Measurements of the Mass and Width of the $\eta_c$ Meson and of an $\eta_c(2S)$ Candidate

B. Aubert, R. Barate, D. Boutigny, J.-M. Gaillard, A. Hicheur, Y. Karyotakis, J. P. Lees, P. Robbe, V. Tisserand, A. Zghiche, A. Palano, A. Pompili, J. C. Chen, N. D. Qi, G. Rong, P. Wang, Y. S. Zhu, G. Eigen, I. Ofte, B. Stugu, G. S. Abrams, A. W. Borgland, A. B. Breon, D. N. Brown, J. Button-Shaffer, R. N. Cahn, E. Charles, C. T. Day, M. S. Gill, A. V. Gritsan, Y. Grotsman, R. G. Jacobsen, R. W. Kadel, J. Kadyk, L. T. Kerth, Yu. G. Kolomensky, J. F. Kral, G. Kulkarstev, C. LeClere, M. E. Levi, G. Lynch, L. M. Mir, P. J. Oddone, T. J. Orimoto, M. Pripstein, N. A. Roe, A. Romenosan, M. T. Ronan, V. G. Shelkov, A. V. Telnov, W. A. Wenzel, K. Ford, T. J. Harrison, M. M. Hawkes, D. J. Knowles, S. E. Morgan, R. C. Penny, A. T. Watson, N. K. Watson, T. Deppermann, K. Goetzen, H. Koch, B. Lewandowski, M. Pelizaues, K. Peters, H. Schmuecker, M. Steinke, N. R. Barlow, J. T. Boyd, N. Chevalier, W. N. Cottingham, M. P. Kelly, T. E. Latham, C. Mackay, F. F. Wilson, K. Abe, C. Tuhadar-Donszelmann, C. Hearty, T. S. Mattison, J. A. McKenna, D. Thiessen, P. Kyberd, A. K. McKenney, V. E. Blinov, A. D. Bukin, V. B. Golubev, V. N. Ivanchenko, A. A. Kравенек, A. P. Onuchin, S. I. Seredyak, Yu. I. Skowpen, E. P. Solodov, A. N. Yushkov, D. Best, M. Brinsma, M. Chao, D. Kirkby, A. J. Lankford, M. Mandelkern, R. K. Mommesen, W. Roethel, D. P. Stoker, C. Buchanan, B. L. Hartfiel, C. B. Shen, D. del Re, H. K. Hadavand, E. J. Hill, B. MacFarlane, H. P. Paar, Sh. Rahatlou, U. Schwanke, V. Sharma, J. W. Berryhill, C. Campagnari, B. Dahmes, N. Kuznetsova, S. L. Levy, O. Long, A. Lu, M. A. Mazur, J. D. Richman, W. Verkerke, T. W. Beck, J. Beringer, A. M. Eisser, C. A. Heusch, W. S. Lockman, T. Schalk, R. E. Schmitz, A. B. Schumm, A. Seiden, M. Turri, W. Walkowink, D. C. Williams, M. G. Wilson, J. Albert, E. Chen, G. P. Dubois-Felsmann, A. Dvoretski, D. G. Hitlin, I. Narsky, F. C. Porter, A. Ryd, A. Samuel, S. Yang, S. Jayatilleke, G. Mancinelli, B. T. Meadows, M. D. Sokoloff, T. Abe, F. Blanc, P. Bloom, B. Chen, P. J. Clark, W. T. Ford, U. Nauenberg, P. Rankin, J. Roy, J. G. Smith, W. C. van Hoek, L. Zhang, J. L. Harton, T. Hu, A. Soffer, W. H. Toki, R. J. Wilson, J. Zhang, D. Altenburg, T. Brandt, J. Brose, T. Collberg, M. Dickopp, R. S. Dubitzky, A. Hauke, H. M. Lack, E. Maly, R. Müller-Pfeifferkorn, R. Nogovski, S. Otto, J. Schubert, K. B. Schubert, R. Schwierz, B. Spaan, L. Wilden, D. Bernard, G. R. Bonneau, F. Brochard, J. Cohen-Tanugi, P. Grenier, Ch. Thiebaux, G. Vasiileiadis, M. Verderi, A. Khan, D. Lavin, F. Muheim, S. Player, J. E. Swain, J. Tinslay, M. Andreotti, V. Azzolini, D. Bettoni, C. Bozzi, R. Calabrese, G. Cibinetto, E. Luppi, M. Negri, L. Piemontese, A. Sarti, E. Treadwell, F. Anulli, R. Baldini-Ferroli, B. Calcaterra, R. de Sangro, D. Falciai, G. Finocchiaro, P. Patteri, I. M. Peruzzi, E. A. Kravchenko, J. G. Smith, M. T. Ronan, T. E. Latham, A. Samuel, H. P. Paar, S. Passaggio, C. Patrignani, E. Robutti, A. Santroni, S. Tosi, S. Bailey, M. Morii, E. Maly, W. Himjui, D. A. Bowerman, P. D. Dauncey, U. Egede, I. Eschrich, J. R. Gaillard, G. W. Morton, J. A. Nash, P. Sanders, G. P. Taylor, G. J. Grenier, S.-J. Lee, U. Mallik, J. Cochran, B. C. Crawford, J. Lamasa, W. T. Meyer, S. Prell, I. Rosenberg, J. Yi, M. Davier, G. Grosdidier, A. Höcker, S. Laplace, F. Le Diberder, V. Lepeltier, A. M. Lutz, T. C. Petersen, S. Plaszczynski, M. H. Schune, L. Tantot, G. Wormier, V. Brigljevic, C. H. Cheng, D. J. Lange, D. M. Wright, A. J. Bevan, J. P. Coleman, J. R. Fry, E. Gabathuler, R. Gamet, M. Kay, R. J. Parry, D. J. Payne, R. J. Sloane, C. Touramanis, J. J. Back, P. F. Harrison, H. Shorthouse, P. Strother, P. B. Vidal, C. L. Brown, C. Gowan, R. L. Flack, H. U. Fluecher, S. George, M. G. Green, A. Kurup, C. E. Marker, T. R. McMahon, S. Ricciardi, F. Salvatore, G. Vaitas, M. A. Winter, D. Brown, C. L. Davis, J. Allison, R. J. Barlow, A. C. Forti, P. A. Hart, F. Jackson, G. D. Lafferty, A. J. Lyon, J. H. Weatherall, J. C. Williams, A. Farbin, A. J. Hawajeha, D. Kovalskyi, C. K. Lue, V. Lillard, D. A. Roberts, G. Blaylock, C. Dallapiccola, K. T. Flood, S. Hertzbach, R. Kofler, V. B. Koptchey, T. B. Moore, S. Saremri, I. Staengle, S. Willocq, R. Cowan, G. Sciolla, F. Taylor, K. R. Yamamoto, D. J. J. Mangeol, M. Milek, P. M. Patel, L. Azzaro, F. Palombo, J. M. Bauer, L. Cremaldi.
The mass $m_{\eta_c}$ and total width $\Gamma_{\eta_c}^{\text{tot}}$ of the $\eta_c$ meson have been measured in two-photon interactions at the SLAC $e^+e^-$ asymmetric B-Factory with the BABAR detector. With a sample of approximately 2500 reconstructed $\eta_c \to K^0_SK^+\pi^-\pi^+$ decays in 88 fb$^{-1}$ of data, the results are $m_{\eta_c} = 2982.5 \pm 1.1$ (stat) $\pm 0.9$ (syst) MeV/$c^2$ and $\Gamma_{\eta_c}^{\text{tot}} = 34.3 \pm 2.3$ (stat) $\pm 0.9$ (syst) MeV/$c^2$. Using the same decay
The mass and width of the $\eta_c$ meson ($J^{PC} = 0^{-+}$), the lowest lying state of charmonium, are not as well established as those of the $J/\psi$ meson. The world average $[1]$ of the total width is $\Gamma^{tot}_{\eta_c} = 16.0^{+3.5}_{-3.0}$ MeV/$c^2$, with individual measurements ranging from 7 MeV/$c^2$ to 27 MeV/$c^2$ with large errors. Recent measurements $[2]$ extend from 17 MeV/$c^2$ to 29 MeV/$c^2$.

A radial excitation of the $\eta_c$, the $\eta_c(2S)$ state, is predicted by heavy quark potential models to lie below the $D\bar{D}$ threshold $[3]$. The hyperfine separations ($\eta_c$, $J/\psi$) and ($\eta_c(2S)$, $\psi(2S)$) are directly related to the spin-spin interaction. These calculations predict the mass splitting $m_{\psi(2S)} - m_{\eta_c(2S)}$ to be in the range 42–103 MeV/$c^2$. The Crystal Ball Collaboration $[4]$ observed a peak at 91 ± 5 MeV, in the inclusive photon spectrum of $\psi(2S)$ decays, with a width $\Gamma \leq 8$ MeV (95% confidence level). This peak was considered most likely to be due to $\psi(2S) \rightarrow \eta_c(2S)\gamma$, with the $\eta_c(2S)$ state having a mass of 3594 ± 5 MeV/$c^2$. The Belle Collaboration recently reported signals attributed to the $\eta_c(2S)$ state, but with substantially higher masses: for the $K^0_S K^+ K^- \pi^+$ mass distribution in exclusive $B \rightarrow K^0_S K^+ K^- \pi^+$ decays $[5]$, they measured 3654 ± 6 (stat) ± 8 (syst) MeV/$c^2$ and $\Gamma \leq 55$ MeV/$c^2$ (90% confidence level); from a signal observed in the inclusive $J/\psi$ spectrum in $e^+ e^-$ annihilation $[6]$, they measured 3622 ± 12 MeV/$c^2$. This state was unsuccessfully searched for in $p \bar{p} \rightarrow X \rightarrow \gamma \gamma$ $[6]$ and $\gamma \gamma \rightarrow \text{hadrons}$ $[7]$. However, an estimate $[8]$ of the two-photon production rate of the $\eta_c(2S)$ suggested that this meson could be identified in the current $e^+ e^- B$-factories.

In this analysis we measure the masses and widths of the $\eta_c$ and of a state interpreted as the $\eta_c(2S)$ meson, by reconstructing $\gamma \gamma \rightarrow X \rightarrow K^0_S K^+ K^- \pi^+$ ($K^0_S \rightarrow \pi^+ \pi^-\pi^0$) events in the $\Upsilon(4S)$ mass resonance, and corresponds to an integrated luminosity of 88 fb$^{-1}$.

The $\Upsilon(4S)$ mass spectrum is shown in Fig. 1 with a large peak at the $\eta_c$ mass and a smaller peak at the $J/\psi$ mass. Although the $J/\psi$ cannot be produced in two-photon fusion, it is expected to be produced with hard photon emission by initial state radiation (ISR). The boost of the asymmetric collider brings the decay products of $J/\psi$ mesons travelling in the backward direction into the acceptance of the detector.

A thorough understanding of the experimental resolution is essential to determine the width of the $\eta_c$ meson. The resolution for the $J/\psi$ can be inferred from data since its natural width is negligible. This is not
the case for the $\eta_c$, which has a natural width somewhat larger than the detector resolution. To help determine the resolution for the $\eta_c$, Monte Carlo calculations were performed. The generator [11] used to simulate $\gamma\gamma \rightarrow \eta_c \rightarrow K_0^0 K^\pm \pi^\mp$ events applies the formalism of Budnev et al. [12] to calculate the cross-section for the process $e^+e^- \rightarrow e^+e^-\gamma \rightarrow e^+e^-\eta_c$. Monte Carlo calculations were also performed to generate $J/\psi$ events produced in $e^+e^-\gamma$ annihilation with initial state radiation. Both $\eta_c$ and $J/\psi$ were assumed to decay into $K_0^0 K^\pm \pi^\mp$ with a phase-space distribution. In the Monte Carlo simulation, the reconstructed $\eta_c$ and $J/\psi$ masses are both shifted by $-1.1$ MeV/$c^2$ (with statistical errors of 0.1 MeV/$c^2$ and 0.2 MeV/$c^2$ respectively) from their generated values. This bias does not affect the mass difference $m_{J/\psi} - m_{\eta_c}$. The mass resolution is estimated by fitting the distribution of the difference between reconstructed mass and generated mass to a Gaussian function. Its standard deviation is found to be $7.3 \pm 0.1$ MeV/$c^2$ for the $\eta_c$ and $8.1 \pm 0.2$ MeV/$c^2$ for the $J/\psi$.

To determine the mass and width of the $\eta_c$, an unbinned maximum likelihood fit to the $K_0^0 K^\pm \pi^\mp$ mass spectrum for masses between 2.5 and 3.5 GeV/$c^2$ is performed. The $\eta_c$ is represented by a Breit–Wigner function $(\Gamma/2)^2((W - m_{\eta_c})^2 + (\Gamma/2)^2)$, with $W$ the invariant $K_0^0 K^\pm \pi^\mp$ mass, convolved with a Gaussian resolution function. The $J/\psi$ peak is fitted with a Gaussian function. The background is represented by an exponential function of $W$, $A \exp(-\lambda W)$. The free parameters of the fits are the $J/\psi$ mass $m_{J/\psi}$, the mass difference $m_{J/\psi} - m_{\eta_c}$, the $\eta_c$ width $\Gamma_{\eta_c}$, the $J/\psi$ resolution $\sigma_{J/\psi}$, the coefficients $A$ and $\lambda$ of the background, and the numbers of events in the $\eta_c$ and $J/\psi$ peaks. The resolution $\sigma_{\eta_c}$ of the $\eta_c$ peak is constrained to a value $0.8$ MeV/$c^2$ lower than the $J/\psi$ resolution, as indicated by the Monte Carlo simulation. The results of the fit are: $m_{J/\psi} = 3093.6 \pm 0.8$ MeV/$c^2$, $m_{J/\psi} - m_{\eta_c} = 114.4 \pm 1.1$ MeV/$c^2$, $\sigma_{J/\psi} = 7.6 \pm 0.8$ MeV/$c^2$, $\Gamma_{\eta_c} = 34.3 \pm 2.3$ MeV/$c^2$. The numbers of $\eta_c$ and $J/\psi$ events are respectively 2547 $\pm$ 90 and 358 $\pm$ 33.

The mass resolution found for the $J/\psi$ is $0.5 \pm 0.8$ MeV/$c^2$ lower than the Monte Carlo prediction, but consistent with it. To evaluate the systematic uncertainty affecting the $\eta_c$ width, the conditions of the fit are varied as shown in Table 1. When $\sigma_{J/\psi}$ and $\sigma_{\eta_c}$ are fixed to the values obtained in the Monte Carlo simulation (second row of Table 1), the width of the $\eta_c$ changes by $0.6$ MeV/$c^2$. We take this value as an estimate of the systematic uncertainty associated with the uncertainty on the $\eta_c$ resolution. The value of $\Gamma_{\eta_c}$ changes by $0.4$ MeV/$c^2$ on average when the mass range of the fit is varied from $2.4 - 3.6$ GeV/$c^2$ to $2.7 - 3.3$ GeV/$c^2$. This gives an estimate of the systematic uncertainty associated with the choice of the mass range of the fit. By varying the event selection parameters, we estimate that the systematic uncertainty associated with the event selection is $0.5$ MeV/$c^2$.

The total systematic uncertainty on the $\eta_c$ width is then $0.9$ MeV/$c^2$. The final value of the $\eta_c$ width is:

$$\Gamma_{\eta_c} = 34.3 \pm 2.3(stat) \pm 0.9(syst) \text{ MeV}/c^2.$$
for the $J/\psi$, $\eta_c$ and $\eta_c(2S)$, in the laboratory frame ($\Theta_c$ is the pion polar angle). The backgrounds determined from sidebands have been subtracted.

![Angular distributions of pions from the decays of $J/\psi$, $\eta_c$ and $\eta_c(2S)$, in the laboratory frame](image)

FIG. 2: Angular distributions of pions from the decays of $J/\psi$, $\eta_c$ and $\eta_c(2S)$, in the laboratory frame ($\Theta_c$ is the pion polar angle). The backgrounds determined from sidebands have been subtracted.

![The $K^0\bar{K}^{\pm}\pi^\mp$ mass spectrum with event selection optimized for the $\eta_c(2S)$ as described in the text. The solid curve is the fit with the $\eta_c(2S)$ resonance shape being represented by a Breit–Wigner function convoluted with a Gaussian resolution function. The dashed curve shows the background component of this fit.](image)

FIG. 3: The $K^0\bar{K}^{\pm}\pi^\mp$ mass spectrum with event selection optimized for the $\eta_c(2S)$ as described in the text. The solid curve is the fit with the $\eta_c(2S)$ resonance shape being represented by a Breit–Wigner function convoluted with a Gaussian resolution function. The dashed curve shows the background component of this fit.

The mass resolution determined from the Monte Carlo simulation is 9.2 MeV/$c^2$ and the reconstructed mass is 0.4 MeV/$c^2$ lower than the generated mass. Since the resolution for the $J/\psi$ was found to be $0.5 \pm 0.8$ MeV/$c^2$ lower in the data than in the Monte Carlo simulation, we assume that the resolution for $\eta_c(2S)$ is also 0.5 MeV/$c^2$ lower in the data, with an uncertainty of 0.8 MeV/$c^2$. The $K^0\bar{K}^{\pm}\pi^\mp$ mass spectrum is then fitted between 3.3 GeV/$c^2$ and 4.0 GeV/$c^2$, the $\eta_c(2S)$ resonance shape being represented by a Breit–Wigner function convoluted with a Gaussian resolution function with standard deviation 8.7 MeV/$c^2$. The background is fitted with an exponential shape. The fit results in 112 ± 24 events in the $\eta_c(2S)$ peak. The significance of this signal is characterized by the quantity $\sqrt{2} \times \log \frac{L_{\text{max}}}{L_0} = 4.9$, where $L_{\text{max}}$ and $L_0$ are respectively the likelihoods for the fits with and without the $\eta_c(2S)$ peak.

The $m_{\eta_c(2S)} - m_{J/\psi}$ mass difference is found to be 534.6 ± 3.4 (stat) MeV/$c^2$. Taking into account the shifts from generated to reconstructed masses of $-1.1$ MeV/$c^2$ for the $J/\psi$ and $-0.4$ MeV/$c^2$ for the $\eta_c(2S)$, as found in the Monte Carlo simulation, this mass difference becomes 533.9 MeV/$c^2$. The $\eta_c(2S)$ mass is then $m_{\eta_c(2S)} = m_{J/\psi} + 533.9 = 3630.8 \pm 3.4$ (stat) MeV/$c^2$. The measured total width is $17.0 \pm 8.3$ (stat) MeV/$c^2$. The resolution uncertainty of 0.8 MeV/$c^2$ results in a systematic uncertainty of 0.1 MeV/$c^2$ on the $\eta_c(2S)$ mass and 2.0 MeV/$c^2$ on its total width. When the mass range for the fit is varied to 3.2–4.1 or 3.4–3.9 GeV/$c^2$, the $\eta_c(2S)$ mass varies by 0.2 MeV/$c^2$ whereas its width varies by 1.2 MeV/$c^2$ on average. The 0.5 MeV/$c^2$ uncertainty on the $-2.2$ MeV/$c^2$ shift observed for the measured $J/\psi$ mass relative to the world average value is taken as a systematic uncertainty on the $\eta_c(2S)$ mass. Based on the upper limit for the branching fraction $\psi(2S) \rightarrow K^+K^-\pi^0$, we estimate that $\psi(2S)$ (with a mass of 3.686 GeV/$c^2$) could contribute up to 5 events to the spectrum of Fig. 3. Allowing for this reduces the $\eta_c(2S)$ width by 0.7 MeV, which we take as a systematic uncertainty, whereas the $\eta_c(2S)$ mass varies by about 0.1 MeV/$c^2$. The systematic uncertainties associated with the event selection are taken to be the same as for the $\eta_c$, 0.8 MeV/$c^2$ for the $\eta_c(2S)$ mass and 0.5 MeV/$c^2$ for its total width. Adding all systematic uncertainties in quadrature, the final results are:

\[ m_{\eta_c(2S)} = 3630.8 \pm 3.4\text{(stat)} \pm 1.0\text{(syst)} \text{ MeV}/c^2 \]

\[ \Gamma_{\text{tot}}^{\eta_c(2S)} = 17.0 \pm 8.3\text{(stat)} \pm 2.5\text{(syst)} \text{ MeV}/c^2. \]

![Total transverse momentum in the center-of-mass](image)

FIG. 4: Total transverse momentum in the center-of-mass. The hatched solid line is the result of the two-photon Monte Carlo simulation for the $\eta_c(2S)$ state, normalized to the data. The data are events in the 3.60–3.66 GeV/$c^2$ mass region; the background determined from mass sidebands 3.30–3.37 GeV/$c^2$ and 3.78–3.86 GeV/$c^2$ has been subtracted.

While we have not measured the quantum numbers of the state at 3630.8 MeV/$c^2$, demonstrating that it is formed from the fusion of two quasi-real photons would at least restrict the possibilities. Such a process can occur only if $C=+\text{ and } J^P = 0^+$ (is excluded by the final state), $2^\pm, 3^+, 4^\pm$, .... Other combinations would be possible if production were via an ISR process, or if at least one of the two photons in two-photon fusion were highly virtual. However ISR is excluded as the source, because
the decay products of this state have angular distributions concentrated in the forward hemisphere, like the $\eta_c$, in contrast to the $J/\psi$ for which the decay products peak in the backward direction. This is illustrated in Fig. 2.

Moreover the distribution of the total transverse momentum (Fig. 3) is peaked at 0, characteristic of quasi-real photons, and this excludes spin-one production. Thus the evidence supports the state having quantum numbers $J^{PC} = 0^{-+}$ or $J \geq 2$. But $J \geq 2$ is disfavored for a charmonium state of such low mass, which suggests that the state has the quantum numbers of the $\eta_c(2S)$.

In summary, we have measured the mass difference between the $J/\psi$ and the $\eta_c$ and the total width of the $\eta_c$, using $2547 \pm 90$ events of $\gamma\gamma \rightarrow \eta_c \rightarrow K_S^0K^\pm\pi^\mp$ and $358 \pm 33 J/\psi \rightarrow K_S^0K^\pm\pi^\mp$ events, selected with the BABAR detector.

A state which could be the expected $\eta_c(2S)$ was also observed in the $K_S^0K^\pm\pi^\mp$ decay mode, with $112 \pm 24$ events, and its mass and total width measured. The measured mass is significantly different from the mass of the state reported by the Crystal Ball Collaboration [4], but consistent with the measurements of the Belle Collaboration [5, 6]. We have presented evidence that this state is produced via the fusion of two quasi-real photons, which suggests that its quantum numbers are those of the $\eta_c(2S)$. The deduced mass splitting $m_{\psi(2S)} - m_{\eta_c(2S)} = 55.2 \pm 4.0\text{ MeV}/c^2$ is consistent with theoretical expectations.

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

---

* Also with Università di Perugia, Perugia, Italy
† Also with Università della Basilicata, Potenza, Italy
‡ Also with IFIC, Instituto de Física Corpuscular, CSIC-Universidad de Valencia, Valencia, Spain
§ Deceased

[1] Particle Data Group, K. Hagiwara et al., Phys. Rev. D 66, 010001 (2002).
[2] Belle Collaboration, F. Fang et al., Phys. Rev. Lett. 90, 071801 (2003); BES Collaboration, J. Z. Bai et al., Phys. Lett. B 555, 174 (2003); Fermilab E835 Collaboration, M. Ambrogiani et al., Phys. Lett. B 566, 45 (2003).
[3] E. Eichten and F. Feinberg, Phys. Rev. D 23, 2724 (1981); W. Buchmüller and S. -H. H. Tye, Phys. Rev. D 24, 132 (1981); S. Godfrey and N. Isgur, Phys. Rev. D 32, 189 (1985); E. J. Eichten and C. Quigg, Phys. Rev. D 49, 5845 (1994); D. Ebert, R. N. Faustov and V. O. Galkin, Phys. Rev. D 62, 034014 (2000).
[4] Crystal Ball Collaboration, C. Edwards et al., Phys. Rev. Lett. 48, 70 (1982).
[5] Belle Collaboration, S. K. Choi et al., Phys. Rev. Lett. 89, 102001 (2002).
[6] Belle Collaboration, K. Abe et al., Phys. Rev. Lett. 89, 142001 (2002).
[7] E760 Collaboration, T. A. Armstrong et al., Phys. Rev. D 52, 4839 (1995); E835 Collaboration, M. Ambrogiani et al., Phys. Rev. D 64, 052003 (2001).
[8] DELPHI Collaboration, P. Abreu et al., Phys. Lett. B 441, 479 (1999); L3 Collaboration, M. Acciarri et al., Phys. Lett. B 461, 155 (1999).
[9] T. Barnes, T. E. Browder and S. F. Tuan, Phys. Lett. B 385, 391 (1996).
[10] BABAR Collaboration, B. Aubert et al., Nucl. Instr. Meth. A 479, 1 (2002).
[11] Private communication from H. P. Paar and M. Sivertz (CLEO Collaboration), adapted to BABAR.
[12] V. M. Budnev et al., Phys. Rep. 15C, 181 (1975).