

## Measurement of the $e^+e^- \rightarrow b\bar{b}$ cross section between $\sqrt{s}=10.54$ and $11.20$ GeV

B. Aubert,<sup>1</sup> M. Bona,<sup>1</sup> Y. Karyotakis,<sup>1</sup> J. P. Lees,<sup>1</sup> V. Poireau,<sup>1</sup> E. Prencipe,<sup>1</sup> X. Prudent,<sup>1</sup> V. Tisserand,<sup>1</sup> J. Garra Tico,<sup>2</sup> E. Grauges,<sup>2</sup> L. Lopez<sup>ab,3</sup>, A. Palano<sup>ab,3</sup>, M. Pappagallo<sup>ab,3</sup>, G. Eigen,<sup>4</sup> B. Stugu,<sup>4</sup> L. Sun,<sup>4</sup> G. S. Abrams,<sup>5</sup> M. Battaglia,<sup>5</sup> D. N. Brown,<sup>5</sup> R. N. Cahn,<sup>5</sup> R. G. Jacobsen,<sup>5</sup> L. T. Kerth,<sup>5</sup> Yu. G. Kolomensky,<sup>5</sup> G. Lynch,<sup>5</sup> I. L. Osipenkov,<sup>5</sup> M. T. Ronan,<sup>5,\*</sup> K. Tackmann,<sup>5</sup> T. Tanabe,<sup>5</sup> C. M. Hawkes,<sup>6</sup> N. Soni,<sup>6</sup> A. T. Watson,<sup>6</sup> H. Koch,<sup>7</sup> T. Schroeder,<sup>7</sup> D. Walker,<sup>8</sup> D. J. Asgeirsson,<sup>9</sup> B. G. Fulsom,<sup>9</sup> C. Hearty,<sup>9</sup> T. S. Mattison,<sup>9</sup> J. A. McKenna,<sup>9</sup> M. Barrett,<sup>10</sup> A. Khan,<sup>10</sup> V. E. Blinov,<sup>11</sup> A. D. Bukin,<sup>11</sup> A. R. Buzykaev,<sup>11</sup> V. P. Druzhinin,<sup>11</sup> V. B. Golubev,<sup>11</sup> A. P. Onuchin,<sup>11</sup> S. I. Serednyakov,<sup>11</sup> Yu. I. Skovpen,<sup>11</sup> E. P. Solodov,<sup>11</sup> K. Yu. Todyshev,<sup>11</sup> M. Bondioli,<sup>12</sup> S. Curry,<sup>12</sup> I. Eschrich,<sup>12</sup> D. Kirkby,<sup>12</sup> A. J. Lankford,<sup>12</sup> P. Lund,<sup>12</sup> M. Mandelkern,<sup>12</sup> E. C. Martin,<sup>12</sup> D. P. Stoker,<sup>12</sup> S. Abachi,<sup>13</sup> C. Buchanan,<sup>13</sup> J. W. Gary,<sup>14</sup> F. Liu,<sup>14</sup> O. Long,<sup>14</sup> B. C. Shen,<sup>14,\*</sup> G. M. Vitug,<sup>14</sup> Z. Yasin,<sup>14</sup> L. Zhang,<sup>14</sup> V. Sharma,<sup>15</sup> C. Campagnari,<sup>16</sup> T. M. Hong,<sup>16</sup> D. Kovalskyi,<sup>16</sup> M. A. Mazur,<sup>16</sup> J. D. Richman,<sup>16</sup> T. W. Beck,<sup>17</sup> A. M. Eisner,<sup>17</sup> C. J. Flacco,<sup>17</sup> C. A. Heusch,<sup>17</sup> J. Kroseberg,<sup>17</sup> W. S. Lockman,<sup>17</sup> A. J. Martinez,<sup>17</sup> T. Schalk,<sup>17</sup> B. A. Schumm,<sup>17</sup> A. Seiden,<sup>17</sup> M. G. Wilson,<sup>17</sup> L. O. Winstrom,<sup>17</sup> C. H. Cheng,<sup>18</sup> D. A. Doll,<sup>18</sup> B. Echenard,<sup>18</sup> F. Fang,<sup>18</sup> D. G. Hitlin,<sup>18</sup> I. Narsky,<sup>18</sup> T. Piatenko,<sup>18</sup> F. C. Porter,<sup>18</sup> R. Andreassen,<sup>19</sup> G. Mancinelli,<sup>19</sup> B. T. Meadows,<sup>19</sup> K. Mishra,<sup>19</sup> M. D. Sokoloff,<sup>19</sup> P. C. Bloom,<sup>20</sup> W. T. Ford,<sup>20</sup> A. Gaz,<sup>20</sup> J. F. Hirschauer,<sup>20</sup> M. Nagel,<sup>20</sup> U. Nauenberg,<sup>20</sup> J. G. Smith,<sup>20</sup> K. A. Ulmer,<sup>20</sup> S. R. Wagner,<sup>20</sup> R. Ayad,<sup>21,†</sup> A. Soffer,<sup>21,‡</sup> W. H. Toki,<sup>21</sup> R. J. Wilson,<sup>21</sup> D. D. Altenburg,<sup>22</sup> E. Feltresi,<sup>22</sup> A. Hauke,<sup>22</sup> H. Jasper,<sup>22</sup> M. Karbach,<sup>22</sup> J. Merkel,<sup>22</sup> A. Petzold,<sup>22</sup> B. Spaan,<sup>22</sup> K. Wacker,<sup>22</sup> M. J. Kobel,<sup>23</sup> W. F. Mader,<sup>23</sup> R. Nogowski,<sup>23</sup> K. R. Schubert,<sup>23</sup> R. Schwierz,<sup>23</sup> A. Volk,<sup>23</sup> D. Bernard,<sup>24</sup> G. R. Bonneaud,<sup>24</sup> E. Latour,<sup>24</sup> M. Verderi,<sup>24</sup> P. J. Clark,<sup>25</sup> S. Playfer,<sup>25</sup> J. E. Watson,<sup>25</sup> M. Andreotti<sup>ab,26</sup>, D. Bettoni<sup>a,26</sup>, C. Bozzi<sup>a,26</sup>, R. Calabrese<sup>ab,26</sup>, A. Cecchi<sup>ab,26</sup>, G. Cibinetto<sup>ab,26</sup>, P. Franchini<sup>ab,26</sup>, E. Luppi<sup>ab,26</sup>, M. Negrini<sup>ab,26</sup>, A. Petrella<sup>ab,26</sup>, L. Piemontese<sup>a,26</sup>, V. Santoro<sup>ab,26</sup>, R. Baldini-Ferrolli,<sup>27</sup> A. Calcaterra,<sup>27</sup> R. de Sangro,<sup>27</sup> G. Finocchiaro,<sup>27</sup> S. Pacetti,<sup>27</sup> P. Patteri,<sup>27</sup> I. M. Peruzzi,<sup>27,§</sup> M. Piccolo,<sup>27</sup> M. Rama,<sup>27</sup> A. Zallo,<sup>27</sup> A. Buzzo<sup>a,28</sup>, R. Contri<sup>ab,28</sup>, M. Lo Vetere<sup>ab,28</sup>, M. M. Macri<sup>a,28</sup>, M. R. Monge<sup>ab,28</sup>, S. Passaggio<sup>a,28</sup>, C. Patrignani<sup>ab,28</sup>, E. Robutti<sup>a,28</sup>, A. Santroni<sup>ab,28</sup>, S. Tosi<sup>ab,28</sup>, K. S. Chaisanguanthum,<sup>29</sup> M. Morii,<sup>29</sup> A. Adametz,<sup>30</sup> J. Marks,<sup>30</sup> S. Schenk,<sup>30</sup> U. Uwer,<sup>30</sup> V. Klose,<sup>31</sup> H. M. Lacker,<sup>31</sup> D. J. Bard,<sup>32</sup> P. D. Dauncey,<sup>32</sup> J. A. Nash,<sup>32</sup> M. Tibbetts,<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> J. Cochran,<sup>34</sup> H. B. Crawley,<sup>34</sup> L. Dong,<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> Y. Y. Gao,<sup>35</sup> A. V. Gritsan,<sup>35</sup> Z. J. Guo,<sup>35</sup> C. K. Lae,<sup>35</sup> N. Arnaud,<sup>36</sup> J. Béquilleux,<sup>36</sup> A. D’Orazio,<sup>36</sup> M. Davier,<sup>36</sup> J. Firmino da Costa,<sup>36</sup> G. Grosdidier,<sup>36</sup> A. Höcker,<sup>36</sup> V. Lepeltier,<sup>36</sup> F. Le Diberder,<sup>36</sup> A. M. Lutz,<sup>36</sup> S. Pruvot,<sup>36</sup> P. Roudeau,<sup>36</sup> M. H. Schune,<sup>36</sup> J. Serrano,<sup>36</sup> V. Sordini,<sup>36,¶</sup> A. Stocchi,<sup>36</sup> G. Wormser,<sup>36</sup> D. J. Lange,<sup>37</sup> D. M. Wright,<sup>37</sup> I. Bingham,<sup>38</sup> J. P. Burke,<sup>38</sup> C. A. Chavez,<sup>38</sup> J. R. Fry,<sup>38</sup> E. Gabathuler,<sup>38</sup> R. Gamet,<sup>38</sup> D. E. Hutchcroft,<sup>38</sup> D. J. Payne,<sup>38</sup> C. Touramanis,<sup>38</sup> A. J. Bevan,<sup>39</sup> C. K. Clarke,<sup>39</sup> K. A. George,<sup>39</sup> F. Di Lodovico,<sup>39</sup> R. Sacco,<sup>39</sup> M. Sigamani,<sup>39</sup> G. Cowan,<sup>40</sup> H. U. Flaecher,<sup>40</sup> D. A. Hopkins,<sup>40</sup> S. Paramesvaran,<sup>40</sup> F. Salvatore,<sup>40</sup> A. C. Wren,<sup>40</sup> D. N. Brown,<sup>41</sup> C. L. Davis,<sup>41</sup> A. G. Denig,<sup>42</sup> M. Fritsch,<sup>42</sup> W. Gradl,<sup>42</sup> G. Schott,<sup>42</sup> K. E. Alwyn,<sup>43</sup> D. Bailey,<sup>43</sup> R. J. Barlow,<sup>43</sup> Y. M. Chia,<sup>43</sup> C. L. Edgar,<sup>43</sup> G. Jackson,<sup>43</sup> G. D. Lafferty,<sup>43</sup> T. J. West,<sup>43</sup> J. I. Yi,<sup>43</sup> J. Anderson,<sup>44</sup> C. Chen,<sup>44</sup> A. Jawahery,<sup>44</sup> D. A. Roberts,<sup>44</sup> G. Simi,<sup>44</sup> J. M. Tuggle,<sup>44</sup> C. Dallapiccola,<sup>45</sup> X. Li,<sup>45</sup> E. Salvati,<sup>45</sup> S. Saremi,<sup>45</sup> R. Cowan,<sup>46</sup> D. Dujmic,<sup>46</sup> P. H. Fisher,<sup>46</sup> G. Sciolla,<sup>46</sup> M. Spitznagel,<sup>46</sup> F. Taylor,<sup>46</sup> R. K. Yamamoto,<sup>46</sup> M. Zhao,<sup>46</sup> P. M. Patel,<sup>47</sup> S. H. Robertson,<sup>47</sup> A. Lazzaro<sup>ab,48</sup>, V. Lombardo<sup>a,48</sup>, F. Palombo<sup>ab,48</sup>, J. M. Bauer,<sup>49</sup> L. Cremaldi,<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> M. Simard,<sup>50</sup> P. Taras,<sup>50</sup> F. B. Viaud,<sup>50</sup> H. Nicholson,<sup>51</sup> G. De Nardo<sup>ab,52</sup>, L. Lista<sup>a,52</sup>, D. Monorchio<sup>ab,52</sup>, G. Onorato<sup>ab,52</sup>, C. Sciacca<sup>ab,52</sup>, G. Raven,<sup>53</sup> H. L. Snoek,<sup>53</sup> C. P. Jessop,<sup>54</sup> K. J. Knoepfel,<sup>54</sup> J. M. LoSecco,<sup>54</sup> W. F. Wang,<sup>54</sup> G. Benelli,<sup>55</sup> L. A. Corwin,<sup>55</sup> K. Honscheid,<sup>55</sup> H. Kagan,<sup>55</sup> R. Kass,<sup>55</sup> J. P. Morris,<sup>55</sup> A. M. Rahimi,<sup>55</sup> J. J. Regensburger,<sup>55</sup> S. J. Sekula,<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> J. A. Kolb,<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> G. Castelli<sup>ab,57</sup>, N. Gagliardi<sup>ab,57</sup>, M. Margoni<sup>ab,57</sup>, M. Morandin<sup>a,57</sup>, M. Posocco<sup>a,57</sup>, M. Rotondo<sup>a,57</sup>, F. Simonetto<sup>ab,57</sup>, R. Stroili<sup>ab,57</sup>, C. Voci<sup>ab,57</sup>, P. del Amo Sanchez,<sup>58</sup> E. Ben-Haim,<sup>58</sup> H. Briand,<sup>58</sup> G. Calderini,<sup>58</sup> J. Chauveau,<sup>58</sup> P. David,<sup>58</sup> L. Del Buono,<sup>58</sup> O. Hamon,<sup>58</sup> Ph. Leruste,<sup>58</sup> J. Ocariz,<sup>58</sup> A. Perez,<sup>58</sup> J. Prendki,<sup>58</sup> S. Sitt,<sup>58</sup> L. Gladney,<sup>59</sup> M. Biasini<sup>ab,60</sup>

R. Covarelli<sup>ab,60</sup> E. Manoni<sup>ab,60</sup> C. Angelini<sup>ab,61</sup> G. Batignani<sup>ab,61</sup> S. Bettarini<sup>ab,61</sup> M. Carpinelli<sup>ab,61,††</sup>  
 A. Cervelli<sup>ab,61</sup> F. Forti<sup>ab,61</sup> M. A. Giorgi<sup>ab,61</sup> A. Lusiani<sup>ac,61</sup> G. Marchiori<sup>ab,61</sup> M. Morganti<sup>ab,61</sup> N. Neri<sup>ab,61</sup>  
 E. Paoloni<sup>ab,61</sup> G. Rizzo<sup>ab,61</sup> J. J. Walsh<sup>a,61</sup> D. Lopes Pegna,<sup>62</sup> C. Lu,<sup>62</sup> J. Olsen,<sup>62</sup> A. J. S. Smith,<sup>62</sup>  
 A. V. Telnov,<sup>62</sup> F. Anulli<sup>a,63</sup> E. Baracchini<sup>ab,63</sup> G. Cavoto<sup>a,63</sup> D. del Re<sup>ab,63</sup> E. Di Marco<sup>ab,63</sup> R. Faccini<sup>ab,63</sup>  
 F. Ferrarotto<sup>a,63</sup> F. Ferroni<sup>ab,63</sup> M. Gaspero<sup>ab,63</sup> P. D. Jackson<sup>a,63</sup> L. Li Gioi<sup>a,63</sup> M. A. Mazzoni<sup>a,63</sup> S. Morganti<sup>a,63</sup>  
 G. Piredda<sup>a,63</sup> F. Polci<sup>ab,63</sup> F. Renga<sup>ab,63</sup> C. Voena<sup>a,63</sup> M. Ebert,<sup>64</sup> T. Hartmann,<sup>64</sup> H. Schröder,<sup>64</sup> R. Waldi,<sup>64</sup>  
 T. Adye,<sup>65</sup> B. Franek,<sup>65</sup> E. O. Olaiya,<sup>65</sup> F. F. Wilson,<sup>65</sup> S. Emery,<sup>66</sup> M. Escalier,<sup>66</sup> L. Esteve,<sup>66</sup> S. F. Ganzhur,<sup>66</sup>  
 G. Hamel de Monchenault,<sup>66</sup> W. Kozanecki,<sup>66</sup> G. Vasseur,<sup>66</sup> Ch. Yèche,<sup>66</sup> M. Zito,<sup>66</sup> X. R. Chen,<sup>67</sup> H. Liu,<sup>67</sup>  
 W. Park,<sup>67</sup> M. V. Purohit,<sup>67</sup> R. M. White,<sup>67</sup> J. R. Wilson,<sup>67</sup> M. T. Allen,<sup>68</sup> D. Aston,<sup>68</sup> R. Bartoldus,<sup>68</sup>  
 P. Bechtle,<sup>68</sup> J. F. Benitez,<sup>68</sup> K. Bertsche,<sup>68</sup> Y. Cai,<sup>68</sup> R. Cenci,<sup>68</sup> J. P. Coleman,<sup>68</sup> M. R. Convery,<sup>68</sup> F. J. Decker,<sup>68</sup>  
 J. C. Dingfelder,<sup>68</sup> J. Dorfan,<sup>68</sup> G. P. Dubois-Felsmann,<sup>68</sup> W. Dunwoodie,<sup>68</sup> S. Ecklund,<sup>68</sup> R. Erickson,<sup>68</sup>  
 R. C. Field,<sup>68</sup> A. Fisher,<sup>68</sup> J. Fox,<sup>68</sup> A. M. Gabareen,<sup>68</sup> S. J. Gowdy,<sup>68</sup> M. T. Graham,<sup>68</sup> P. Grenier,<sup>68</sup> C. Hast,<sup>68</sup>  
 W. R. Innes,<sup>68</sup> R. Iverson,<sup>68</sup> J. Kaminski,<sup>68</sup> M. H. Kelsey,<sup>68</sup> H. Kim,<sup>68</sup> P. Kim,<sup>68</sup> M. L. Kocian,<sup>68</sup> A. Kulikov,<sup>68</sup>  
 D. W. G. S. Leith,<sup>68</sup> S. Li,<sup>68</sup> B. Lindquist,<sup>68</sup> S. Luitz,<sup>68</sup> V. Luth,<sup>68</sup> H. L. Lynch,<sup>68</sup> D. B. MacFarlane,<sup>68</sup>  
 H. Marsiske,<sup>68</sup> R. Messner,<sup>68</sup> D. R. Muller,<sup>68</sup> H. Neal,<sup>68</sup> S. Nelson,<sup>68</sup> A. Novokhatski,<sup>68</sup> C. P. O'Grady,<sup>68</sup> I. Ofte,<sup>68</sup>  
 A. Perazzo,<sup>68</sup> M. Perl,<sup>68</sup> B. N. Ratcliff,<sup>68</sup> C. Rivetta,<sup>68</sup> A. Roodman,<sup>68</sup> A. A. Salnikov,<sup>68</sup> R. H. Schindler,<sup>68</sup>  
 J. Schwiening,<sup>68</sup> J. Seeman,<sup>68</sup> A. Snyder,<sup>68</sup> D. Su,<sup>68</sup> M. K. Sullivan,<sup>68</sup> K. Suzuki,<sup>68</sup> S. K. Swain,<sup>68</sup>  
 J. M. Thompson,<sup>68</sup> J. Va'vra,<sup>68</sup> D. Van Winkle,<sup>68</sup> A. P. Wagner,<sup>68</sup> M. Weaver,<sup>68</sup> C. A. West,<sup>68</sup> U. Wienands,<sup>68</sup>  
 W. J. Wisniewski,<sup>68</sup> M. Wittgen,<sup>68</sup> W. Wittmer,<sup>68</sup> D. H. Wright,<sup>68</sup> H. W. Wulsin,<sup>68</sup> Y. Yan,<sup>68</sup> A. K. Yarritu,<sup>68</sup>  
 K. Yi,<sup>68</sup> G. Yocky,<sup>68</sup> C. C. Young,<sup>68</sup> V. Ziegler,<sup>68</sup> P. R. Burchat,<sup>69</sup> A. J. Edwards,<sup>69</sup> S. A. Majewski,<sup>69</sup>  
 T. S. Miyashita,<sup>69</sup> B. A. Petersen,<sup>69</sup> L. Wilden,<sup>69</sup> S. Ahmed,<sup>70</sup> M. S. Alam,<sup>70</sup> J. A. Ernst,<sup>70</sup> B. Pan,<sup>70</sup> M. A. Saeed,<sup>70</sup>  
 S. B. Zain,<sup>70</sup> S. M. Spanier,<sup>71</sup> B. J. Wogslund,<sup>71</sup> R. Eckmann,<sup>72</sup> J. L. Ritchie,<sup>72</sup> A. M. Ruland,<sup>72</sup> C. J. Schilling,<sup>72</sup>  
 R. F. Schwitters,<sup>72</sup> B. W. Drummond,<sup>73</sup> J. M. Izen,<sup>73</sup> X. C. Lou,<sup>73</sup> F. Bianchi<sup>ab,74</sup> D. Gamba<sup>ab,74</sup> M. Pelliccioni<sup>ab,74</sup>  
 M. Bomben<sup>ab,75</sup> L. Bosisio<sup>ab,75</sup> C. Cartaro<sup>ab,75</sup> G. Della Ricca<sup>ab,75</sup> L. Lancieri<sup>ab,75</sup> L. Vitale<sup>ab,75</sup> V. Azzolini,<sup>76</sup>  
 N. Lopez-March,<sup>76</sup> F. Martinez-Vidal,<sup>76</sup> D. A. Milanes,<sup>76</sup> A. Oyanguren,<sup>76</sup> J. Albert,<sup>77</sup> Sw. Banerjee,<sup>77</sup>  
 B. Bhuyan,<sup>77</sup> H. H. F. Choi,<sup>77</sup> K. Hamano,<sup>77</sup> R. Kowalewski,<sup>77</sup> M. J. Lewczuk,<sup>77</sup> I. M. Nugent,<sup>77</sup> J. M. Roney,<sup>77</sup>  
 R. J. Sobie,<sup>77</sup> T. J. Gershon,<sup>78</sup> P. F. Harrison,<sup>78</sup> J. Ilic,<sup>78</sup> T. E. Latham,<sup>78</sup> G. B. Mohanty,<sup>78</sup> H. R. Band,<sup>79</sup>  
 X. Chen,<sup>79</sup> S. Dasu,<sup>79</sup> K. T. Flood,<sup>79</sup> Y. Pan,<sup>79</sup> M. Pierini,<sup>79</sup> R. Prepost,<sup>79</sup> C. O. Vuosalo,<sup>79</sup> and S. L. Wu<sup>79</sup>

(The BABAR Collaboration)

<sup>1</sup>Laboratoire de Physique des Particules, IN2P3/CNRS et Université de Savoie, F-74941 Annecy-Le-Vieux, France

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

<sup>3</sup>INFN Sezione di Bari<sup>a</sup>; Dipartimento di Fisica, Università di Bari<sup>b</sup>, I-70126 Bari, Italy

<sup>4</sup>University of Bergen, Institute of Physics, N-5007 Bergen, Norway

<sup>5</sup>Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA

<sup>6</sup>University of Birmingham, Birmingham, B15 2TT, United Kingdom

<sup>7</sup>Ruhr Universität Bochum, Institut für Experimentalphysik 1, D-44780 Bochum, Germany

<sup>8</sup>University of Bristol, Bristol BS8 1TL, United Kingdom

<sup>9</sup>University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1

<sup>10</sup>Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom

<sup>11</sup>Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia

<sup>12</sup>University of California at Irvine, Irvine, California 92697, USA

<sup>13</sup>University of California at Los Angeles, Los Angeles, California 90024, USA

<sup>14</sup>University of California at Riverside, Riverside, California 92521, USA

<sup>15</sup>University of California at San Diego, La Jolla, California 92093, USA

<sup>16</sup>University of California at Santa Barbara, Santa Barbara, California 93106, USA

<sup>17</sup>University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA

<sup>18</sup>California Institute of Technology, Pasadena, California 91125, USA

<sup>19</sup>University of Cincinnati, Cincinnati, Ohio 45221, USA

<sup>20</sup>University of Colorado, Boulder, Colorado 80309, USA

<sup>21</sup>Colorado State University, Fort Collins, Colorado 80523, USA

<sup>22</sup>Technische Universität Dortmund, Fakultät Physik, D-44221 Dortmund, Germany

<sup>23</sup>Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany

<sup>24</sup>Laboratoire Leprince-Ringuet, CNRS/IN2P3, Ecole Polytechnique, F-91128 Palaiseau, France

<sup>25</sup>University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom

<sup>26</sup>INFN Sezione di Ferrara<sup>a</sup>; Dipartimento di Fisica, Università di Ferrara<sup>b</sup>, I-44100 Ferrara, Italy

<sup>27</sup>INFN Laboratori Nazionali di Frascati, I-00044 Frascati, Italy

- <sup>28</sup>INFN Sezione di Genova<sup>a</sup>; Dipartimento di Fisica, Università di Genova<sup>b</sup>, I-16146 Genova, Italy  
<sup>29</sup>Harvard University, Cambridge, Massachusetts 02138, USA
- <sup>30</sup>Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany
- <sup>31</sup>Humboldt-Universität zu Berlin, Institut für Physik, Newtonstr. 15, D-12489 Berlin, 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>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>37</sup>Lawrence Livermore National Laboratory, Livermore, California 94550, USA
- <sup>38</sup>University of Liverpool, Liverpool L69 7ZE, United Kingdom
- <sup>39</sup>Queen Mary, University of London, London, E1 4NS, United Kingdom
- <sup>40</sup>University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom
- <sup>41</sup>University of Louisville, Louisville, Kentucky 40292, USA
- <sup>42</sup>Johannes Gutenberg-Universität Mainz, Institut für Kernphysik, D-55099 Mainz, Germany
- <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>INFN Sezione di Milano<sup>a</sup>; Dipartimento di Fisica, Università di Milano<sup>b</sup>, 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>INFN Sezione di Napoli<sup>a</sup>; Dipartimento di Scienze Fisiche, Università di Napoli Federico II<sup>b</sup>, 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>INFN Sezione di Padova<sup>a</sup>; Dipartimento di Fisica, Università di Padova<sup>b</sup>, I-35131 Padova, Italy
- <sup>58</sup>Laboratoire de Physique Nucléaire et de Hautes Energies, IN2P3/CNRS, Université Pierre et Marie Curie-Paris6, Université Denis Diderot-Paris7, F-75252 Paris, France
- <sup>59</sup>University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA
- <sup>60</sup>INFN Sezione di Perugia<sup>a</sup>; Dipartimento di Fisica, Università di Perugia<sup>b</sup>, I-06100 Perugia, Italy
- <sup>61</sup>INFN Sezione di Pisa<sup>a</sup>; Dipartimento di Fisica, Università di Pisa<sup>b</sup>; Scuola Normale Superiore di Pisa<sup>c</sup>, I-56127 Pisa, Italy
- <sup>62</sup>Princeton University, Princeton, New Jersey 08544, USA
- <sup>63</sup>INFN Sezione di Roma<sup>a</sup>; Dipartimento di Fisica, Università di Roma La Sapienza<sup>b</sup>, I-00185 Roma, Italy
- <sup>64</sup>Universität Rostock, D-18051 Rostock, Germany
- <sup>65</sup>Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom
- <sup>66</sup>CEA, Irfu, SPP, Centre de Saclay, F-91191 Gif-sur-Yvette, France
- <sup>67</sup>University of South Carolina, Columbia, South Carolina 29208, USA
- <sup>68</sup>Stanford Linear Accelerator Center, Stanford, California 94309, USA
- <sup>69</sup>Stanford University, Stanford, California 94305-4060, USA
- <sup>70</sup>State University of New York, Albany, New York 12222, USA
- <sup>71</sup>University of Tennessee, Knoxville, Tennessee 37996, USA
- <sup>72</sup>University of Texas at Austin, Austin, Texas 78712, USA
- <sup>73</sup>University of Texas at Dallas, Richardson, Texas 75083, USA
- <sup>74</sup>INFN Sezione di Torino<sup>a</sup>; Dipartimento di Fisica Sperimentale, Università di Torino<sup>b</sup>, I-10125 Torino, Italy
- <sup>75</sup>INFN Sezione di Trieste<sup>a</sup>; Dipartimento di Fisica, Università di Trieste<sup>b</sup>, I-34127 Trieste, Italy
- <sup>76</sup>IFIC, Universitat de Valencia-CSIC, E-46071 Valencia, Spain
- <sup>77</sup>University of Victoria, Victoria, British Columbia, Canada V8W 3P6
- <sup>78</sup>Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom
- <sup>79</sup>University of Wisconsin, Madison, Wisconsin 53706, USA

We report  $e^+e^- \rightarrow b\bar{b}$  cross section measurements by the BABAR experiment performed during an energy scan in the range of 10.54 to 11.20 GeV at the PEP-II  $e^+e^-$  collider. A total relative error of about 5% is reached in more than three hundred center-of-mass energy steps, separated by about 5 MeV. These measurements can be used to derive precise information on the parameters of the

$\Upsilon(10860)$  and  $\Upsilon(11020)$  resonances. In particular we show that their widths may be smaller than previously measured.

PACS numbers: 13.25.Hw, 14.40.Nd

Recent discoveries of non-baryonic charmonium states that do not behave as two-quark states [1] call for a search for other resonances belonging to this possible new spectroscopy. Given the charmonium content of these new states, one could infer the presence of similar resonances containing  $b$  quark pairs. The observed  $J^{PC} = 1^{--}$  exotic states ( $Y(4260)$ ,  $Y(4350)$ , and  $Y(4660)$  [2]) scaled up by the mass difference between the  $J/\psi$  and the  $\Upsilon(1S)$  ( $\Delta M \sim 6360 \text{ MeV}/c^2$ ) would be exotic bottomonium states with masses above the  $\Upsilon(4S)$  and below 11.2 GeV. Moreover, the  $\Upsilon(10860)$  and the  $\Upsilon(11020)$  states, which are candidate  $\Upsilon(5S)$  and  $\Upsilon(6S)$  respectively, were observed in the same region [3, 4].

Between March 28 and April 7, 2008 the PEP-II  $e^+e^-$  collider [5] delivered colliding beams at a center-of-mass energy ( $\sqrt{s}$ ) in the range of 10.54 to 11.20 GeV. First, an energy scan over the whole range in 5 MeV steps, collecting approximately  $25 \text{ pb}^{-1}$  per step for a total of about  $3.3 \text{ fb}^{-1}$ , was performed. It was then followed by a  $600 \text{ pb}^{-1}$  scan in the range of  $\sqrt{s}=10.96$  to 11.10 GeV, in 8 steps with non-regular energy spacing, performed in order to investigate the  $\Upsilon(6S)$  region. This data set outclasses the previous scans [3, 4] by a factor  $> 30$  in the luminosity and  $\sim 4$  in the size of the energy steps. Across the scan, the energy of the positron beam was kept fixed at 3.12 GeV, while the electron beam energy was varied accordingly, to set the required  $\sqrt{s}$ . This produced a variation of the boost of the center-of-mass frame during the scan.

In this Letter we present, for each step in  $\sqrt{s}$ , the measurement of  $R_b(s) = \sigma_b(s)/\sigma_{\mu\mu}^0(s)$ , where  $\sigma_{\mu\mu}^0 = 4\pi\alpha^2/3s$  is the lowest-order cross section for  $e^+e^- \rightarrow \mu^+\mu^-$  and  $\sigma_b$  is the total cross section for  $e^+e^- \rightarrow b\bar{b}(\gamma)$ , including  $b\bar{b}$  states produced in initial state radiation ( $ISR$ ) below the open beauty threshold, i.e. the  $\Upsilon(1S)$ ,  $\Upsilon(2S)$ , and  $\Upsilon(3S)$  resonances.

The particles produced in the collisions are detected by the *BABAR* detector, described elsewhere [6]. Charged-particle tracking is provided by a five-layer silicon vertex tracker (SVT) and a 40-layer drift chamber (DCH). In addition to providing precise position information for tracking, the SVT and DCH also measure the specific ionization ( $dE/dx$ ), which is used for particle identification of low-momentum charged particles. At higher momenta ( $p > 0.7 \text{ GeV}/c$ ) pions and kaons are identified by Cherenkov radiation detected in a ring-imaging device (DIRC). The position and energy of neutral clusters (photons) are measured with an electromagnetic calorimeter (EMC) consisting of 6580 thallium-doped CsI crystals. These systems are mounted inside a 1.5-T solenoidal super-conducting magnet. Muon identifi-

cation is provided by the magnetic flux return system instrumented with Resistive Plate Chambers and Limited Streamer Tubes. The full detector is simulated, for background and efficiency studies, with a Monte Carlo program (MC) based on GEANT4 [7].

To measure  $R_b$ , we count the number of events passing a selection that enriches the sample in events containing  $B$  mesons ( $N_h$ ) and those passing an independent di-muon selection ( $N_\mu$ ) at each energy point and at a reference energy below the open beauty production threshold. Indicating with a prime the quantities at the reference energy, we write:

$$N_h(s) = \left[ (R_b(s) \sigma_{\mu\mu}^0(s) - \sigma_{ISR}(s)) \epsilon_B(s) \right. \quad (1)$$

$$\left. + \sum_X \sigma_X(s) \epsilon_X(s) + \sigma_{ISR}(s) \epsilon_{ISR}(s) \right] \mathcal{L}(s)$$

$$N'_h = \left( \sum_X \sigma'_X \epsilon'_X + \sigma'_{ISR} \epsilon'_{ISR} \right) \mathcal{L}' \quad (2)$$

$$N_\mu(s) = \sigma_{\mu\mu}(s) \epsilon_\mu(s) \mathcal{L}(s) \quad (3)$$

$$N'_\mu = \sigma'_{\mu\mu} \epsilon'_\mu \mathcal{L}' \quad (4)$$

where  $\epsilon_B$  is the efficiency for open  $b$  production to satisfy the hadronic selection,  $X$  represents the different background components described later,  $\sigma_i$  represents the cross-sections for the process  $i$ ,  $\epsilon_i$  the corresponding efficiency, and  $\mathcal{L}$  is the integrated luminosity collected at a given value of  $\sqrt{s}$ . Measurements of  $N_\mu$  and  $N'_\mu$  are needed in order to normalize the hadronic rates to the collected luminosities. As reference we choose the sample collected at  $\sqrt{s}=10.54$  GeV, about 40 MeV below the  $\Upsilon(4S)$  mass, taken during 2006-2007. Special mention is made of the  $ISR$  sample, the production of  $\Upsilon(nS)$  ( $n = 1, 2, 3$ ) mesons via initial state radiation: albeit part of the signal, this process can occur at the reference energy and has an efficiency and an energy dependence of the cross-section different from the open beauty production.

Solving the system of equations one obtains:

$$R_b = \left( \frac{N_h(s)}{N_\mu(s)} - \frac{N'_h}{N'_\mu} \kappa_{\sigma\epsilon}(s) \right) \frac{\epsilon_\mu(s) \xi_\mu}{\epsilon_B(s)} + R_{ISR}(s), \quad (5)$$

where we defined:

$$\kappa_{\sigma\epsilon}(s) = \frac{\epsilon'_\mu}{\epsilon_\mu(s)} \times \times \frac{\sum_X R_X(s) \epsilon_X(s) + R_{ISR}(s) \epsilon_{ISR}(s)}{\sum_X R'_X \epsilon'_X + R'_{ISR} \epsilon'_{ISR}}, \quad (6)$$

and  $R_i = \sigma_i/\sigma_{\mu\mu}^0$  for each process and  $\xi_\mu = \sigma_{\mu\mu}/\sigma_{\mu\mu}^0$ , assumed independent of  $\sqrt{s}$ . It should be noted that these equations assume that the background scales with the integrated luminosity, i.e. that the machine background is negligible, and that the di-muon selection leaves a negligible level of background.

We select the  $b$ -enriched sample by requiring at least three tracks in the event, a total visible energy in the event greater than 4.5 GeV, and a vertex reconstructed from the observed charged tracks within 5 mm of the beam crossing point in the plane transverse to the beam axis and 6 cm along the beam axis. These quantities are computed using exclusively tracks in the fiducial volume of the DCH (i.e. forming an angle with the beam axis  $0.41 < \theta < 2.54$  rad). A further rejection of the main backgrounds,  $e^+e^- \rightarrow q\bar{q}$ ,  $q = u, d, s, c$  events (“continuum” events) and  $e^+e^- \rightarrow \ell^+\ell^-$ ,  $\ell = e, \mu, \tau$  events, is obtained by means of a cut on the ratio of the second and zeroth Fox-Wolfram moments [8],  $R_2$ , calculated using only the charged tracks. After optimization of the statistical sensitivity, we require  $R_2 < 0.2$ . Events that pass this selection at the reference energy comprise 91% continuum, 2% two photon ( $e^+e^- \rightarrow e^+e^-\gamma^*\gamma^* \rightarrow e^+e^-X_h$ ), and 7%  $ISR$  ( $e^+e^- \rightarrow \Upsilon(nS)\gamma_{ISR}$ ) events.

To select di-muon events, we require that two tracks have an invariant mass greater than 7.5 GeV/ $c^2$ ; their angle with the beam axis in the center-of-mass frame,  $\theta_{cms}$ , must satisfy  $\cos\theta_{cms} < 0.7485$ , and the two muons must be collinear to within  $10^\circ$ . To exploit the fact that muons are minimum ionizing particles, we require that at least one of them leaves a signal in the EMC, and neither deposits more than 1 GeV.

In the following we describe the method used to derive the inputs to Eq. 5 and the corresponding errors, separating correlated and uncorrelated errors. The covariance matrix for the measurements of  $R_b$  at different energies is  $V_{ij} = [\sigma_{stat}^2(s_i) + \sigma_{unc}^2(s_i)] \delta_{ij} + \sigma_{corr}(s_i)\sigma_{corr}(s_j)$ , where  $\sigma_{stat}(s_i)$ ,  $\sigma_{corr}(s_i)$ , and  $\sigma_{unc}(s_i)$  are the statistical, correlated, and uncorrelated systematic error respectively, and  $\delta_{ij}$  is the Kronecker delta.

The efficiency for the di-muon selection  $\epsilon_\mu$  is extracted from a sample of fully simulated MC events generated with KK2f [9] at several values of  $\sqrt{s}$ . Due to the change in boost this efficiency is found to change by 1.5% over the whole range and the MC statistics error we assign to the corresponding correction is 0.2%. The correlated uncertainty on the absolute scale of the efficiency is estimated to be 1% and to come primarily from uncertainties in the simulation of the trigger, of the quantities used in the selection and of the tracking efficiency. We also account for differences in the trigger configurations between the scan data and the reference data taken during the year 2007 and estimate the efficiency on the reference data to be lower by  $(0.5 \pm 0.2)\%$ . The same generator is consistently used to extract  $\xi_\mu = 1.48 \pm 0.02$ , where this correlated error is due to the uncertainty on the cross-

section.

The efficiency for  $e^+e^- \rightarrow b\bar{b}$  events is estimated by using EvtGen [10] as generator, separately for each possible two-body final state including  $B$ ,  $B_s$ , and  $B_s^*$  mesons, and at different values of  $\sqrt{s}$ . Because we ignore the relative composition in terms of final states at each energy we consider the largest and the smallest efficiencies among the allowed final states and take their mean value as the central value and half their difference as uncorrelated error. The correlated error on the absolute scale of  $\epsilon_B$  is estimated by varying the selection criteria and it is found to amount to 1.3%.

The calculation of the double ratio  $\kappa_{\sigma\epsilon}$  requires the dependence on  $\sqrt{s}$  of  $\epsilon_\mu$ , which has already been discussed, and the cross-sections and efficiencies for the  $ISR$  and the background processes.

The  $ISR$  cross-section is computed to second-order according to Ref. [11]. The corresponding efficiency ( $\epsilon_{ISR}$ ) is estimated with MC simulation to be 41% on average. The relative efficiency change across the scan, estimated to be  $\sim 5\%$ , is used as a correlated uncertainty and it propagates to an error on  $R_b$  of at most 0.7%.

The cross-section for two-photon events scales as the square of the logarithm of  $s$ , and the corresponding efficiency is considered to be flat. The product of the cross-section and the efficiency ( $\sigma_{\gamma\gamma}\epsilon_{\gamma\gamma}$ ) before the  $R_2$  is fitted from the distribution of the direction of the missing momentum and then multiplied by the  $R_2$  cut efficiency. We attribute 50% uncertainty to this estimate, leading to a relative correlated error of at most 0.2%. Finally, the product of the continuum cross-section and efficiency is computed by subtracting the  $ISR$  and two photon components from  $N'_h$  (see Eq. 2). The continuum contribution to  $R$  ( $R_{cont}$ ) is assumed to be constant with  $\sqrt{s}$ , while the corresponding efficiency ( $\epsilon_{cont}$ ) was estimated on a sample of MC events generated with JETSET [12]. No correction to account for the fact that the reference data were taken in a different data-taking period was found necessary. The relative change of  $\epsilon_{cont}$  over the whole scan range is estimated to be 3% and a 0.2% systematic error due to MC statistics is assigned to it. We also find that the distribution of  $R_2$  is not perfectly reproduced by the MC. We therefore estimate the scaling of  $\epsilon_{cont}$  separately with and without the  $R_2 < 0.2$  requirement and take the difference among the results as a correlated systematic error. Its contribution depends on the value of  $R_b$  and it is at most 2%.

To measure  $\sqrt{s}$  of each point we fit the distribution of the invariant mass of the two muons in the selected di-muon sample with a function made of a Gaussian with an exponential tail on the side below the peak mass. We then use the mean of the Gaussian as estimator of  $\sqrt{s}$  and we determine a bias of  $(20.9 \pm 1.5)$  MeV for this quantity by comparing the  $\Upsilon(3S)$  mass measured on the data taken during the  $\sim 100 \text{ pb}^{-1}$  scan performed by PEP-II at the beginning of the last data-taking period with the

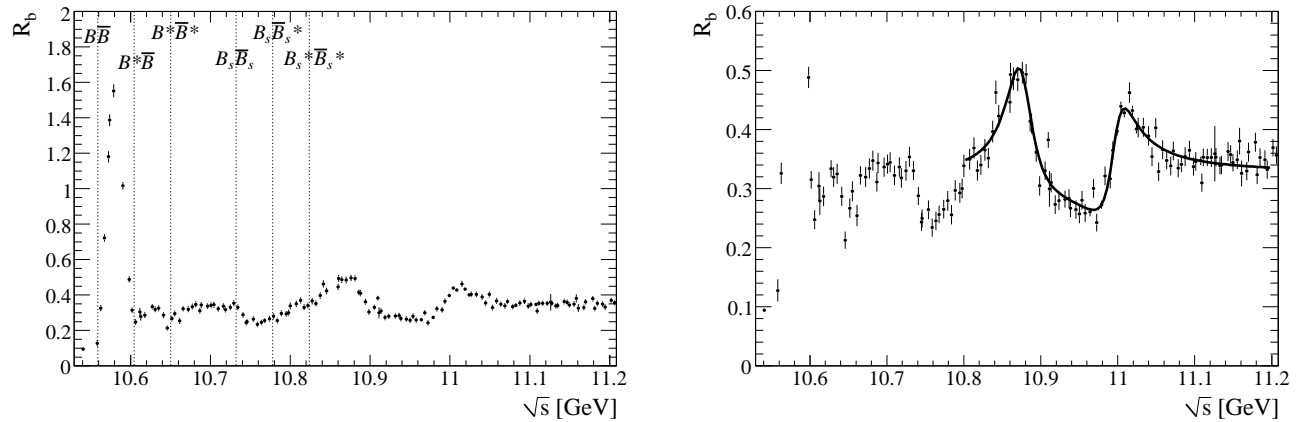


FIG. 1: (Left) Measured  $R_b$  as a function of  $\sqrt{s}$  with the position of the opening thresholds of the  $e^+e^- \rightarrow B_{(s)}^{(*)}\bar{B}_{(s)}^{(*)}$  processes indicated by dotted lines. (Right) A zoom of the same plot with the result of the fit described in the text superimposed. The errors on data represent the statistical and the uncorrelated systematic errors added in quadrature.

TABLE I: Contributions to the relative correlated systematic error on  $R_b$ .

Contribution	Relative error (%)
$\mu\mu$ MC statistics	0.2
$\mu\mu$ radiative corrections	1.4
$\epsilon_\mu$	1.3
$\epsilon_B$	1.3
$\epsilon_{cont}$	< 2.0
$\epsilon_{ISR}$	< 0.7
$\sigma_{\gamma\gamma}\epsilon_{\gamma\gamma}$	< 0.2

resonant depolarization result [13]. We correct for this bias, that comes from the (strongly) non linear impact of the momentum resolution in the invariant mass, and verify on simulated events that it does not depend on  $\sqrt{s}$ .

TABLE II: Fit results for the  $\Upsilon(10860)$  and  $\Upsilon(11020)$  resonances resulting from the fit described in the text. The  $\phi$  phases are relative to the interfering continuum. The corresponding world averages [17] are also reported.

	$\Upsilon(10860)$	$\Upsilon(11020)$
mass (GeV)	$10.876 \pm 0.002$	$10.996 \pm 0.002$
width (MeV)	$43 \pm 4$	$37 \pm 3$
$\phi$ (rad)	$2.11 \pm 0.12$	$0.12 \pm 0.07$
PDG mass (GeV)	$10.865 \pm 0.008$	$11.019 \pm 0.008$
PDG width (MeV)	$110 \pm 13$	$79 \pm 16$

The resulting measurements of  $R_b$  as a function of  $\sqrt{s}$  are shown in Fig. 1, where the error bars represent the sum of the statistical and uncorrelated systematic errors and dotted lines show the different  $B$  meson production thresholds. The relative correlated systematic errors on  $R_b$  are summarized in Table I. The numerical results

for each energy point, together with the estimated ISR cross section, can be found in Ref. [14]. It is important to stress that radiative corrections have not been applied since they would require an a-priori knowledge of the resonant region. The measured  $R_b$  therefore includes all final- or initial- state radiation processes.

The large statistics and the small energy steps of this scan make it possible to observe clear structures corresponding to the opening of new thresholds: dips corresponding to the  $B^{(*)}B^*$  and  $B_sB_s^*$  openings and a plateau close to the  $B_s^*B_s^*$  one. It is also evident that the  $\Upsilon(10860)$  and  $\Upsilon(11020)$  behave differently above and below the corresponding peaks. Finally, the plateau above the  $\Upsilon(11020)$  is clearly visible.

We fit the following simple model to our data between 10.80 and 11.20 GeV: a flat component representing  $b\bar{b}$ -continuum states not interfering with resonance decays, added incoherently to a second flat component interfering with two relativistic Breit Wigner resonances:  $\sigma = |A_{nr}|^2 + |A_r + A_{10860}e^{i\phi_{10860}}BW(M_{10860}, \Gamma_{10860}) + A_{11020}e^{i\phi_{11020}}BW(M_{11020}, \Gamma_{11020})|^2$ , with  $BW(M, \Gamma) = 1/[(s - M^2) + iM\Gamma]$ . The results summarized in Table II and Fig. 1 differ substantially from the PDG values. In particular the  $B_s^*B_s$  and  $B_s^*B_s^*$  thresholds have a very large impact on the determination of the  $\Upsilon(10860)$  width.

The number of states is, a priori, unknown as are their energy dependencies. Therefore, a proper coupled channel approach [15, 16] including the effects of the various thresholds outlined earlier, would be likely to modify the results obtained from our simple fit. As an illustration of the systematic uncertainties arising from the assumptions in our fit, a simple modification is to replace the flat nonresonant term by a threshold function at  $\sqrt{s} = 2m_B$ . This leads to a larger width ( $74 \pm 4$  MeV) and a lower mass ( $10869 \pm 2$  MeV) for the  $\Upsilon(10860)$ .

In summary, we have performed an accurate measurement of  $R_b$  in fine grained center-of-mass energy steps and have shown that these measurements have the potential to yield information on the bottomonium spectrum and possible exotic extensions.

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), 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 Temple University, Philadelphia, Pennsylvania 19122, USA

‡ Now at Tel Aviv University, Tel Aviv, 69978, Israel

§ Also with Università di Perugia, Dipartimento di Fisica, Perugia, Italy

¶ Also with Università di Roma La Sapienza, I-00185 Roma, Italy

\*\* Now at University of South Alabama, Mobile, Alabama 36688, USA

†† Also with Università di Sassari, Sassari, Italy

[1] For a comprehensive review see for example E. J. Eichten, K. Lane and C. Quigg, Phys. Rev. D **73** (2006) 014014

[Erratum-ibid. D **73** (2006) 079903].

- [2] B. Aubert *et al.* [BABAR Collaboration], Phys. Rev. Lett. **95**, 142001 (2005); B. Aubert *et al.* [BABAR Collaboration], Phys. Rev. Lett. **98** (2007) 212001; X. L. Wang *et al.* [Belle Collaboration], Phys. Rev. Lett. **99** (2007) 142002; C. Z. Yuan *et al.* [Belle Collaboration], Phys. Rev. Lett. **99**, 182004 (2007).
- [3] D. Besson, *et al.* [CLEO collaboration], Phys. Rev. Lett. **54**, 381 (1985).
- [4] D.M.Lovelock, *et al.* [CUSB collaboration], Phys. Rev. Lett. **54**, 377 (1985).
- [5] PEP-II Conceptual Design Report, SLAC-0418 (1993).
- [6] B. Aubert *et al.* [BABAR Collaboration], Nucl. Instrum. and Methods Phys. Res., Sec. A **479**, 1 (2002).
- [7] S. Agostinelli *et al.* [GEANT4 Collaboration], Nucl. Instrum. Meth. A **506** (2003) 250.
- [8] G.C. Fox and S. Wolfram, Phys. Rev. Lett. **41**, 1581 (1978).
- [9] S. Jadach, B. F. L. Ward and Z. Was, Comput. Phys. Commun. **130** (2000) 260.
- [10] D. J. Lange, Nucl. Instrum. Meth. A **462** (2001) 152.
- [11] M. Benayoun, S. I. Eidelman, V. N. Ivanchenko and Z. K. Silagadze, Mod. Phys. Lett. A **14** (1999) 2605.
- [12] T. Sjostrand, Comput. Phys. Commun. **39** (1986) 347.
- [13] A. S. Artamonov, *et al.* [MD1 Collaboration], Phys. Lett. B **474** (2000) 427.
- [14] While awaiting publication on EPAPS the full list of results is available as PUB-08/042 in [https://oraweb.slac.stanford.edu/pls/slacquery/babar\\_documents.startup](https://oraweb.slac.stanford.edu/pls/slacquery/babar_documents.startup)
- [15] E. Eichten *et al.*, Phys. Rev. D **17** (1978) 3090; E. Eichten *et al.*, Phys. Rev. D **21** (1980) 203.
- [16] N. A. Tornqvist, Phys. Rev. Lett. **53**, 878 (1984).
- [17] W. M. Yao *et al.* [Particle Data Group], J. Phys. G **33** (2006) 1.