

## Observation of $B \rightarrow \eta' K^*$ and Evidence for $B^+ \rightarrow \eta' \rho^+$

B. Aubert,<sup>1</sup> R. Barate,<sup>1</sup> M. Bona,<sup>1</sup> D. Boutigny,<sup>1</sup> F. Couderc,<sup>1</sup> Y. Karyotakis,<sup>1</sup> J. P. Lees,<sup>1</sup> V. Poireau,<sup>1</sup> V. Tisserand,<sup>1</sup> A. Zghiche,<sup>1</sup> E. Grauges,<sup>2</sup> A. Palano,<sup>3</sup> J. C. Chen,<sup>4</sup> N. D. Qi,<sup>4</sup> G. Rong,<sup>4</sup> P. Wang,<sup>4</sup> Y. S. Zhu,<sup>4</sup> G. Eigen,<sup>5</sup> I. Ofte,<sup>5</sup> B. Stugu,<sup>5</sup> G. S. Abrams,<sup>6</sup> M. Battaglia,<sup>6</sup> D. N. Brown,<sup>6</sup> J. Button-Shafer,<sup>6</sup> R. N. Cahn,<sup>6</sup> E. Charles,<sup>6</sup> M. S. Gill,<sup>6</sup> Y. Groysman,<sup>6</sup> R. G. Jacobsen,<sup>6</sup> J. A. Kadyk,<sup>6</sup> L. T. Kerth,<sup>6</sup> Yu. G. Kolomensky,<sup>6</sup> G. Kukartsev,<sup>6</sup> G. Lynch,<sup>6</sup> L. M. Mir,<sup>6</sup> T. J. Orimoto,<sup>6</sup> M. Pripstein,<sup>6</sup> N. A. Roe,<sup>6</sup> M. T. Ronan,<sup>6</sup> W. A. Wenzel,<sup>6</sup> P. del Amo Sanchez,<sup>7</sup> M. Barrett,<sup>7</sup> K. E. Ford,<sup>7</sup> T. J. Harrison,<sup>7</sup> A. J. Hart,<sup>7</sup> C. M. Hawkes,<sup>7</sup> S. E. Morgan,<sup>7</sup> A. T. Watson,<sup>7</sup> T. Held,<sup>8</sup> H. Koch,<sup>8</sup> B. Lewandowski,<sup>8</sup> M. Pelizaeus,<sup>8</sup> K. Peters,<sup>8</sup> T. Schroeder,<sup>8</sup> M. Steinke,<sup>8</sup> J. T. Boyd,<sup>9</sup> J. P. Burke,<sup>9</sup> W. N. Cottingham,<sup>9</sup> D. Walker,<sup>9</sup> T. Cuhadar-Donszelmann,<sup>10</sup> B. G. Fulsom,<sup>10</sup> C. Hearty,<sup>10</sup> N. S. Knecht,<sup>10</sup> T. S. Mattison,<sup>10</sup> J. A. McKenna,<sup>10</sup> A. Khan,<sup>11</sup> P. Kyberd,<sup>11</sup> M. Saleem,<sup>11</sup> D. J. Sherwood,<sup>11</sup> L. Teodorescu,<sup>11</sup> V. E. Blinov,<sup>12</sup> A. D. Bukin,<sup>12</sup> V. P. Druzhinin,<sup>12</sup> V. B. Golubev,<sup>12</sup> A. P. Onuchin,<sup>12</sup> S. I. Serednyakov,<sup>12</sup> Yu. I. Skovpen,<sup>12</sup> E. P. Solodov,<sup>12</sup> K. Yu. Todyshev,<sup>12</sup> D. S. Best,<sup>13</sup> M. Bondioli,<sup>13</sup> M. Bruinsma,<sup>13</sup> M. Chao,<sup>13</sup> S. Curry,<sup>13</sup> I. Eschrich,<sup>13</sup> D. Kirkby,<sup>13</sup> A. J. Lankford,<sup>13</sup> P. Lund,<sup>13</sup> M. Mandelkern,<sup>13</sup> R. K. Mommsen,<sup>13</sup> W. Roethel,<sup>13</sup> D. P. Stoker,<sup>13</sup> S. Abachi,<sup>14</sup> C. Buchanan,<sup>14</sup> S. D. Foulkes,<sup>15</sup> J. W. Gary,<sup>15</sup> O. Long,<sup>15</sup> B. C. Shen,<sup>15</sup> K. Wang,<sup>15</sup> L. Zhang,<sup>15</sup> H. K. Hadavand,<sup>16</sup> E. J. Hill,<sup>16</sup> H. P. Paar,<sup>16</sup> S. Rahatlou,<sup>16</sup> V. Sharma,<sup>16</sup> J. W. Berryhill,<sup>17</sup> C. Campagnari,<sup>17</sup> A. Cunha,<sup>17</sup> B. Dahmes,<sup>17</sup> T. M. Hong,<sup>17</sup> D. Kovalskyi,<sup>17</sup> J. D. Richman,<sup>17</sup> T. W. Beck,<sup>18</sup> A. M. Eisner,<sup>18</sup> C. J. Flacco,<sup>18</sup> C. A. Heusch,<sup>18</sup> J. Kroseberg,<sup>18</sup> W. S. Lockman,<sup>18</sup> G. Nesom,<sup>18</sup> T. Schalk,<sup>18</sup> B. A. Schumm,<sup>18</sup> A. Seiden,<sup>18</sup> P. Spradlin,<sup>18</sup> D. C. Williams,<sup>18</sup> M. G. Wilson,<sup>18</sup> J. Albert,<sup>19</sup> E. Chen,<sup>19</sup> A. Dvoretzkii,<sup>19</sup> F. Fang,<sup>19</sup> D. G. Hitlin,<sup>19</sup> I. Narsky,<sup>19</sup> T. Piatenko,<sup>19</sup> F. C. Porter,<sup>19</sup> A. Ryd,<sup>19</sup> A. Samuel,<sup>19</sup> G. Mancinelli,<sup>20</sup> B. T. Meadows,<sup>20</sup> K. Mishra,<sup>20</sup> M. D. Sokoloff,<sup>20</sup> F. Blanc,<sup>21</sup> P. C. Bloom,<sup>21</sup> S. Chen,<sup>21</sup> W. T. Ford,<sup>21</sup> J. F. Hirschauer,<sup>21</sup> A. Kreisel,<sup>21</sup> M. Nagel,<sup>21</sup> U. Nauenberg,<sup>21</sup> A. Olivas,<sup>21</sup> W. O. Ruddick,<sup>21</sup> J. G. Smith,<sup>21</sup> K. A. Ulmer,<sup>21</sup> S. R. Wagner,<sup>21</sup> J. Zhang,<sup>21</sup> A. Chen,<sup>22</sup> E. A. Eckhart,<sup>22</sup> A. Soffer,<sup>22</sup> W. H. Toki,<sup>22</sup> R. J. Wilson,<sup>22</sup> F. Winklmeier,<sup>22</sup> Q. Zeng,<sup>22</sup> D. D. Altenburg,<sup>23</sup> E. Feltresi,<sup>23</sup> A. Hauke,<sup>23</sup> H. Jasper,<sup>23</sup> A. Petzold,<sup>23</sup> B. Spaan,<sup>23</sup> T. Brandt,<sup>24</sup> V. Klose,<sup>24</sup> H. M. Lacker,<sup>24</sup> W. F. Mader,<sup>24</sup> R. Nogowski,<sup>24</sup> J. Schubert,<sup>24</sup> K. R. Schubert,<sup>24</sup> R. Schwierz,<sup>24</sup> J. E. Sundermann,<sup>24</sup> A. Volk,<sup>24</sup> D. Bernard,<sup>25</sup> G. R. Bonneaud,<sup>25</sup> P. Grenier,<sup>25,\*</sup> E. Latour,<sup>25</sup> Ch. Thiebaut,<sup>25</sup> M. Verderi,<sup>25</sup> P. J. Clark,<sup>26</sup> W. Gradl,<sup>26</sup> F. Muheim,<sup>26</sup> S. Playfer,<sup>26</sup> A. I. Robertson,<sup>26</sup> Y. Xie,<sup>26</sup> M. Andreotti,<sup>27</sup> D. Bettoni,<sup>27</sup> C. Bozzi,<sup>27</sup> R. Calabrese,<sup>27</sup> G. Cibinetto,<sup>27</sup> E. Luppi,<sup>27</sup> M. Negrini,<sup>27</sup> A. Petrella,<sup>27</sup> L. Piemontese,<sup>27</sup> E. Prencipe,<sup>27</sup> F. Anulli,<sup>28</sup> R. Baldini-Ferrolì,<sup>28</sup> A. Calcaterra,<sup>28</sup> R. de Sangro,<sup>28</sup> G. Finocchiaro,<sup>28</sup> S. Pacetti,<sup>28</sup> P. Patteri,<sup>28</sup> I. M. Peruzzi,<sup>28,†</sup> M. Piccolo,<sup>28</sup> M. Rama,<sup>28</sup> A. Zallo,<sup>28</sup> A. Buzzo,<sup>29</sup> R. Capra,<sup>29</sup> R. Contri,<sup>29</sup> M. Lo Vetere,<sup>29</sup> M. M. Macri,<sup>29</sup> M. R. Monge,<sup>29</sup> S. Passaggio,<sup>29</sup> C. Patrignani,<sup>29</sup> E. Robutti,<sup>29</sup> A. Santroni,<sup>29</sup> S. Tosi,<sup>29</sup> G. Brandenburg,<sup>30</sup> K. S. Chaisanguanthum,<sup>30</sup> M. Morii,<sup>30</sup> J. Wu,<sup>30</sup> R. S. Dubitzky,<sup>31</sup> J. Marks,<sup>31</sup> S. Schenk,<sup>31</sup> U. Uwer,<sup>31</sup> D. J. Bard,<sup>32</sup> W. Bhimji,<sup>32</sup> D. A. Bowerman,<sup>32</sup> P. D. Dauncey,<sup>32</sup> U. Egede,<sup>32</sup> R. L. Flack,<sup>32</sup> J. A. Nash,<sup>32</sup> M. B. Nikolich,<sup>32</sup> W. Panduro Vazquez,<sup>32</sup> P. K. Behera,<sup>33</sup> X. Chai,<sup>33</sup> M. J. Charles,<sup>33</sup> U. Mallik,<sup>33</sup> N. T. Meyer,<sup>33</sup> V. Ziegler,<sup>33</sup> J. Cochran,<sup>34</sup> H. B. Crawley,<sup>34</sup> L. Dong,<sup>34</sup> V. Eyges,<sup>34</sup> W. T. Meyer,<sup>34</sup> S. Prell,<sup>34</sup> E. I. Rosenberg,<sup>34</sup> A. E. Rubin,<sup>34</sup> A. V. Gritsan,<sup>35</sup> A. G. Denig,<sup>36</sup> M. Fritsch,<sup>36</sup> G. Schott,<sup>36</sup> N. Arnaud,<sup>37</sup> M. Davier,<sup>37</sup> G. Grosdidier,<sup>37</sup> A. Höcker,<sup>37</sup> F. Le Diberder,<sup>37</sup> V. Lepeltier,<sup>37</sup> A. M. Lutz,<sup>37</sup> A. Oyanguren,<sup>37</sup> S. Pruvot,<sup>37</sup> S. Rodier,<sup>37</sup> P. Roudeau,<sup>37</sup> M. H. Schune,<sup>37</sup> A. Stocchi,<sup>37</sup> W. F. Wang,<sup>37</sup> G. Wormser,<sup>37</sup> C. H. Cheng,<sup>38</sup> D. J. Lange,<sup>38</sup> D. M. Wright,<sup>38</sup> C. A. Chavez,<sup>39</sup> I. J. Forster,<sup>39</sup> J. R. Fry,<sup>39</sup> E. Gabathuler,<sup>39</sup> R. Gamet,<sup>39</sup> K. A. George,<sup>39</sup> D. E. Hutchcroft,<sup>39</sup> D. J. Payne,<sup>39</sup> K. C. Schofield,<sup>39</sup> C. Touramanis,<sup>39</sup> A. J. Bevan,<sup>40</sup> F. Di Lodovico,<sup>40</sup> W. Menges,<sup>40</sup> R. Sacco,<sup>40</sup> G. Cowan,<sup>41</sup> H. U. Flaecher,<sup>41</sup> D. A. Hopkins,<sup>41</sup> P. S. Jackson,<sup>41</sup> T. R. McMahon,<sup>41</sup> S. Ricciardi,<sup>41</sup> F. Salvatore,<sup>41</sup> A. C. Wren,<sup>41</sup> D. N. Brown,<sup>42</sup> C. L. Davis,<sup>42</sup> J. Allison,<sup>43</sup> N. R. Barlow,<sup>43</sup> R. J. Barlow,<sup>43</sup> Y. M. Chia,<sup>43</sup> C. L. Edgar,<sup>43</sup> G. D. Lafferty,<sup>43</sup> M. T. Naisbit,<sup>43</sup> J. C. Williams,<sup>43</sup> J. I. Yi,<sup>43</sup> C. Chen,<sup>44</sup> W. D. Hulsbergen,<sup>44</sup> A. Jawahery,<sup>44</sup> C. K. Lae,<sup>44</sup> D. A. Roberts,<sup>44</sup> G. Simi,<sup>44</sup> G. Blaylock,<sup>45</sup> C. Dallapiccola,<sup>45</sup> S. S. Hertzbach,<sup>45</sup> X. Li,<sup>45</sup> T. B. Moore,<sup>45</sup> S. Saremi,<sup>45</sup> H. Staengle,<sup>45</sup> R. Cowan,<sup>46</sup> G. Sciolla,<sup>46</sup> S. J. Sekula,<sup>46</sup> M. Spitznagel,<sup>46</sup> F. Taylor,<sup>46</sup> R. K. Yamamoto,<sup>46</sup> H. Kim,<sup>47</sup> S. E. Mclachlin,<sup>47</sup> P. M. Patel,<sup>47</sup> S. H. Robertson,<sup>47</sup> A. Lazzaro,<sup>48</sup> V. Lombardo,<sup>48</sup> F. Palombo,<sup>48</sup> J. M. Bauer,<sup>49</sup> L. Cremaldi,<sup>49</sup> V. Eschenburg,<sup>49</sup> R. Godang,<sup>49</sup> R. Kroeger,<sup>49</sup> D. A. Sanders,<sup>49</sup> D. J. Summers,<sup>49</sup> H. W. Zhao,<sup>49</sup> S. Brunet,<sup>50</sup> D. Côté,<sup>50</sup> M. Simard,<sup>50</sup> P. Taras,<sup>50</sup> F. B. Viaud,<sup>50</sup> H. Nicholson,<sup>51</sup> N. Cavallo,<sup>52,‡</sup> G. De Nardo,<sup>52</sup> F. Fabozzi,<sup>52,‡</sup> C. Gatto,<sup>52</sup> L. Lista,<sup>52</sup> D. Monorchio,<sup>52</sup> P. Paolucci,<sup>52</sup> D. Piccolo,<sup>52</sup> C. Sciacca,<sup>52</sup> M. Baak,<sup>53</sup> G. Raven,<sup>53</sup> H. L. Snoek,<sup>53</sup> C. P. Jessop,<sup>54</sup> J. M. LoSecco,<sup>54</sup> T. Allmendinger,<sup>55</sup> G. Benelli,<sup>55</sup> K. K. Gan,<sup>55</sup> K. Honscheid,<sup>55</sup> D. Hufnagel,<sup>55</sup> P. D. Jackson,<sup>55</sup> H. Kagan,<sup>55</sup> R. Kass,<sup>55</sup> A. M. Rahimi,<sup>55</sup> R. Ter-Antonyan,<sup>55</sup> Q. K. Wong,<sup>55</sup> N. L. Blount,<sup>56</sup> J. Brau,<sup>56</sup> R. Frey,<sup>56</sup> O. Igonkina,<sup>56</sup> M. Lu,<sup>56</sup> R. Rahmat,<sup>56</sup> N. B. Sinev,<sup>56</sup> D. Strom,<sup>56</sup> J. Strube,<sup>56</sup> E. Torrence,<sup>56</sup> A. Gaz,<sup>57</sup> M. Margoni,<sup>57</sup>

M. Morandin,<sup>57</sup> A. Pompili,<sup>57</sup> M. Posocco,<sup>57</sup> M. Rotondo,<sup>57</sup> F. Simonetto,<sup>57</sup> R. Stroili,<sup>57</sup> C. Voci,<sup>57</sup> M. Benayoun,<sup>58</sup> J. Chauveau,<sup>58</sup> H. Briand,<sup>58</sup> P. David,<sup>58</sup> L. Del Buono,<sup>58</sup> Ch. de la Vaissière,<sup>58</sup> O. Hamon,<sup>58</sup> B. L. Hartfiel,<sup>58</sup> M. J. J. John,<sup>58</sup> Ph. Leruste,<sup>58</sup> J. Malclès,<sup>58</sup> J. Ocariz,<sup>58</sup> L. Roos,<sup>58</sup> G. Therin,<sup>58</sup> L. Gladney,<sup>59</sup> J. Panetta,<sup>59</sup> M. Biasini,<sup>60</sup> R. Covarelli,<sup>60</sup> C. Angelini,<sup>61</sup> G. Batignani,<sup>61</sup> S. Bettarini,<sup>61</sup> F. Bucci,<sup>61</sup> G. Calderini,<sup>61</sup> M. Carpinelli,<sup>61</sup> R. Cenci,<sup>61</sup> F. Forti,<sup>61</sup> M. A. Giorgi,<sup>61</sup> A. Lusiani,<sup>61</sup> G. Marchiori,<sup>61</sup> M. A. Mazur,<sup>61</sup> M. Morganti,<sup>61</sup> N. Neri,<sup>61</sup> E. Paoloni,<sup>61</sup> G. Rizzo,<sup>61</sup> J. J. Walsh,<sup>61</sup> M. Haire,<sup>62</sup> D. Judd,<sup>62</sup> D. E. Wagoner,<sup>62</sup> J. Biesiada,<sup>63</sup> N. Danielson,<sup>63</sup> P. Elmer,<sup>63</sup> Y. P. Lau,<sup>63</sup> C. Lu,<sup>63</sup> J. Olsen,<sup>63</sup> A. J. S. Smith,<sup>63</sup> A. V. Telnov,<sup>63</sup> F. Bellini,<sup>64</sup> G. Cavoto,<sup>64</sup> A. D’Orazio,<sup>64</sup> D. del Re,<sup>64</sup> E. Di Marco,<sup>64</sup> R. Faccini,<sup>64</sup> F. Ferrarotto,<sup>64</sup> F. Ferroni,<sup>64</sup> M. Gaspero,<sup>64</sup> L. Li Gioi,<sup>64</sup> M. A. Mazzoni,<sup>64</sup> S. Morganti,<sup>64</sup> G. Piredda,<sup>64</sup> F. Polci,<sup>64</sup> F. Safai Tehrani,<sup>64</sup> C. Voena,<sup>64</sup> M. Ebert,<sup>65</sup> H. Schröder,<sup>65</sup> R. Waldi,<sup>65</sup> T. Adye,<sup>66</sup> N. De Groot,<sup>66</sup> B. Franek,<sup>66</sup> E. O. Olaiya,<sup>66</sup> F. F. Wilson,<sup>66</sup> R. Aleksan,<sup>67</sup> S. Emery,<sup>67</sup> A. Gaidot,<sup>67</sup> S. F. Ganzhur,<sup>67</sup> G. Hamel de Monchenault,<sup>67</sup> W. Kozanecki,<sup>67</sup> M. Legendre,<sup>67</sup> G. Vasseur,<sup>67</sup> Ch. Yèche,<sup>67</sup> M. Zito,<sup>67</sup> X. R. Chen,<sup>68</sup> H. Liu,<sup>68</sup> W. Park,<sup>68</sup> M. V. Purohit,<sup>68</sup> J. R. Wilson,<sup>68</sup> M. T. Allen,<sup>69</sup> D. Aston,<sup>69</sup> R. Bartoldus,<sup>69</sup> P. Bechtel,<sup>69</sup> N. Berger,<sup>69</sup> R. Claus,<sup>69</sup> J. P. Coleman,<sup>69</sup> M. R. Convery,<sup>69</sup> M. Cristinziani,<sup>69</sup> J. C. Dingfelder,<sup>69</sup> J. Dorfan,<sup>69</sup> G. P. Dubois-Felsmann,<sup>69</sup> D. Dujmic,<sup>69</sup> W. Dunwoodie,<sup>69</sup> R. C. Field,<sup>69</sup> T. Glanzman,<sup>69</sup> S. J. Gowdy,<sup>69</sup> M. T. Graham,<sup>69</sup> V. Halyo,<sup>69</sup> C. Hast,<sup>69</sup> T. Hryn’ova,<sup>69</sup> W. R. Innes,<sup>69</sup> M. H. Kelsey,<sup>69</sup> P. Kim,<sup>69</sup> D. W. G. S. Leith,<sup>69</sup> S. Li,<sup>69</sup> S. Luitz,<sup>69</sup> V. Luth,<sup>69</sup> H. L. Lynch,<sup>69</sup> D. B. MacFarlane,<sup>69</sup> H. Marsiske,<sup>69</sup> R. Messner,<sup>69</sup> D. R. Muller,<sup>69</sup> C. P. O’Grady,<sup>69</sup> V. E. Ozcan,<sup>69</sup> A. Perazzo,<sup>69</sup> M. Perl,<sup>69</sup> T. Pulliam,<sup>69</sup> B. N. Ratcliff,<sup>69</sup> A. Roodman,<sup>69</sup> A. A. Salnikov,<sup>69</sup> R. H. Schindler,<sup>69</sup> J. Schwiening,<sup>69</sup> A. Snyder,<sup>69</sup> J. Stelzer,<sup>69</sup> D. Su,<sup>69</sup> M. K. Sullivan,<sup>69</sup> K. Suzuki,<sup>69</sup> S. K. Swain,<sup>69</sup> J. M. Thompson,<sup>69</sup> J. Va’vra,<sup>69</sup> N. van Bakel,<sup>69</sup> M. Weaver,<sup>69</sup> A. J. R. Weinstein,<sup>69</sup> W. J. Wisniewski,<sup>69</sup> M. Wittgen,<sup>69</sup> D. H. Wright,<sup>69</sup> A. K. Yarritu,<sup>69</sup> K. Yi,<sup>69</sup> C. C. Young,<sup>69</sup> P. R. Burchat,<sup>70</sup> A. J. Edwards,<sup>70</sup> S. A. Majewski,<sup>70</sup> B. A. Petersen,<sup>70</sup> C. Roat,<sup>70</sup> L. Wilden,<sup>70</sup> S. Ahmed,<sup>71</sup> M. S. Alam,<sup>71</sup> R. Bula,<sup>71</sup> J. A. Ernst,<sup>71</sup> V. Jain,<sup>71</sup> B. Pan,<sup>71</sup> M. A. Saeed,<sup>71</sup> F. R. Wappler,<sup>71</sup> S. B. Zain,<sup>71</sup> W. Bugg,<sup>72</sup> M. Krishnamurthy,<sup>72</sup> S. M. Spanier,<sup>72</sup> R. Eckmann,<sup>73</sup> J. L. Ritchie,<sup>73</sup> A. Satpathy,<sup>73</sup> C. J. Schilling,<sup>73</sup> R. F. Schwitters,<sup>73</sup> J. M. Izen,<sup>74</sup> X. C. Lou,<sup>74</sup> S. Ye,<sup>74</sup> F. Bianchi,<sup>75</sup> F. Gallo,<sup>75</sup> D. Gamba,<sup>75</sup> M. Bomben,<sup>76</sup> L. Bosisio,<sup>76</sup> C. Cartaro,<sup>76</sup> F. Cossutti,<sup>76</sup> G. Della Ricca,<sup>76</sup> S. Dittongo,<sup>76</sup> L. Lanceri,<sup>76</sup> L. Vitale,<sup>76</sup> V. Azzolini,<sup>77</sup> F. Martinez-Vidal,<sup>77</sup> Sw. Banerjee,<sup>78</sup> B. Bhuyan,<sup>78</sup> C. M. Brown,<sup>78</sup> D. Fortin,<sup>78</sup> K. Hamano,<sup>78</sup> R. Kowalewski,<sup>78</sup> I. M. Nugent,<sup>78</sup> J. M. Roney,<sup>78</sup> R. J. Sobie,<sup>78</sup> J. J. Back,<sup>79</sup> P. F. Harrison,<sup>79</sup> T. E. Latham,<sup>79</sup> G. B. Mohanty,<sup>79</sup> M. Pappagallo,<sup>79</sup> H. R. Band,<sup>80</sup> X. Chen,<sup>80</sup> B. Cheng,<sup>80</sup> S. Dasu,<sup>80</sup> M. Datta,<sup>80</sup> K. T. Flood,<sup>80</sup> J. J. Hollar,<sup>80</sup> P. E. Kutter,<sup>80</sup> B. Mellado,<sup>80</sup> A. Mihalyi,<sup>80</sup> Y. Pan,<sup>80</sup> M. Pierini,<sup>80</sup> R. Prepost,<sup>80</sup> S. L. Wu,<sup>80</sup> Z. Yu,<sup>80</sup> and H. Neal<sup>81</sup>

(BABAR Collaboration)

<sup>1</sup>Laboratoire de Physique des Particules, F-74941 Annecy-le-Vieux, France

<sup>2</sup>Universitat de Barcelona, Facultat de Fisica Departament ECM, E-08028 Barcelona, Spain

<sup>3</sup>Università di Bari, Dipartimento di Fisica and INFN, I-70126 Bari, Italy

<sup>4</sup>Institute of High Energy Physics, Beijing 100039, China

<sup>5</sup>University of Bergen, Institute of Physics, N-5007 Bergen, Norway

<sup>6</sup>Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA

<sup>7</sup>University of Birmingham, Birmingham, B15 2TT, United Kingdom

<sup>8</sup>Ruhr Universität Bochum, Institut für Experimentalphysik I, D-44780 Bochum, Germany

<sup>9</sup>University of Bristol, Bristol BS8 1TL, United Kingdom

<sup>10</sup>University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1

<sup>11</sup>Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom

<sup>12</sup>Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia

<sup>13</sup>University of California at Irvine, Irvine, California 92697, USA

<sup>14</sup>University of California at Los Angeles, Los Angeles, California 90024, USA

<sup>15</sup>University of California at Riverside, Riverside, California 92521, USA

<sup>16</sup>University of California at San Diego, La Jolla, California 92093, USA

<sup>17</sup>University of California at Santa Barbara, Santa Barbara, California 93106, USA

<sup>18</sup>University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA

<sup>19</sup>California Institute of Technology, Pasadena, California 91125, USA

<sup>20</sup>University of Cincinnati, Cincinnati, Ohio 45221, USA

<sup>21</sup>University of Colorado, Boulder, Colorado 80309, USA

<sup>22</sup>Colorado State University, Fort Collins, Colorado 80523, USA

<sup>23</sup>Universität Dortmund, Institut für Physik, D-44221 Dortmund, Germany

<sup>24</sup>Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany

- <sup>25</sup>*Ecole Polytechnique, Laboratoire Leprince-Ringuet, F-91128 Palaiseau, France*
- <sup>26</sup>*University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom*
- <sup>27</sup>*Università di Ferrara, Dipartimento di Fisica and INFN, I-44100 Ferrara, Italy*
- <sup>28</sup>*Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy*
- <sup>29</sup>*Università di Genova, Dipartimento di Fisica and INFN, I-16146 Genova, Italy*
- <sup>30</sup>*Harvard University, Cambridge, Massachusetts 02138, USA*
- <sup>31</sup>*Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany*
- <sup>32</sup>*Imperial College London, London, SW7 2AZ, United Kingdom*
- <sup>33</sup>*University of Iowa, Iowa City, Iowa 52242, USA*
- <sup>34</sup>*Iowa State University, Ames, Iowa 50011-3160, USA*
- <sup>35</sup>*Johns Hopkins University, Baltimore, Maryland 21218, USA*
- <sup>36</sup>*Universität Karlsruhe, Institut für Experimentelle Kernphysik, D-76021 Karlsruhe, Germany*
- <sup>37</sup>*Laboratoire de l'Accélérateur Linéaire, IN2P3-CNRS et Université Paris-Sud 11, Centre Scientifique d'Orsay, B.P. 34, F-91898 Orsay Cedex, France*
- <sup>38</sup>*Lawrence Livermore National Laboratory, Livermore, California 94550, USA*
- <sup>39</sup>*University of Liverpool, Liverpool L69 7ZE, United Kingdom*
- <sup>40</sup>*Queen Mary, University of London, E1 4NS, United Kingdom*
- <sup>41</sup>*University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom*
- <sup>42</sup>*University of Louisville, Louisville, Kentucky 40292, USA*
- <sup>43</sup>*University of Manchester, Manchester M13 9PL, United Kingdom*
- <sup>44</sup>*University of Maryland, College Park, Maryland 20742, USA*
- <sup>45</sup>*University of Massachusetts, Amherst, Massachusetts 01003, USA*
- <sup>46</sup>*Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Massachusetts 02139, USA*
- <sup>47</sup>*McGill University, Montréal, Québec, Canada H3A 2T8*
- <sup>48</sup>*Università di Milano, Dipartimento di Fisica and INFN, I-20133 Milano, Italy*
- <sup>49</sup>*University of Mississippi, University, Mississippi 38677, USA*
- <sup>50</sup>*Université de Montréal, Physique des Particules, Montréal, Québec, Canada H3C 3J7*
- <sup>51</sup>*Mount Holyoke College, South Hadley, Massachusetts 01075, USA*
- <sup>52</sup>*Università di Napoli Federico II, Dipartimento di Scienze Fisiche and INFN, I-80126, Napoli, Italy*
- <sup>53</sup>*NIKHEF, National Institute for Nuclear Physics and High Energy Physics, NL-1009 DB Amsterdam, The Netherlands*
- <sup>54</sup>*University of Notre Dame, Notre Dame, Indiana 46556, USA*
- <sup>55</sup>*Ohio State University, Columbus, Ohio 43210, USA*
- <sup>56</sup>*University of Oregon, Eugene, Oregon 97403, USA*
- <sup>57</sup>*Università di Padova, Dipartimento di Fisica and INFN, I-35131 Padova, Italy*
- <sup>58</sup>*Universités Paris VI et VII, Laboratoire de Physique Nucléaire et de Hautes Energies, F-75252 Paris, France*
- <sup>59</sup>*University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA*
- <sup>60</sup>*Università di Perugia, Dipartimento di Fisica and INFN, I-06100 Perugia, Italy*
- <sup>61</sup>*Università di Pisa, Dipartimento di Fisica, Scuola Normale Superiore and INFN, I-56127 Pisa, Italy*
- <sup>62</sup>*Prairie View A&M University, Prairie View, Texas 77446, USA*
- <sup>63</sup>*Princeton University, Princeton, New Jersey 08544, USA*
- <sup>64</sup>*Università di Roma La Sapienza, Dipartimento di Fisica and INFN, I-00185 Roma, Italy*
- <sup>65</sup>*Universität Rostock, D-18051 Rostock, Germany*
- <sup>66</sup>*Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom*
- <sup>67</sup>*DSM/Dapnia, CEA/Saclay, F-91191 Gif-sur-Yvette, France*
- <sup>68</sup>*University of South Carolina, Columbia, South Carolina 29208, USA*
- <sup>69</sup>*Stanford Linear Accelerator Center, Stanford, California 94309, USA*
- <sup>70</sup>*Stanford University, Stanford, California 94305-4060, USA*
- <sup>71</sup>*State University of New York, Albany, New York 12222, USA*
- <sup>72</sup>*University of Tennessee, Knoxville, Tennessee 37996, USA*
- <sup>73</sup>*University of Texas at Austin, Austin, Texas 78712, USA*
- <sup>74</sup>*University of Texas at Dallas, Richardson, Texas 75083, USA*
- <sup>75</sup>*Università di Torino, Dipartimento di Fisica Sperimentale and INFN, I-10125 Torino, Italy*
- <sup>76</sup>*Università di Trieste, Dipartimento di Fisica and INFN, I-34127 Trieste, Italy*
- <sup>77</sup>*IFIC, Universitat de Valencia-CSIC, E-46071 Valencia, Spain*
- <sup>78</sup>*University of Victoria, Victoria, British Columbia, Canada V8W 3P6*
- <sup>79</sup>*Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom*
- <sup>80</sup>*University of Wisconsin, Madison, Wisconsin 53706, USA*
- <sup>81</sup>*Yale University, New Haven, Connecticut 06511, USA*

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We present an observation of  $B \rightarrow \eta' K^*$ . The data sample corresponds to  $232 \times 10^6 B\bar{B}$  pairs collected with the *BABAR* detector at the PEP-II asymmetric-energy  $B$  factory at the Stanford Linear Accelerator Center. We measure the branching fractions (in units of  $10^{-6}$ )  $\mathcal{B}(B^0 \rightarrow \eta' K^{*0}) = 3.8 \pm 1.1 \pm 0.5$  and  $\mathcal{B}(B^+ \rightarrow \eta' K^{*+}) = 4.9^{+1.9}_{-1.7} \pm 0.8$ , where the first error is statistical and the second systematic. A simultaneous fit results in the observation of  $B \rightarrow \eta' K^*$  with  $\mathcal{B}(B \rightarrow \eta' K^*) = 4.1^{+1.0}_{-0.9} \pm 0.5$ . We also search for  $B \rightarrow \eta' \rho$  and  $\eta' f_0(980)(f_0 \rightarrow \pi^+ \pi^-)$  with results and 90% confidence level upper limits  $\mathcal{B}(B^+ \rightarrow \eta' \rho^+) = 8.7^{+3.1+2.3}_{-2.8-1.3} (<14)$ ,  $\mathcal{B}(B^0 \rightarrow \eta' \rho^0) < 3.7$ , and  $\mathcal{B}(B^0 \rightarrow \eta' f_0(980)(f_0 \rightarrow \pi^+ \pi^-)) < 1.5$ . Charge asymmetries in the channels with significant yields are consistent with zero.

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Decays of  $B$  mesons involving the flavor-changing neutral current transition  $b \rightarrow s$  are an important place to search for evidence of physics beyond the standard model. A comparison of the amplitude  $\sin 2\beta$  of time-dependent  $CP$  violation in the neutral  $CP$  eigenstates  $J/\psi K_S^0$  and  $\eta' K_S^0$  provides one of the most sensitive tests [1]. In order to unambiguously interpret the time-dependent  $CP$  violation measurement in  $\eta' K_S^0$ , it is important to understand the full set of underlying amplitudes by making measurements of branching fractions in the  $\eta' K^*$  decays.

In  $B$  decays to final states comprising  $\eta^{(\prime)} K^{(*)}$ , the final states  $\eta' K^*$  and  $\eta K$  are suppressed, and the final states  $\eta' K$  and  $\eta K^*$  are enhanced. Two explanations of the experimentally observed pattern differ substantially in the details of the suppression for  $B \rightarrow \eta' K^*$  [2,3]. From previous experimental data and flavor SU(3) arguments, it is expected that the branching fractions for  $B \rightarrow \eta' K^*$  are less than  $10^{-5}$  [4]. The related decays  $B \rightarrow \eta' \rho$  occur via tree diagrams that are suppressed by the small magnitudes of the involved elements of the Cabibbo-Kobayashi-Maskawa quark mixing matrix and are expected to be small. Theoretical approaches using QCD factorization [5] and perturbative QCD [6] predict branching fractions for  $B^+ \rightarrow \eta' \rho^+$  of  $6-9 \times 10^{-6}$  and for  $B^0 \rightarrow \eta' \rho^0$  of  $0.5-2 \times 10^{-7}$ .

In this Letter, we present searches for  $B \rightarrow \eta' K^*$ ,  $B \rightarrow \eta' \rho$ , and  $B^0 \rightarrow \eta' f_0(980)(f_0 \rightarrow \pi^+ \pi^-)$ , which shares the same final state as  $B^0 \rightarrow \eta' \rho^0$ . Throughout this Letter, charge conjugation is implied. Results are obtained from unbinned, extended maximum likelihood (ML) fits to data collected with the *BABAR* detector at the PEP-II asymmetric  $e^+e^-$  collider located at the Stanford Linear Accelerator Center. The *BABAR* detector and relevant details specific to this analysis are described elsewhere [7,8]. The analysis uses  $211 \text{ fb}^{-1}$  of data recorded at the  $Y(4S)$  resonance, corresponding to  $232 \times 10^6 B\bar{B}$  pairs, and closely follows the approach described in Ref. [8].

We select  $\eta'$ ,  $K^*$ ,  $\rho$ ,  $\eta$ ,  $K_S^0$ , and  $\pi^0$  candidates through the decays  $\eta' \rightarrow \eta \pi^+ \pi^-$  ( $\eta'_{\eta\pi\pi}$ ),  $\eta' \rightarrow \rho^0 \gamma$  ( $\eta'_{\rho\gamma}$ ),  $K^{*0} \rightarrow K^+ \pi^-$ ,  $K^{*+} \rightarrow K_S^0 \pi^+$  ( $K_{K^0\pi^+}^{*+}$ ),  $K^{*+} \rightarrow K^+ \pi^0$  ( $K_{K^+\pi^0}^{*+}$ ),  $\rho^0$  (and  $f_0$ )  $\rightarrow \pi^+ \pi^-$ ,  $\rho^+ \rightarrow \pi^+ \pi^0$ ,  $\eta \rightarrow \gamma\gamma$ ,  $K_S^0 \rightarrow \pi^+ \pi^-$ , and  $\pi^0 \rightarrow \gamma\gamma$ . We impose the following requirements on candidate invariant masses, in  $\text{MeV}/c^2$ :  $910 < (m_{\eta\pi\pi}, m_{\rho\gamma}) < 1000$  for  $\eta'$ ,  $755 < m_{K\pi} < 1035$  for

$K^*$ ,  $510 < m_{\pi\pi^0} < 1070$  for  $\rho^+$ ,  $510 < m_{\pi\pi} < 1060$  for  $\rho^0$  ( $f_0$ ),  $490 < m_{\gamma\gamma} < 600$  for  $\eta$ ,  $486 < m_{\pi\pi} < 510$  for  $K_S^0$ , and  $120 < m_{\gamma\gamma} < 150$  for  $\pi^0$ . For the masses of  $\eta'$ ,  $K^*$ , and  $\rho$ , which will be included as observables in the ML fit described below, the selection is wide enough to allow for a parametrization of the background. For  $K_S^0$  candidates, we require a flight distance of at least 3 times its estimated uncertainty.

We also use the helicity-frame decay angle  $\theta_H$  of  $K^*$ ,  $\rho$ , and  $f_0(980)$ . The helicity frame is defined as the vector meson rest frame with the polar axis along the direction of the boost from the  $B$  rest frame. The angle  $\theta_H$  is the angle between the polar axis and the flight direction of the charged resonance daughter. For  $K^{*0}$  and  $\rho^0$ , the kaon candidate and the positively charged pion, respectively, are used to define that angle. We use mode-dependent selection criteria on  $\cos\theta_H$ , with the lower bound between  $-0.95$  and  $-0.70$  and the upper bound of either  $0.95$  or  $1.00$ . Decay modes suffering from a higher combinatoric background due to low momentum pions have the tighter cuts applied. The helicity has a  $\cos^2\theta_H$  distribution for  $K^*$  and  $\rho$  signal events and is flat for  $f_0(980)$ .

All charged pion candidates are required to have particle identification (PID) consistent with pions and inconsistent with protons, kaons, and electrons. No such requirement is made of  $K_S^0$  daughters. Charged kaon candidates are required to have PID consistent with kaons and inconsistent with pions, protons, and electrons.

We form  $B$  meson candidates by combining an  $\eta'$  candidate with either a  $K^*$  or a  $\rho$  candidate.  $B$  meson candidates are characterized kinematically by the energy substituted mass  $m_{\text{ES}} = (s/4 - \mathbf{p}_B^2)^{1/2}$  and the energy difference  $\Delta E = E_B - \sqrt{s}/2$ , where  $(E_B, \mathbf{p}_B)$  is the four-momentum of the  $B$  candidate, expressed in the  $Y(4S)$  frame, and  $\sqrt{s}$  is the  $e^+e^-$  center of mass energy. Signal events peak at zero for  $\Delta E$  and at the  $B$  mass for  $m_{\text{ES}}$ , with typical resolutions of  $20 \text{ MeV}$  and  $3.0 \text{ MeV}/c^2$ , respectively. We require  $5.25 \leq m_{\text{ES}} \leq 5.29 \text{ GeV}/c^2$  for all modes,  $-0.2 \leq \Delta E \leq 0.150 \text{ GeV}$  for modes where the vector meson decay includes a neutral pion, and  $-0.2 \leq \Delta E \leq 0.125 \text{ GeV}$  otherwise.

Backgrounds arise primarily from random combinations of particles in continuum  $e^+e^- \rightarrow q\bar{q}$  ( $q = u, d, s, c$ ) events. To reject these events, we employ the angle  $\theta_T$  in the  $Y(4S)$  frame between the thrust axis of the  $B$  candi-

date's daughters and that of the remaining particles in the event. Continuum events are produced well above threshold, with a jetlike topology resulting in a distribution of  $|\cos\theta_T|$  that is sharply peaked near 1 for candidates formed in such events. Events containing true  $Y(4S)$  decays are produced near threshold with particles distributed isotropically, resulting in a uniform distribution of  $|\cos\theta_T|$ . We require  $|\cos\theta_T| < 0.9$  for decays with  $\eta'_{\eta\pi\pi}$  and  $|\cos\theta_T| < 0.75$  for the higher-background  $\eta'_{\rho\gamma}$  decays. Because of large backgrounds in  $\eta'_{\rho\gamma}$ , we use only the  $\eta'_{\eta\pi\pi}$  decay in reconstructing  $B \rightarrow \eta' \rho / f_0(980)$ .

Additional discrimination against continuum background occurs in the ML fit and is provided by a Fisher discriminant  $\mathcal{F}$ . This is a linear combination of discriminating variables with weights chosen to maximize the separation between the signal and the continuum background.  $\mathcal{F}$  contains the angles of the  $B$  momentum and  $B$  thrust axis with respect to the beam axis, the  $B$ -flavor tagging category [9], and the zeroth and second angular moment of the energy flow in the rest of the event with respect to the  $B$  candidate thrust axis [8].

After selection, events containing multiple  $B$  candidates occur less than 30% of the time. In such cases, we choose the  $B$  candidate with the  $\eta'$  mass closest to the Particle Data Group value [10].

We use Monte Carlo (MC) simulation [11] for an initial survey of the background from  $B\bar{B}$  events and to identify for detailed study any decays that are not rejected by candidate selection. The remaining background is composed almost entirely of charmless resonant  $B$  decays, especially  $B \rightarrow \eta' K$ . We account for  $B$  backgrounds by including in the ML fit an additional component which models these charmless, resonant decays. Backgrounds arising from charmed  $B$  decays have been studied and found to be negligible or accounted for by our continuum background model. Backgrounds from nonresonant  $B$  decays have been found to be consistent with zero.

We determine yields and charge asymmetries [ $\mathcal{A}_{\text{ch}} = (n^+ - n^-)/(n^+ + n^-)$ ] for each decay chain from a ML fit with the observables  $\Delta E$ ,  $m_{\text{ES}}$ ,  $\mathcal{F}$ ,  $m_{\eta'}$ , the mass of the candidate vector meson  $m_V$ , and  $\mathcal{H} \equiv \cos\theta_H$ . For charged (neutral)  $B$  decays,  $n^\pm$  is defined as the number of  $B^\pm$  decays (final states with  $K^\pm$ ). For each event  $i$  and hypothesis  $j$  (signal, continuum,  $B\bar{B}$ ), we define the probability density function (PDF) as a simple product of the individual observable PDFs:

$$\mathcal{P}_j^i = \mathcal{P}_j(m_{\text{ES}}^i) \mathcal{P}_j(\Delta E^i) \mathcal{P}_j(\mathcal{F}^i) \mathcal{P}_j(m_{\eta'}^i) \mathcal{P}_j(m_V^i) \mathcal{P}_j(\mathcal{H}^i).$$

For the  $\eta' \pi^+ \pi^-$  final state, a fourth hypothesis is added to account explicitly for a possible  $\eta' f_0$  signal.

The total likelihood function is then given by

$$\mathcal{L} = \frac{\exp(-\sum_j n_j)}{N!} \prod_i^N \left( \sum_j n_j \mathcal{P}_j^i \right),$$

where  $N$  is the number of events in the sample and  $n_j$  is the yield of events of hypothesis  $j$  to be found by maximizing  $\mathcal{L}$ . In addition to the yields and  $\mathcal{A}_{\text{ch}}$  for each hypothesis, parameters describing the continuum PDFs are also allowed to vary (see below).

We parametrize the PDFs for peaking observables with either a single or asymmetric Gaussian, a sum of two Gaussians, or a Breit-Wigner line shape as required. Slowly varying observables are described by low degree polynomials or phase-space motivated functions [8]. Several PDFs require linear combinations of peaking and nonpeaking shapes. We parametrize the  $f_0(980)$  mass and width using measured values [12].

For the signal and  $B\bar{B}$  background components, we determine the PDF parameters from simulation. Control samples with topologies similar to our signal (e.g.,  $B^- \rightarrow D^0 \pi^-$ ) are used to verify and adjust simulated resolutions [8]. For the continuum background, we obtain initial PDF parameters from data excluding the  $\Delta E$  and  $m_{\text{ES}}$  signal region (sideband). We further refine the continuum PDFs by letting as many parameters as feasible vary in the fit to the full data. The final fitted continuum background PDF parameters are found to be in close agreement with their initial values.

We apply several tests to the fitting procedure for validation before implementing it on the data. In particular, we evaluate any possible bias in our event yields due to our neglect of small correlations between the observables, which our PDFs ignore by construction. We determine the bias by fitting ensembles of simulated continuum experiments generated from the PDF into which we embed the expected number of signal and  $B\bar{B}$  background events randomly taken from samples of fully simulated MC events. Measured correlations in the sideband data (pure  $q\bar{q}$ ) are found to be small. The measured biases for each decay chain are given in Table I.

We compute the branching fraction for each decay by subtracting the fit bias from the measured yield and dividing the result by the efficiency (determined from simulation and ancillary studies), the product of the daughter branching fractions, and the number of produced  $B\bar{B}$  pairs. We assume equal decay rates of the  $Y(4S)$  to  $B^+ B^-$  and  $B^0 \bar{B}^0$ . In Table I, we show for each decay the measured branching fraction, event yield, efficiency, and daughter branching fraction, as well as  $\mathcal{A}_{\text{ch}}$ .

Measurements for separate decay chains are combined by adding the values of  $-2 \ln \mathcal{L}$  as functions of the branching fraction, taking appropriate account of correlated and uncorrelated systematic uncertainties (described below) [8]. The significance is taken as the square root of the difference between the value of  $-2 \ln \mathcal{L}$  (including systematics) for zero signal and the minimum. For modes where the combined significance is less than 4 standard deviations, we quote 90% confidence level (C.L.) upper limits. We compute these as the branching fraction below which

TABLE I. Summary of results showing (from left): fitted signal yield  $n$  before bias correction, fit bias, detection efficiency  $\varepsilon$ , product daughter branching fraction  $\prod \mathcal{B}_i$  [10], significance  $S$  (including systematic uncertainties) in standard deviations, measured branching fraction  $\mathcal{B}$ , and signal charge asymmetry  $\mathcal{A}_{\text{ch}}$  for each mode. The values in parentheses are 90% C.L. upper limits. The result for  $B^0 \rightarrow \eta' f_0(980)(f_0 \rightarrow \pi^+ \pi^-)$  includes the branching fraction for  $f_0 \rightarrow \pi^+ \pi^-$ , which is not well known. Results in bold represent combined fits to multiple decay chains (when present).

| Mode                                                 | $n$ (ev.)              | Bias (ev.)      | $\varepsilon$ (%) | $\prod \mathcal{B}_i$ (%) | $S(\sigma)$ | $\mathcal{B}(10^{-6})$                                  | $\mathcal{A}_{\text{ch}}$       |
|------------------------------------------------------|------------------------|-----------------|-------------------|---------------------------|-------------|---------------------------------------------------------|---------------------------------|
| $B \rightarrow \eta' K^{*0}$                         |                        |                 |                   |                           | <b>5.6</b>  | <b><math>4.1_{-0.9}^{+1.0} \pm 0.5</math></b>           |                                 |
| $B^0 \rightarrow \eta' K^{*0}$                       |                        |                 |                   |                           | <b>4.3</b>  | <b><math>3.8 \pm 1.1 \pm 0.5</math></b>                 | $-0.08 \pm 0.25 \pm 0.02$       |
| $\eta'_{\eta\pi\pi} K^{*0}$                          | $22.6_{-6.7}^{+7.7}$   | $+1.7 \pm 0.9$  | $19.0 \pm 1.2$    | 11.6                      | 3.9         | $4.1_{-1.3}^{+1.5}$                                     |                                 |
| $\eta'_{\rho\gamma} K^{*0}$                          | $35.1_{-12.7}^{+14.2}$ | $+9.5 \pm 4.8$  | $16.9 \pm 1.1$    | 19.7                      | 2.0         | $3.3_{-1.6}^{+1.9}$                                     |                                 |
| $B^+ \rightarrow \eta' K^{*+}$                       |                        |                 |                   |                           | <b>3.6</b>  | <b><math>4.9_{-1.7}^{+1.9} \pm 0.8 (&lt;7.9)</math></b> | $0.30_{-0.37}^{+0.33} \pm 0.02$ |
| $\eta'_{\eta\pi\pi} K^{*+}_{K^0\pi^+}$               | $11.2_{-4.5}^{+5.7}$   | $+0.8 \pm 0.5$  | $18.0 \pm 1.2$    | 4.0                       | 3.2         | $6.2_{-2.7}^{+3.4}$                                     |                                 |
| $\eta'_{\rho\gamma} K^{*+}_{K^0\pi^+}$               | $14.8_{-9.7}^{+11.2}$  | $+2.9 \pm 1.5$  | $15.8 \pm 1.1$    | 6.8                       | 1.2         | $4.7_{-3.9}^{+4.5}$                                     |                                 |
| $\eta'_{\eta\pi\pi} K^{*+}_{K^+\pi^0}$               | $5.2_{-3.6}^{+5.4}$    | $+1.0 \pm 0.5$  | $10.7 \pm 0.6$    | 5.8                       | 1.2         | $2.9_{-2.6}^{+3.7}$                                     |                                 |
| $\eta'_{\rho\gamma} K^{*+}_{K^+\pi^0}$               | $3.1_{-9.6}^{+12.1}$   | $-2.3 \pm 1.3$  | $8.0 \pm 0.5$     | 9.8                       | 0.5         | $2.9_{-5.4}^{+6.7}$                                     |                                 |
| $B^0 \rightarrow \eta' \rho^0$                       | $14.9_{-8.4}^{+10.6}$  | $+11.2 \pm 5.7$ | $22.8 \pm 1.4$    | 17.5                      | 0.3         | $0.4_{-0.6}^{+1.2+1.6} (<3.7)$                          |                                 |
| $B^0 \rightarrow \eta' f_0(\rightarrow \pi^+ \pi^-)$ | $-2.6_{-4.0}^{+6.0}$   | $-3.8 \pm 2.0$  | $25.4 \pm 1.6$    | 17.5                      | 0.2         | $0.1_{-0.4}^{+0.6+0.9} (<1.5)$                          |                                 |
| $B^+ \rightarrow \eta' \rho^+$                       | $57.3_{-14.7}^{+16.0}$ | $+11.5 \pm 5.8$ | $13.0 \pm 1.0$    | 17.5                      | 3.2         | $8.7_{-2.8-1.3}^{+3.1+2.3} (<14)$                       | $-0.04 \pm 0.28 \pm 0.02$       |

lies 90% of the total likelihood integral in the positive branching fraction domain.

For modes with evidence of a signal, we show in Fig. 1 projections onto  $m_{\text{ES}}$  and  $\Delta E$  of subsamples (containing 63%–85% of all signal events) enriched by a requirement on the ratio of the signal likelihood to the total likelihood.

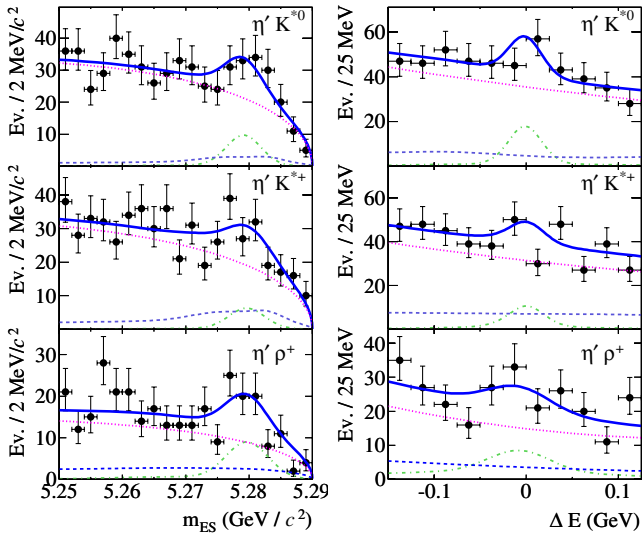


FIG. 1 (color online).  $B$  candidate  $m_{\text{ES}}$  (left) and  $\Delta E$  (right) projections obtained with a cut on the likelihood (see text) for  $B^0 \rightarrow \eta' K^{*0}$  (top),  $B^+ \rightarrow \eta' K^{*+}$  (middle), and  $B^+ \rightarrow \eta' \rho^+$  (bottom). Submodes have been combined. The data are represented by points with uncertainties, full fit functions by solid curves,  $B\bar{B}$  background by dashed curves, continuum by dotted curves, and signal by dotted-dashed curves. Depending on the decay, the plots contain 63%–85% of all signal events.

The likelihood is computed excluding the plotted variable. Figure 2 shows background-subtracted distributions of the  $K\pi$  mass and helicity obtained with the event-weighting technique described in Ref. [13]. These plots illustrate that the  $K\pi$  signal we observe is consistent with the  $K^*(892)$  and is polarized as one would expect in a pseudoscalar-vector  $B$  decay.

Systematic uncertainties in this analysis are dominated by our knowledge of signal and  $B\bar{B}$  background PDF modeling, along with the fit bias and the efficiencies of the track and neutral particle selections. Uncertainty due to continuum PDF modeling is largely incorporated into the statistical uncertainty, since most continuum background parameters are allowed to vary in the fit. Uncertainties in the signal PDF parameters are estimated from comparisons between data and simulation in control samples. Varying the signal PDF parameters within these errors results in a

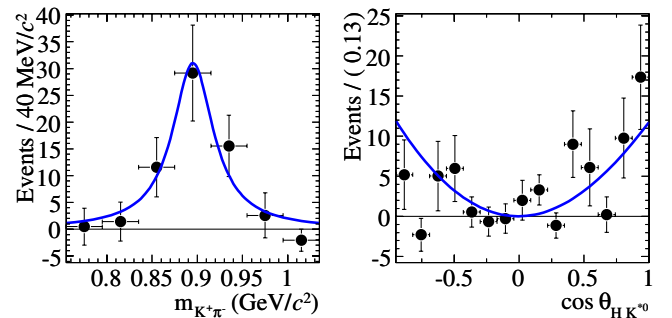


FIG. 2 (color online). Distributions of the  $K\pi$  mass (left) and helicity (right) for the decay  $B^0 \rightarrow \eta' K^{*0}$ . Points with error bars: data, background subtracted with the event-weighting technique described in Ref. [13]; solid curve: signal PDF.

mode-dependent variation in signal yield of between 0.1 and 1.6 events.

The uncertainty in the fit bias is taken to be half of the correction. We estimate the uncertainty from  $B\bar{B}$  modeling by taking half of the difference between the signal yield fitted with and without the  $B\bar{B}$  component (0.2–10 events). The uncertainty due to the nonresonant  $B\bar{B}$  background is estimated by taking half the difference between the signal yield in the nominal fit and in a fit in which a nonresonant background component has been added (0.7–4.8 events). Uncertainties in reconstruction efficiency are determined from supplementary studies of control samples. These include 0.8% per charged track (excluding daughters of the  $K_S^0$ ), 1.5% per photon, and 1.9% for a  $K_S^0$ . The systematic uncertainty in the number of  $B\bar{B}$  pairs is 1.1% [14]. Published data [10] provide the uncertainties in the  $B$ -daughter product branching fractions (3.4%). Uncertainties in the event selection efficiency are 0.5%–3% for the requirement on  $\cos\theta_T$ .

We assign a systematic uncertainty on  $\mathcal{A}_{\text{ch}}$  of 0.02, based on studies of inclusive samples of kaons and  $B$  decays. This is due primarily to asymmetries in charged kaon identification and slow pion reconstruction.

We present measurements for the decays  $B^{+,0} \rightarrow \eta' K^{*+,0}$  and  $B^+ \rightarrow \eta' \rho^+$ . They allow the level of suppression of these decays, with respect to the enhanced  $\eta' K$  and  $\eta K^*$ , to be determined. A simultaneous fit of all charged and neutral  $\eta' K^*$  submodes results in the observation of  $B \rightarrow \eta' K^*$  with a total significance of  $5.6\sigma$ , including systematics, as shown in Table I. The measurements place constraints on possible enhanced flavor-singlet contributions to these decays [2,15]. These results are consistent with previous upper limits, where they existed. In all cases, predictions based on SU(3) flavor symmetry [4], QCD factorization [5], and perturbative QCD [6] are in excellent agreement with our measured central values. Values of  $\mathcal{A}_{\text{ch}}$  are consistent with zero in all channels.

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\*Also at Laboratoire de Physique Corpusculaire, Clermont-Ferrand, France.

† Also with Università di Perugia, Dipartimento di Fisica, Perugia, Italy.

‡ Also with Università della Basilicata, Potenza, Italy.

- [1] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. Lett. **94**, 191802 (2005).
- [2] M. Beneke and M. Neubert, Nucl. Phys. **B651**, 225 (2003).
- [3] H. J. Lipkin, Phys. Lett. B **254**, 247 (1991).
- [4] C.-W. Chiang *et al.*, Phys. Rev. D **69**, 034001 (2004).
- [5] M. Beneke and M. Neubert, Nucl. Phys. **B675**, 333 (2003).
- [6] X. Liu *et al.*, Phys. Rev. D **73**, 074002 (2006).
- [7] B. Aubert *et al.* (*BABAR* Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A **479**, 1 (2002).
- [8] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. D **70**, 032006 (2004).
- [9] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. Lett. **94**, 161803 (2005).
- [10] S. Eidelman *et al.* (Particle Data Group), Phys. Lett. B **592**, 1 (2004).
- [11] The *BABAR* detector Monte Carlo simulation is based on GEANT4: S. Agostinelli *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).
- [12] E. M. Aitala *et al.* (FNAL E791 Collaboration), Phys. Rev. Lett. **86**, 765 (2001).
- [13] M. Pivk and F. R. Le Diberder, Nucl. Instrum. Methods Phys. Res., Sect. A **555**, 356 (2005).
- [14] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. D **67**, 032002 (2003).
- [15] C.-W. Chiang and J. L. Rosner, Phys. Rev. D **65**, 074035 (2002).