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Observation of a Charged Charmoniumlike Structure in $e^+e^- \to \pi^+\pi^- J/\psi$ at $\sqrt{s} = 4.26$ GeV

(BESIII Collaboration)

Abstract

We study the process $e^+e^- \to \pi^+\pi^- J/\psi$ at a center-of-mass energy of 4.260 GeV using a 525 pb^{-1} data sample collected with the BESIII detector operating at the Beijing Electron Positron Collider. The Born cross section is measured to be $(62.9 \pm 1.9 \pm 3.7)$ pb, consistent with the production of the $Y(4260)$. We observe a structure at around 3.9 GeV/c^2 in the $\pi^\pm J/\psi$ mass spectrum, which we refer to as the $Z_c(3900)$. If interpreted as a new particle, it is unusual in that it carries an electric charge and couples to charmonium. A fit to the $\pi^\pm J/\psi$ invariant mass spectrum, neglecting interference, results in a mass of $(3899.0 \pm 3.6 \pm 4.9)$ MeV/c^2 and a width of $(46 \pm 10 \pm 20)$ MeV. Its production ratio is measured to be $R = (\sigma(e^+e^- \to \pi^\pm Z_c(3900)^\mp \to \pi^+\pi^- J/\psi)/\sigma(e^+e^- \to \pi^+\pi^- J/\psi)) = (21.5 \pm 3.3 \pm 7.5)\%$. In all measurements the first errors are statistical and the second are systematic.

Introduction

Unlike other charmonium states with the same quantum numbers and in the same mass region, the Y(4260) state does not have a natural place within the quark model of charmonium.

...indicate that the Y(4260) is not a conventional state of charmonium.
...suggests there may exist interesting substructure in the Y(4260)→$\pi^+\pi^-$J/ψ process in the charmonium region.

In this Letter, we present a study of the process $e^+e^- \to \pi^+\pi^- J/\psi$ at a center-of-mass (c.m.) energy of $\sqrt{s} = (4.260 \pm 0.001)$ GeV, which corresponds to the peak of the $Y(4260)$ cross section. We observe a charged structure

After imposing these selection criteria, the invariant mass distributions of the lepton pairs are shown in Fig. 1.

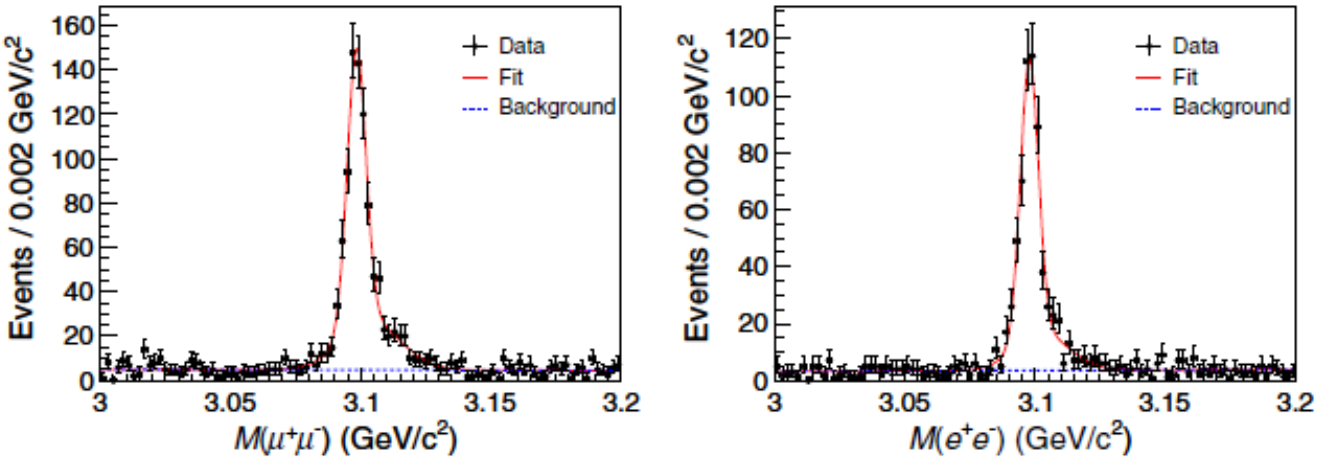

FIG. 1 (color online). The distributions of $M(\mu^+\mu^-)$ (left panel) and $M(e^+e^-)$ (right panel) after performing a 4C kinematic fit and imposing all selection criteria. Dots with error bars are data and the curves are the best fit described in the text.

Figure 2 shows the Dalitz plot of events in the J/ψ signal region, where there are structures in the $\pi^+\pi^-$ system and evidence for an exotic charmoniumlike structure in the $\pi^\pm J/\psi$ system. The inset shows background events from J/ψ mass sidebands (not normalized), where no obvious structures are observed.

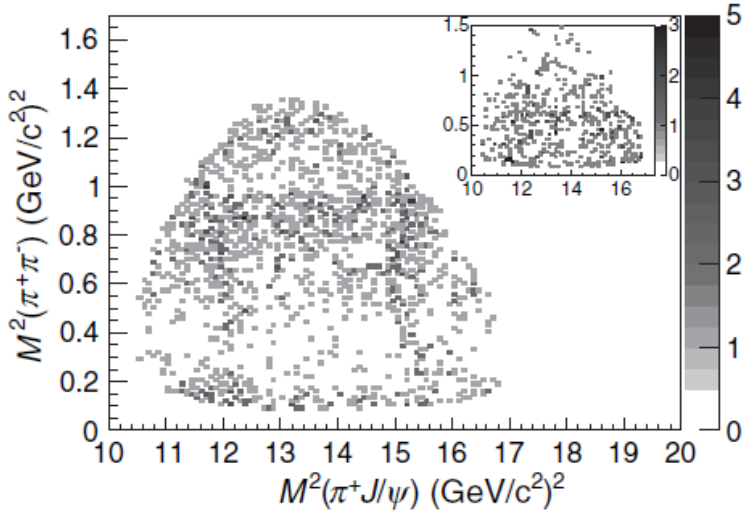

FIG. 2. Dalitz distributions of $M^2(\pi^+\pi^-)$ vs $M^2(\pi^+J/\psi)$ for selected $e^+e^- \to \pi^+\pi^- J/\psi$ events in the J/ψ signal region. The inset shows background events from the J/ψ mass sidebands (not normalized).

Figure 3 shows the projections of the $M(\pi^+ J/\psi)$, $M(\pi^- J/\psi)$, and $M(\pi^+\pi^-)$ distributions for the signal events, as well as the background events estimated from normalized J/ψ mass sidebands. In the $\pi^\pm J/\psi$ mass

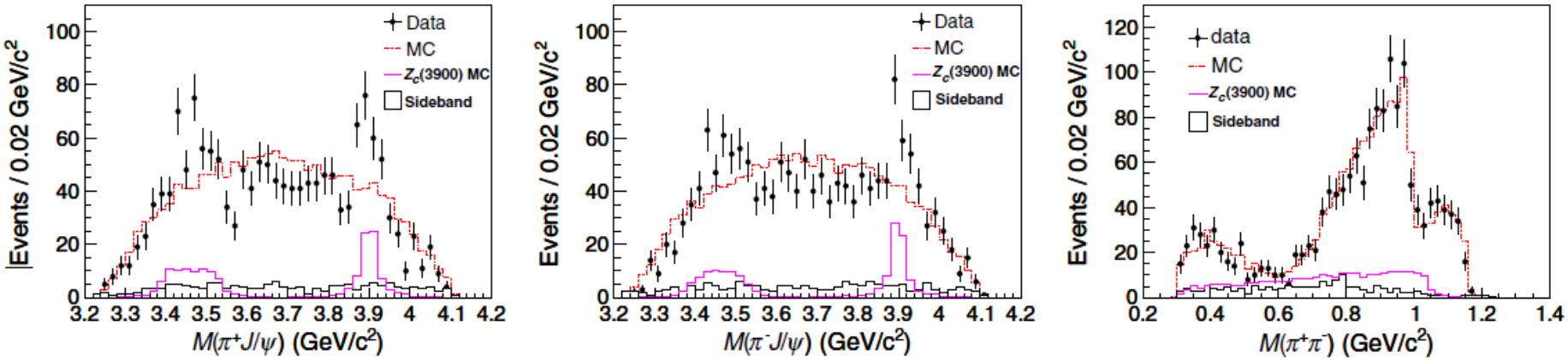

FIG. 3 (color online). One dimensional projections of the $M(\pi^+ J/\psi)$, $M(\pi^- J/\psi)$, and $M(\pi^+\pi^-)$ invariant mass distributions in $e^+e^- \to \pi^+\pi^- J/\psi$ for data in the J/ψ signal region (dots with error bars), data in the J/ψ sideband region (shaded histograms), and MC simulation results from $\sigma(500)$, $f_0(980)$, and nonresonant $\pi^+\pi^-$ amplitudes (red dotted-dashed histograms). The pink blank histograms show a MC simulation of the $Z_c(3900)$ signal with arbitrary normalization.

shows the fit results; the fit yields a mass of $(3899.0 \pm 3.6)\ \mathrm{MeV}/c^2$, and a width of (46 ± 10) MeV. The goodness of the fit is found to be $\chi^2/\mathrm{ndf} = 32.6/37 = 0.9$.

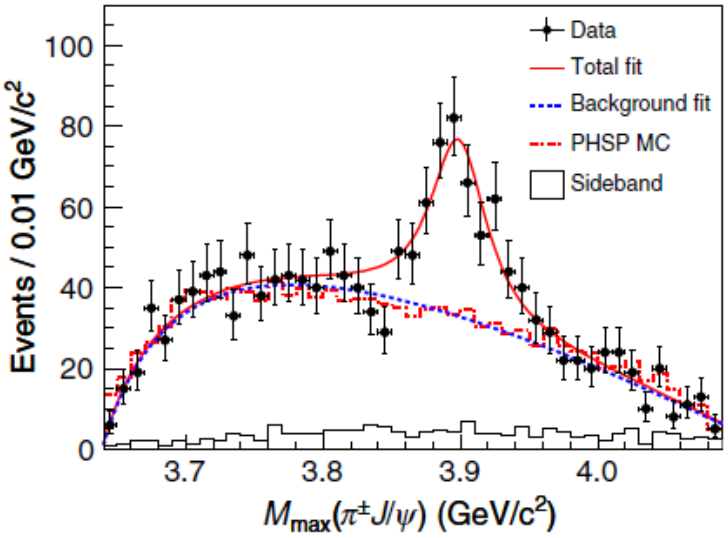

FIG. 4 (color online). Fit to the $M_{\mathrm{max}}(\pi^{\pm} J/\psi)$ distribution as described in the text. Dots with error bars are data; the red solid curve shows the total fit, and the blue dotted curve the background from the fit; the red dotted-dashed histogram shows the result of a phase space (PHSP) MC simulation; and the green shaded histogram shows the normalized J/ψ sideband events.

Summary

In Summary, we have studied $e^+e^- \to \pi^+\pi^- J/\psi$ at a c.m. energy of 4.26 GeV. The cross section is measured to be $(62.9 \pm 1.9 \pm 3.7)$ pb, which agrees with the existing results from the *BABAR* [5], Belle [3], and CLEO [4] experiments. In addition, a structure with a mass of $(3899.0 \pm 3.6 \pm 4.9)$ MeV$/c^2$ and a width of $(46 \pm 10 \pm 20)$ MeV is observed in the $\pi^\pm J/\psi$ mass spectrum. This structure couples to charmonium and has an electric charge, which is suggestive of a state containing more quarks than just a charm and anticharm quark. Similar studies were performed in B decays, with unconfirmed structures reported in the $\pi^\pm\psi(3686)$ and $\pi^\pm\chi_{c1}$ systems [23–26]. It is also noted that model-dependent calculations exist that attempt to explain the charged bottomonium-like structures which may also apply to the charmonium-like structures, and there were model predictions of charmoniumlike structures near the $D\bar{D}^*$ and $D^*\bar{D}^*$ thresholds [27].