

Study of the $\pi^+\pi^-J/\psi$ Mass Spectrum
via Initial-State Radiation at BABAR

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Abstract

We present an update of the study of the $Y(4260)$ resonance, produced in the process $e^+e^- \rightarrow \gamma_{ISR} \pi^+\pi^- J/\psi$ using initial-state radiation events at the PEP-II e^+e^- storage rings. This study is based on 454 fb^{-1} of data recorded with the *BABAR* detector at a center-of-mass energy in the $\mathcal{T}(4S)$ resonance region. From a fit with a single non-relativistic Breit-Wigner shape we obtain updated parameters for the $Y(4260)$ resonance which are $m_Y = 4252 \pm 6^{+2}_{-3} \text{ MeV}/c^2$ and $\Gamma_Y = 105 \pm 18^{+4}_{-6} \text{ MeV}/c^2$; we also measure $\mathcal{B}(\pi^+\pi^- J/\psi)\Gamma_{e^+e^-} = (7.5 \pm 0.9 \pm 0.8) \text{ eV}$. We cannot confirm the recent BELLE observation of a broad structure around $4.05 \text{ GeV}/c^2$ in this decay mode.

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1 INTRODUCTION

The observation of X(3872) [1], followed by the discovery of many other states such as the Z(3930) [2], the Y(3940) [3] and the X(3940) [4], has reopened interest in charmonium spectroscopy. Some of these resonances cannot be fully explained by a simple charmonia model [5]; four-quark state [6] and $D^0\bar{D}^{0*}$ molecule [7] are some of the interpretations that have been proposed to explain their nature. Among these new states the Y(4260) [8] that has been observed by *BABAR* in the process $e^+e^- \rightarrow \gamma_{ISR} Y(4260) \rightarrow \gamma_{ISR} J/\psi \pi^+ \pi^-$, where *ISR* denotes initial state radiation. Being formed directly in e^+e^- annihilation, it is known to have $J^{PC} = 1^{--}$. Nonetheless its properties do not fit with any simple charmonium interpretation and its nature is still unclear. A recent ISR analysis by BELLE [9] suggests the existence of a second state in the same decay mode, called Y(4008) [10], with the same production mechanism.

After the discovery of Y(4260), other $J^{PC} = 1^{--}$ states, produced through the same e^+e^- initial state radiation mechanism, have been observed in the $\psi(2S)\pi^+\pi^-$ final state, such as the Y(4320) and the Y(4660) [11, 12].

In this letter, we present updated measurements of the resonance parameters and $\mathcal{B}(\pi^+\pi^- J/\psi)\Gamma_{e^+e^-}$ of the Y(4260) based on the full *BABAR* data set which is approximately two times larger than the one used in the original analysis [8].

2 THE *BABAR* DETECTOR AND DATASET

The original *BABAR* analysis [8] is updated here with the same method on a data set corresponding to a total integrated luminosity of 454 fb^{-1} obtained at the SLAC PEP-II B-factory, running at the center-of-mass energy near the $\Upsilon(4S)$ resonance.

The *BABAR* detector is described in detail elsewhere [13]. Charged-particle momenta are measured in a tracking system consisting of a five-layer double-sided silicon vertex tracker (SVT) and a 40-layer central drift chamber (DCH), both situated in a 1.5-T axial magnetic field. An internally reflecting ring-imaging Cherenkov detector (DIRC) provides charged-particle identification together with dE/dx measurements from SVT and DCH. A CsI(Tl) electromagnetic calorimeter (EMC) is used to detect and identify photons and electrons. Muons are identified using information from the Instrumented Flux Return (IFR) system, together with E/p , where the energy E is determined by the EMC and the momentum p by the SVT and DCH.

3 ANALYSIS METHOD

In this analysis we reconstruct events:

$$e^+e^- \rightarrow \gamma_{\text{ISR}} \pi^+ \pi^- J/\psi, \quad (1)$$

where γ_{ISR} represents a photon that is radiated from the initial state e^\pm , lowering the center-of-mass energy of the e^+e^- system. This mechanism allows to perform an energy scan of e^+e^- interactions at the B-factories, where the center-of-mass energy of the interactions is fixed in the region of the $\Upsilon(4S)$ resonance.

A candidate J/ψ meson is reconstructed via its decay to e^+e^- or $\mu^+\mu^-$. The lepton tracks, at least one of which must be identified as an electron or muon candidate, must be well reconstructed and must originate from the same vertex: a geometric fit of the J/ψ candidate is conducted with

beam-spot constraint. An algorithm to recover energy lost to bremsstrahlung is applied to electron candidates. An e^+e^- pair with its invariant mass within the interval $(-75,+40)$ MeV/c^2 around the PDG [14] J/ψ mass is taken as a J/ψ candidate. For a $\mu^+\mu^-$ pair, the interval is $(-40,+40)$ MeV/c^2 . The J/ψ candidate is then kinematically constrained to the nominal J/ψ mass and combined with a pair of oppositely-charged tracks identified as pion candidates.

In the event reconstruction, we do not require observation of the initial state radiation photon γ_{ISR} , as it is preferentially produced along the beam directions and it is not detected.

We select $e^+e^- \rightarrow \gamma_{\text{ISR}}\pi^+\pi^-J/\psi$ events with the following criteria: the invariant mass squared recoiling against the $\pi^+\pi^-J/\psi$ system (m_{rec}^2) is required to be in the range $(-0.50,+0.75)$ $(\text{GeV}/c^2)^2$; the total number of reconstructed tracks in the event ≤ 5 . Since the transverse component of the missing momentum ($p_{T,\text{miss}}^*$) is small for events with initial state radiation, we select events with $p_{T,\text{miss}}^* < 2.25 \text{ GeV}/c$. The cosine of the angle between the ℓ^+ momentum in the J/ψ rest frame and the J/ψ momentum in the center-of-mass frame ($\cos\theta_l$) is required to be $|\cos\theta_l| < 0.925$.

After this selection, a clean $\psi(2S)$ signal is apparent in the $\pi^+\pi^-J/\psi$ invariant mass spectrum, as shown in figure 1; in the same distribution, a clean Y(4260) peak is also visible.

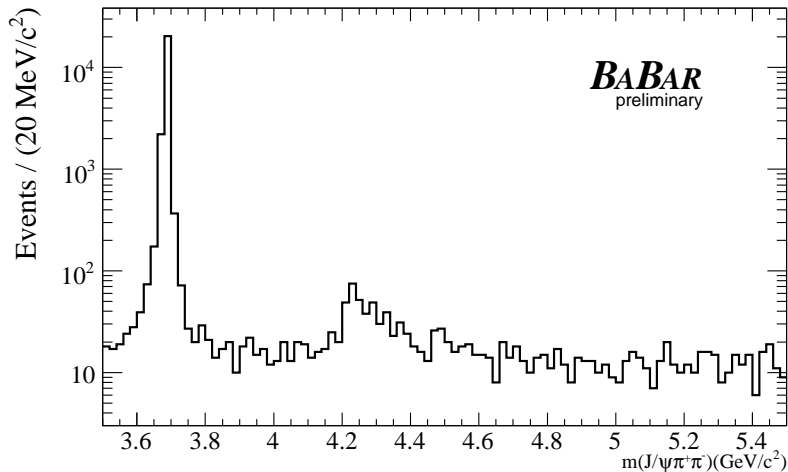


Figure 1: The invariant mass distribution of $\pi^+\pi^-J/\psi$ candidates with a logarithmic vertical scale.

By means of Monte Carlo simulations we determine that the selection efficiency at the Y(4260) energy is 15.3%. The method used for the efficiency determination is checked at the $\psi(2S)$, where we obtain a value of the cross section that is consistent with the measurement performed by previous experiments [9]. The $\psi(2S)$ mass is measured as $3685.35 \pm 0.02 \text{ MeV}/c^2$ (where the error is statistical only); the mass shift with respect to the PDG value [14] is taken into account as a systematic error in the Y(4260) mass measurement.

The Monte Carlo $\pi^+\pi^-J/\psi$ invariant mass resolution and mass scale have been calibrated by comparing the widths of $\pi^+\pi^-J/\psi$ invariant mass distributions from $\psi(2S)$ decays in data and Monte Carlo. We find that the Monte Carlo simulation reproduces the observed r.m.s. of the $\pi^+\pi^-J/\psi$ distribution for the $\psi(2S)$ state. The mass resolution is around $5 \text{ MeV}/c^2$ in the mass range $4.16 \text{ GeV}/c^2 < m(\pi^+\pi^-J/\psi) < 4.36 \text{ GeV}/c^2$

The typical ISR-production signature of the Y(4260) can be obtained by subtracting distributions for events with $\pi^+\pi^-J/\psi$ mass in the region $(3.95,4.1) \text{ GeV}/c^2$ and $(4.4,4.55) \text{ GeV}/c^2$ from

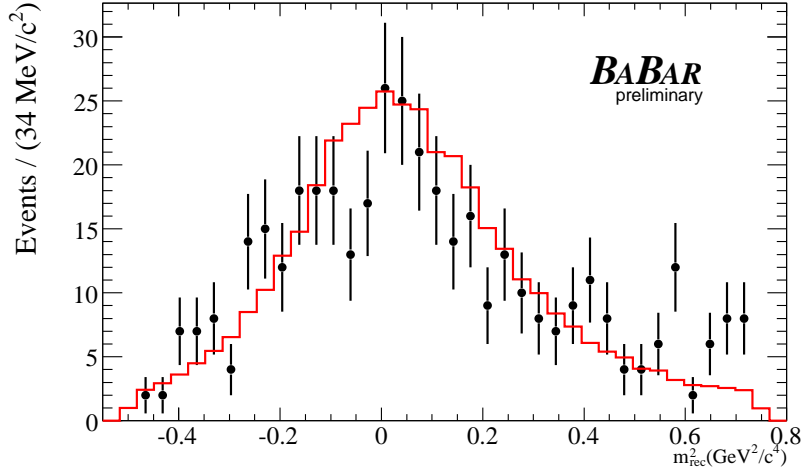


Figure 2: The distribution of m_{rec}^2 . The points represent the data events passing all selection criteria and having a $\pi^+\pi^-J/\psi$ mass near $4260 \text{ MeV}/c^2$. They are obtained by subtracting the distribution from neighboring $\pi^+\pi^-J/\psi$ mass regions (see text). The solid histogram represents ISR Y(4260) Monte Carlo events.

those with mass in the signal region defined as $(4.1, 4.4) \text{ GeV}/c^2$. The distributions of m_{rec}^2 and of the cosine of the $\pi^+\pi^-J/\psi$ system polar angle in the c.m. frame are shown in figure 2 and 3 along with the corresponding distributions for ISR Y(4260) Monte Carlo events.

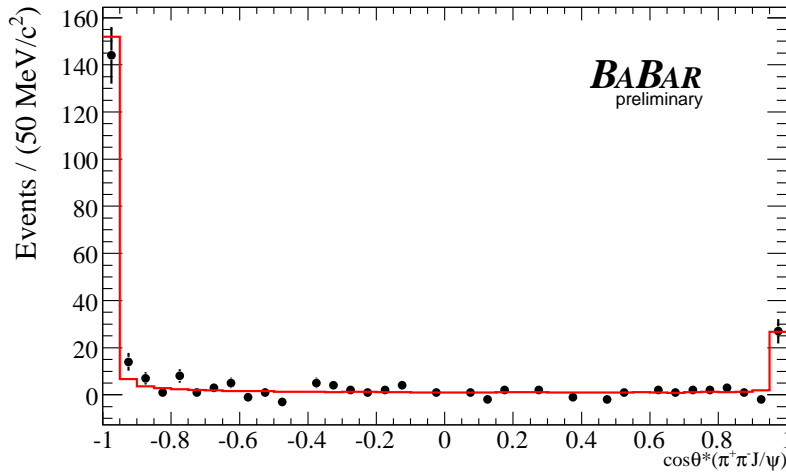


Figure 3: The distribution of $\cos\theta_{\pi^+\pi^-J/\psi}^*$. The points represent the data events passing all selection criteria and having a $\pi^+\pi^-J/\psi$ mass near $4260 \text{ MeV}/c^2$. They are obtained by subtracting the distribution from neighboring $\pi^+\pi^-J/\psi$ mass regions (see text). The solid histogram represents ISR Y(4260) Monte Carlo events.

4 RESULTS

We have performed an unbinned maximum likelihood fit to the $\pi^+\pi^-J/\psi$ invariant mass distribution between $3.8\text{ GeV}/c^2$ and $5\text{ GeV}/c^2$. The signal probability density function (PDF) is described by convolving a non-relativistic Breit-Wigner function with a Gaussian and we use a first degree polynomial function to describe the background. All the fit parameters for the signal and the background PDF are floating, except the Gaussian sigma which is fixed to the resolution found at the $\psi(2S)$ in data but linearly scaled to the Y mass value based on the Monte Carlo simulation.

From the fit shown in figure 4 we obtain a signal yield $N_Y = 344 \pm 39$ and resonance mass $m_Y = 4252 \pm 6 \text{ }^{+2}_{-3} \text{ MeV}/c^2$ and width $\Gamma_Y = 105 \pm 18 \text{ }^{+4}_{-6} \text{ MeV}/c^2$. Systematic uncertainties include contributions from the fitting procedure (evaluated by changing the fit range and the background PDF), the mass scale, the mass-resolution function and the dependence on the model of $Y(4260) \rightarrow \pi^+\pi^-J/\psi$ decay. They have been added in quadrature.

To measure $\mathcal{B}(\pi^+\pi^-J/\psi)\Gamma_{e^+e^-}$ we use Eq. 2, where $N(\gamma\psi(2S))$, $N(\gamma Y)$, $m(\psi(2S))$, $m(Y)$, $\varepsilon(\psi(2S))$, $\varepsilon(Y)$ and $W(\psi(2S))$, $W(Y)$ are the number of events, mass, selection efficiency and the photon emission probability density function for the $\psi(2S)$ and $Y(4260)$ respectively.

$$\frac{\Gamma_{ee}(Y)\mathcal{B}(Y \rightarrow \pi^+\pi^-J/\psi)}{\Gamma_{ee}(\psi(2S))\mathcal{B}(\psi(2S) \rightarrow \pi^+\pi^-J/\psi)} = \left(\frac{N(\gamma Y)}{N(\gamma\psi(2S))}\right) \cdot \left(\frac{m(Y)}{m(\psi(2S))}\right) \cdot \left(\frac{\varepsilon(\psi(2S))}{\varepsilon(Y)}\right) \cdot \left(\frac{W(\psi(2S))}{W(Y)}\right) \quad (2)$$

This way, the entire uncertainties of integrated luminosity and $\mathcal{B}(J/\psi \rightarrow \ell^+\ell^-)$ are canceled. Most uncertainties of the selection efficiency, particle ID efficiency, tracking efficiency, and photon emission probability density $W(s, x)$ are canceled out. Meanwhile, we also introduce some new uncertainties pertaining to the ISR $\psi(2S)$ such as $\mathcal{B}(\psi(2S) \rightarrow \pi^+\pi^-J/\psi)$, $\Gamma_{\psi(2S) \rightarrow e^-e^-}$, and statistical uncertainty of the $N(\psi(2S))$. We obtain $\mathcal{B}(\pi^+\pi^-J/\psi)\Gamma_{e^+e^-} = (7.5 \pm 0.9 \pm 0.8) \text{ eV}$.

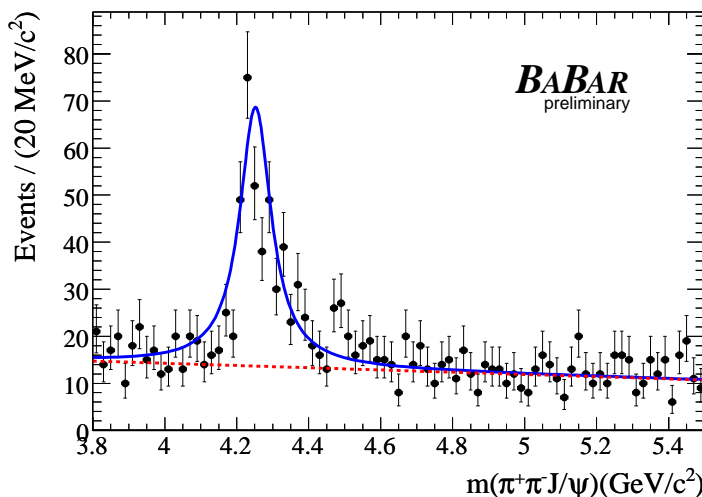


Figure 4: The $\pi^+\pi^-J/\psi$ invariant mass spectrum in the range $3.8\text{-}5.5\text{ GeV}/c^2$. The points with error bars represent the selected data, the solid curve shows the result of the fit described in the text, while the dashed curve represents the background component.

A recent BELLE analysis reported evidence for a broad enhancement with mass $m = 4008 \pm 40^{+114}_{-28} \text{ MeV}/c^2$ and width $\Gamma = 226 \pm 44 \pm 87 \text{ MeV}/c^2$ [9]. We cannot confirm this observation and obtain an upper limit $\mathcal{B}(\pi^+\pi^- J/\psi)\Gamma_{e^+e^-} < 0.7 \text{ eV}$ at 90% C.L. for this state.

We also study the $\pi^+\pi^-$ invariant mass distribution for Y(4260) events, obtained by dividing the total sample into several dipion invariant mass regions and fitting the Y(4260) peak in each one of these regions.

The results reported in figure 5 show that, in Y(4260) decays, the $\pi^+\pi^-$ invariant mass distribution does not agree with the MC based on phase space and tends to peak at large values.

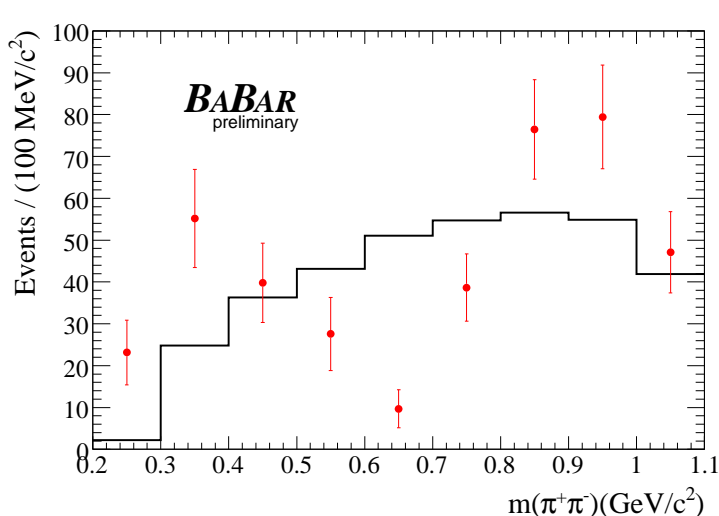


Figure 5: Di-pion invariant mass distribution of Y(4260) events: the points with error bars are signal events, the histogram is the phase-space distribution from MC events.

5 CONCLUSIONS

In summary, we have analyzed initial-state radiation events to study the process $e^+e^- \rightarrow \pi^+\pi^- J/\psi$ across the charmonium mass range. We observe 344 ± 39 Y(4260) events with $m_Y = 4252 \pm 6^{+2}_{-3} \text{ MeV}/c^2$ and $\Gamma_Y = 105 \pm 18^{+4}_{-6} \text{ MeV}/c^2$. The $\pi^+\pi^-$ invariant mass distribution, in Y(4260) region, tends to peak at large values consistently with other studies [8] [9]. There is no evidence for the broad enhancement reported by BELLE around $4.05 \text{ GeV}/c^2$ [9] and we obtain an upper limit $\mathcal{B}(\pi^+\pi^- J/\psi)\Gamma_{e^+e^-} < 0.7 \text{ eV}$ at 90% C.L. for this state.

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References

- [1] BELLE Collaboration, S. K. Choi *et al.*, Phys. Rev. Lett. **91**, 262001 (2003).
- [2] BELLE Collaboration, S. Uehara *et al.*, Phys. Rev. Lett. **96**, 082003 (2006).
- [3] BELLE Collaboration, S. K. Choi *et al.*, Phys. Rev. Lett. **94**, 182002 (2005).
- [4] BELLE Collaboration, K. Abe *et al.*, Phys. Rev. Lett. **98**, 082001 (2007).
- [5] T Appelquist *et al.*, Annu. Rev. Nucl. Part. Sci. **28**, 387 (1978).
- [6] I. Bigi *et al.*, Phys. Rev. D **72**, 114016 (2005).
- [7] Eric S. Swanson, Phys. Lett. B **598**, 197-202 (2004).
- [8] BABAR Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **95**, 142001 (2005).
- [9] BELLE Collaboration, C. Z. Yuan *et al.*, Phys. Rev. Lett. **99**, 182004 (2007).
- [10] Xiang Liu, Eur. Phys. J. C, **54** 3, 471-474 (2008).
- [11] BABAR Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **98**, 212001 (2007).
- [12] BELLE Collaboration, X. L. Wang *et al.*, Phys. Rev. Lett. **99**, 142002 (2007).
- [13] BABAR Collaboration, B. Aubert *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **479**, 1 (2002).
- [14] Particle Data Group, W.-M. Yao *et al.*, Journal of Physics **G**, 1 (2006).