode	$B^0 \to e^+e^-$	$B^0 \to \mu^+\mu^-$	$B^0 \to e^\pm\mu^\mp$
SM prediction	1.9×10^{-15}	8.0×10^{-11}	0
BABAR [9]	6.1×10^{-8}	8.3×10^{-8}	18×10^{-8}
Belle [10]	1.9×10^{-7}	1.6×10^{-7}	1.7×10^{-7}
CDF [11]	-	2.3×10^{-8}	-
CLEO [12]	8.3×10^{-7}	6.1×10^{-7}	15×10^{-7}

The dataset used consists of 384×10^6 $B\overline{B}$ pairs accumulated at the $\Upsilon(4S)$ resonance ("on-resonance"), equivalent to an integrated luminosity of 347 fb^{-1}, and 37 fb^{-1} accumulated at a center-of-mass (CM) energy about 40 MeV below the $\Upsilon(4S)$ resonance ("off-resonance"). The latter sample is used to characterize background contributions not originating from B decays.

Hadronic two body decays of B mesons such as $B^0 \to \pi^+\pi^-$ and $B^0 \to K^\pm\pi^\mp$ have the same event topology as the leptonic ones and are therefore the main source of background from B decays. We use Monte Carlo (MC) simulations [14] of $B^0 \to e^+e^-$, $B^0 \to \mu^+\mu^-$, $B^0 \to e^\pm\mu^\mp$ decays (signal) and $B^0 \to \pi^+\pi^-$ and $B^0 \to K^\pm\pi^\mp$ (background) of approximately 3×10^5 events each to optimize event selection criteria and to estimate efficiencies.

Charged particles are detected and their momenta measured by the combination of a silicon vertex tracker, consisting of five layers of double-sided silicon detectors, and a 40-layer central drift chamber, both operating in the 1.5-T magnetic field of a solenoid. The tracking system covers 92% of the solid angle in the CM frame.

Identification of charged hadrons is provided by the average energy loss ($\mathrm{d}E/\mathrm{d}x$) in the tracking devices and by an internally-reflecting ring-imaging Cherenkov detector. For lepton identification, we also use the energy deposit in the electromagnetic calorimeter consisting of 6580 CsI(Tl) crystals and the pattern of hits in resistive plate chambers (partially upgraded to limited streamer tubes for a subset of the data used in this analysis) interleaved with the passive material comprising the solenoid magnetic flux return.

We reconstruct B^0 meson candidates from two oppositely charged tracks originating from a common vertex. Signal events are characterized by two kinematic quantities:

$$m_{\rm ES} \equiv \sqrt{(s/2 + \mathbf{p_0}\cdot\mathbf{p_B})^2/E_0^2 - p_B^2} \qquad (1)$$

$$\Delta E \equiv E_B^* - \sqrt{s}/2, \qquad (2)$$

where $\sqrt{s}/2$ is the beam energy in the CM frame, the subscripts 0 and B refer to the initial $\Upsilon(4S)$ and to the B candidate in the laboratory frame, respectively, and the asterisk denotes the $\Upsilon(4S)$ rest frame. In Eq. (1), the variable s is used as opposed to E_B^* because s is known with much greater precision and the resulting correlation between $m_{\rm ES}$ and ΔE is nearly zero. For correctly reconstructed B^0 mesons, $m_{\rm ES}$ peaks at the mass of the B^0 meson with RMS of about 2.5 MeV/c^2, and ΔE peaks at zero with RMS of about 25 MeV. We require $|\Delta E| < 150$ MeV and $m_{\rm ES} > 5.2$ GeV/c^2.

Since we use the pion mass hypothesis for the reconstruction of tracks, the distribution of ΔE peaks near zero for the $\pi^+\pi^-$ and leptonic modes and at -50 MeV for $K^\pm\pi^\mp$. The mass hypothesis does not affect the distribution of $m_{\rm ES}$.

Energy loss by electrons due to final state radiation or Bremsstrahlung in detector material leads to tails in the ΔE and $m_{\rm ES}$ distributions, in particular for the $B^0 \to e^+e^-$ decay mode. We partially correct for this effect by adding the momentum of a photon emitted at a small angle from the track to the electron momentum.

We apply stringent requirements on particle identification (PID) to reduce the contamination from misidentified hadrons and leptons. In this way, we retain $\sim 93\%$ ($\sim 73\%$) of the electrons (muons), with a misidentification rate for pions of less than $\sim 0.1\%$ ($\sim 3\%$).

According to the information provided by the PID, we separate our dataset into three samples, $2e$, 2μ, and $1\mu1e$, containing events with two electrons, two muons and one muon and one electron, respectively. The rest of the dataset ($h^+h'^-$) comprises two oppositely charged hadrons and is used to characterize background contamination to the three signal samples.

Based on MC simulations, we expect negligible cross feed of events between the leptonic and hadronic data samples.

Contamination from non-resonant $q\overline{q}$ ($q = u, d, s, c$) and $\tau^+\tau^-$ production is reduced by exploiting their different event topology with respect of that of the signal events. In particular, we examine the distribution of final-state particles in the rest frame of the $\Upsilon(4S)$ candidate, in which the fragmentation of a $B\overline{B}$ pair (non-resonant event) produces an isotropic (jet-like) angular distribution of the particles.

Non-$B\overline{B}$ events are rejected by requiring the cosine of the sphericity angle [15] to be $|\cos\theta_S| < 0.8$, and the second normalized Fox-Wolfram moment [16] to be $R_2 < 0.95$. In addition, we use a Fisher discriminant [17] ($\mathcal{F}$) in the maximum likelihood (ML) fit to separate the residual background from signal events. $\mathcal{F}$ is constructed from the CM momentum p_i and angle θ_i of each particle i in the rest of the event (ROE) with respect to the thrust axis [18] of the B candidate.

$$\mathcal{F} \equiv 0.5319 - 0.6023 L_0 + 1.2698 L_2, \qquad (3)$$

where $L_0 \equiv \sum_i^{\rm ROE} p_i$ and $L_2 \equiv \sum_i^{\rm ROE} p_i \cos^2\theta_i$. The coefficients of the linear combination have been optimized on samples of signal and background simulated events. Since the variable $\mathcal{F}$ depends only on the ROE, we use the same coefficients for the three leptonic decays in the ML fit.

The background from other $B\overline{B}$ events is found to be negligible after applying the PID requirements. Backgrounds originating from QED events (electrons and muons coming from e^+e^- interactions) are rejected by requiring more than four charged tracks in the event.

To ensure the quality of the measurement of the Cherenkov angle θ_c, we require more than five detected Cherenkov photons and $\theta_c > 0$. For pion or lepton candidates, in order to reject protons, we require θ_c to be within 4σ of the value expected for pions. For kaon candidates, we require θ_c to be within 4σ of the expected value for kaons.

Applying the criteria described above, we select 67 events in the $2e$ sample, 56 in the 2μ sample, 86 in the $1\mu1e$ sample and $\approx 94\times10^3$ in the $h^+h'^-$ sample.

Among these events, the three signal yields are independently determined by ML fits on the $2e$, 2μ and $1\mu1e$ samples. Each likelihood function is based on the variables $m_{\rm ES}$, ΔE and $\mathcal{F}$. The probability density functions (PDFs) for the signal $m_{\rm ES}$ and ΔE distributions are parameterized as:

$$f(x) = \exp\left(-\frac{(x-\mu)^2}{2\cdot\sigma_{R/L}^2 + \alpha_{R/L}\cdot(x-\mu)^2}\right), \qquad (4)$$

where μ is the maximum, $\sigma_{R/L}$ represent the standard deviation of the Gaussian component and $\alpha_{R/L}$ describe the non-Gaussian tails of the PDF for $x > \mu$ (R) and $x < \mu$ (L). The $\mathcal{F}$ distribution for signal events is described by a Gaussian function with different RMS on the left and right side. The PDF of the background $m_{\rm ES}$

distribution is parameterized by an ARGUS [19] function, the background ΔE distribution by a second order polynomial and the background $\mathcal{F}$ distribution by the sum of two Gaussian functions. Figure 2 shows the estimated background distributions for the three subsamples (solid lines) and, just for comparison, the corresponding signal PDFs obtained from Monte Carlo (dotted lines) with arbitrary normalization.

We find that the residual background distributions of $m_{\rm ES}$, ΔE and $\mathcal{F}$ are the same in the three leptonic samples. This has been verified using data in the off-resonance sample and on-resonance events populating the kinematic sidebands ($m_{\rm ES} < 5.27$ GeV/c^2 or $|\Delta E| > 150$ MeV).

In the fit the shape parameters for the $B^0 \to l^+l'^-$ (signal) PDFs are obtained from the MC simulation with a correction factor that accounts for differences between data and MC, while the background PDF shape parameters are determined on data with a procedure described below.

We determine the parameters of the background PDFs by fitting their distribution on the $h^+h'^-$ sample, where we use the Cherenkov angle to separate $B^0 \to \pi^+\pi^-$ and $B^0 \to K^\pm\pi^\mp$.

The yields of $B^0 \to \pi^+\pi^-$ and $K^\pm\pi^\mp$ in our $h^+h'^-$ sample are consistent with the results of the previous BABAR analysis [21]. We find ~ 600 signal and $\sim 3.5\times10^4$ background events for $\pi^+\pi^-$, ~ 2200 signal and $\sim 2.3\times 10^4$ background events for $K^\pm\pi^\mp$.

The background shape parameters in the $B^0 \to l^+l'^-$ fit are fixed to the central values obtained in the fit to $B^0 \to \pi^+\pi^-$ and $B^0 \to K^\pm\pi^\mp$ samples, and their errors are used to estimate the associated systematic uncertainty on the leptonic yields.

We find no bias in the background shape parameters determined by the procedure described above on a large number of MC simulated $h^+h'^-$ event samples.

We correct for discrepancies between data and MC in the $B^0 \to l^+l'^-$ signal shape parameters by rescaling the PDF parameters obtained from the simulation by the ratio between the values of the $B^0 \to \pi^+\pi^-$ PDF parameters in data and MC.

The knowledge of the rescaled shapes is limited by the size of the $B^0 \to \pi^+\pi^-$ component in data, which causes a strong correlation among the parameters of each signal PDF. In order to avoid double-counting of these effects, we take the largest observed deviation as the systematic error induced on the leptonic yields. The errors on the signal yields due to the PDF shapes are ~ 1.1, ~ 0.4 and ~ 0.2 events for the e^+e^-, $\mu^+\mu^-$ and $e^\pm\mu^\mp$ channels, respectively.

Our results are summarized in Table II. We find no evidence of signal in any of the three modes. Using a bayesian approach, a 90% probability upper limit (UL) on the branching fraction (BF) is calculated as

$$\int_0^{UL} \mathcal{L}(BF)\, dBF \Big/ \int_0^{\infty} \mathcal{L}(BF)\, dBF = 0.9. \quad (5)$$

The BF is calculated as

$$BF \equiv \frac{N_{ll'}}{\epsilon_{ll'} N_{B\overline{B}}} \ , \quad (6)$$

with $N_{ll'}$ indicating the signal yield, $\epsilon_{ll'}$ the reconstruction efficiency, and $N_{B\overline{B}}$ the number of $B\overline{B}$ pairs in the dataset, $N_{B\overline{B}} = (383.6 \pm 4.2) \times 10^6$. We make the assumption that the $\Upsilon(4S)$ branching fractions to B^+B^- and $B^0\overline{B}^0$ are equal.

The likelihood $\mathcal{L}(BF)$ is obtained by including in the likelihood function for the signal yield $\mathcal{L}(N_{ll'})$ the systematic errors on $N_{ll'}$ and the total number of $B\overline{B}$ pairs, and the statistical and systematic errors on the efficiency $\epsilon_{ll'}$. We use the relation of Eq.(6) and assume Gaussian shapes for the errors. Figure 3 shows the likelihood distributions of the three leptonic decays.

We evaluate the efficiencies for individual selection criteria from MC simulation and correct the results for small differences between the simulation and the data. We take these observed differences as a measure of the systematic uncertainties on the efficiencies.

The efficiency of PID requirements is calculated by using MC simulations of signal events. It is then corrected with efficiency ratios computed on data and MC, as function of track charge, momentum, and polar angle. We take into account the systematic error associated to this correction.

The total systematic error on the efficiencies is $\sim 4\%$, calculated as the sum in quadrature of all these contributions.

In summary, we find no evidence of signal for $B^0 \to l^+l'^-$ and place 90% confidence level upper limits on the branching fractions of $B^0 \to e^+e^-$, $\mu^+\mu^-$ and $e^\pm\mu^\mp$.

Table II reports the efficiency, the number of signal events and the UL expected in each of these modes based on MC simulation for a sample of the size of our data sample.

The present result on $B^0 \to e^\pm\mu^\mp$ and $B^0 \to \mu^+\mu^-$ improve the previous BABAR upper limits [9] based on 111 fb^{-1}.

The upper limit reported here for $B^0 \to e^+e^-$ is higher than the value obtained in [9]. In our previous paper we used a largely frequentist approach [22] that does not explicitly require a non-negative signal. The present results supercede our previous results: the analysis has a higher sensitivity, estimated from the value of the expected UL, and is based on a larger dataset that includes the sample used in [9].

We are grateful for the excellent luminosity and machine conditions provided by our PEP-II colleagues, and

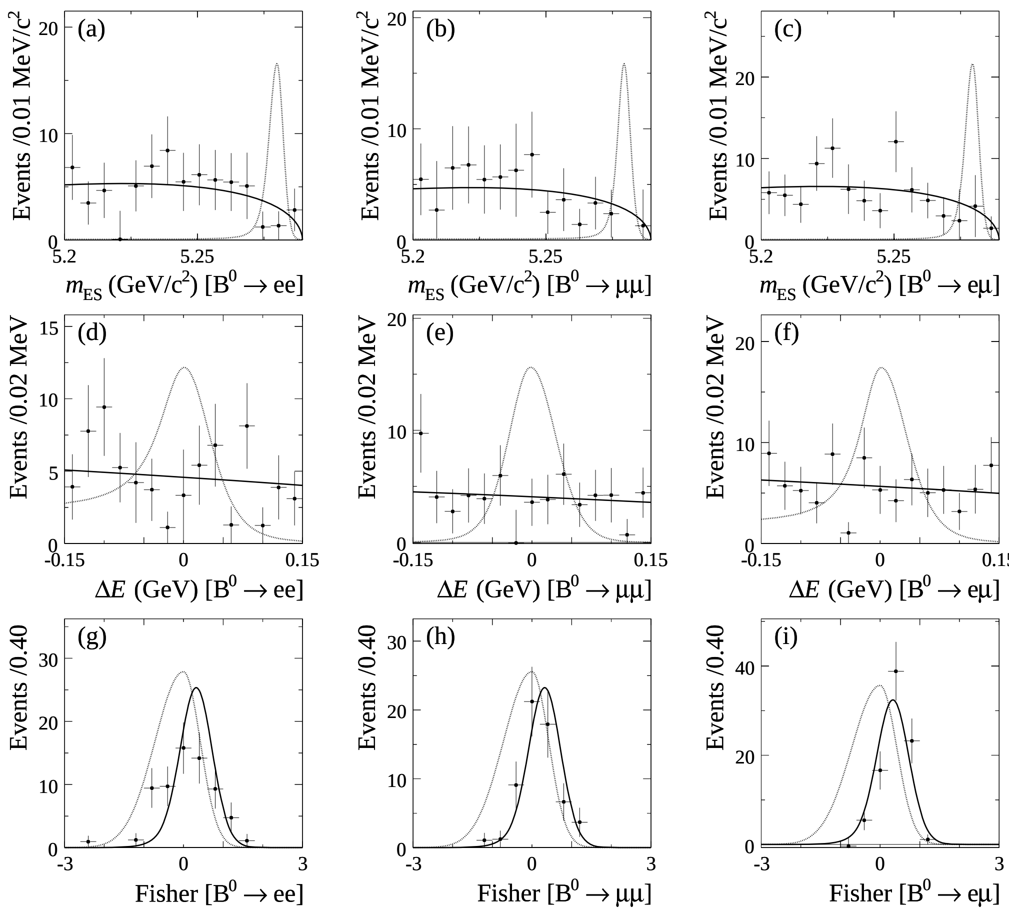

FIG. 2: Distribution of events in $m_{\rm ES}$ (a,b,c), ΔE (d,e,f) and $\mathcal{F}$ (g,h,i) for $B^0 \to e^+e^-$ (left), $B^0 \to \mu^+\mu^-$ (middle) and $B^0 \to e^\pm\mu^\mp$ (right). The overlaid solid curves in each plot are the background ${}_sPlot$ [20] distributions obtained when the corresponding component is ignored in the maximum likelihood fit and the likelihood maximized with respect to all the other components. The dotted line is the PDF obtained from signal Monte Carlo with arbitrary normalization.

TABLE II: Efficiency ($\epsilon_{ll'}$), number of signal events ($N_{ll'}$), 90% C.L. Upper Limit on the BF (UL(BF)) for the three leptonic decays $B^0 \to e^+e^-$, $B^0 \to \mu^+\mu^-$ and $B^0 \to e^\pm\mu^\mp$ and the corresponding expected value based on MC simulation.

	$\epsilon_{ll'}(\%)$	$N_{ll'}$	UL(BF) $\times 10^{-8}$	Exp(UL)
$B^0 \to e^+e^-$	16.6 ± 0.3	0.6 ± 2.1	11.3	7.4
$B^0 \to \mu^+\mu^-$	15.7 ± 0.2	-4.9 ± 1.4	5.2	5.9
$B^0 \to e^\pm\mu^\mp$	17.1 ± 0.2	1.1 ± 1.8	9.2	6.3

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), MES (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
† Now at Tel Aviv University, Tel Aviv, 69978, Israel
‡ 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] K. S. Babu and C. F. Kolda, Phys. Rev. Lett. **84**, 228 (2000); P. H. Chankowski and L. Slawianowska, Phys. Rev. D **63**, 054012 (2001); C. Bobeth, T. Ewerth, F. Kruger, J. Urban, Phys. Rev. D **64**, 074014 (2001).
[2] M. Misiak and J. Urban, Phys. Lett. B **451**, 161 (1999); G. Buchalla and A. J. Buras, Nucl. Phys. B **548**, 309 (1999).
[3] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **96**, 241802 (2006).
[4] M. Blanke *et al.*, JHEP **0705**, 013 (2007); R. A. Diaz,

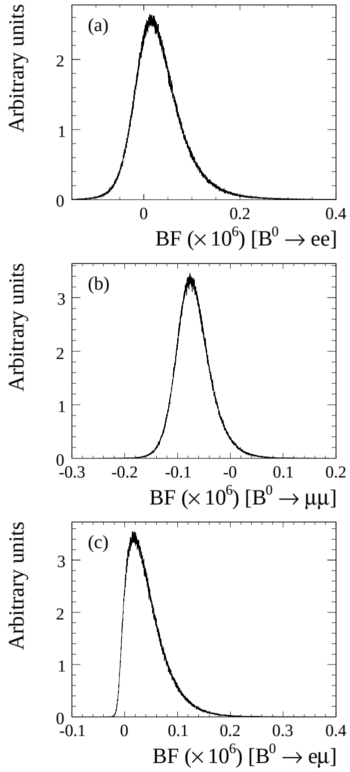

FIG. 3: Distribution of the likelihood as function of the BF for e^+e^- (a), $\mu^+\mu^-$ (b) and $e^\pm\mu^\mp$ (c) decays.

Eur. Phys. J. C **41**, 305 (2005); A. Ilakovac Phys. Rev. D **62**, 036010 (2000).

[5] A. J. Buras, Acta Phys. Polon. B **34**, 5615 (2003); G. D'Ambrosio *et al.*, Nucl. Phys. B **645**, 155 (2002).

[6] A. J. Buras *et al.*, Phys. Lett. B **500**, 161 (2001).

[7] C. Bobeth *et al.*, Nucl. Phys. B **726**, 252 (2005).

[8] G. Isidori and A. Retico, JHEP **0111**, 001 (2001); G. Isidori and P. Paradisi, Phys. Lett. B **639**, 499 (2006).

[9] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **94**, 221803 (2005).

[10] Belle Collaboration, M.-C. Chang *et al.*, Phys. Rev. D **68**, 111101(R) (2003).

[11] CDF Public note #8176. `http://www-cdf.fnal.gov/physics/new/bottom/060316.blessed-bsmumu3/bsmumupub3_v02.ps` .

[12] CLEO Collaboration, T. Bergfeld *et al.*, Phys. Rev. D **62**, 091102(R) (2000).

[13] *BABAR* Collaboration, B. Aubert *et al.*, Nucl. Instrum. Methods **A479**, 1 (2002).

[14] S. Agostinelli *et al.*, Nucl. Instrum. Methods **A506**, 250 (2003).

[15] S. L. Wu, Phys. Rep. **107**, 59 (1984).

[16] G.C. Fox and S. Wolfram, Phys. Rev. Lett. **41**, 1581 (1978).

[17] R. A. Fisher, Annals Eugen. **7**, 179 (1936).

[18] S. Brandt *et al.* Phys. Lett. **12**, 57 (1964); E. Farhi, Phys. Rev. Lett. **39**, 1587 (1977).

[19] H. Albrecht *et al.*, [ARGUS Collaboration], Phys. Lett. B **241**, 278 (1990)

[20] M. Pivk and F. R. Le Diberder, Nucl. Instrum. Meth. A **555**, 356 (2005).

[21] B. Aubert *et al.* [BABAR Collaboration], Phys. Rev. D **75**, 012008 (2007).

[22] R. Barlow, Comput. Phys. Commun. **149**, 97 (2002).