of $(46 \pm 10 \pm 20)$ MeV. Its production ratio is measured to be $R = \frac{\sigma(e^+e^- \to \pi^\pm Z_c(3900)^\mp \to \pi^+\pi^- J/\psi))}{\sigma(e^+e^- \to \pi^+\pi^- J/\psi)} = (21.5 \pm 3.3 \pm 7.5)\%$. In all measurements the first errors are statistical and the second are systematic.

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Since its discovery in the initial-state-radiation (ISR) process $e^+e^- \to \gamma_{\rm ISR}\pi^+\pi^- J/\psi$ [1], and despite its subsequent observations [2–5], the nature of the $Y(4260)$ state has remained a mystery. Unlike other charmonium states with the same quantum numbers and in the same mass region, such as the $\psi(4040)$, $\psi(4160)$, and $\psi(4415)$, the $Y(4260)$ state does not have a natural place within the quark model of charmonium [6]. Furthermore, while being well above the $D\bar{D}$ threshold, the $Y(4260)$ shows strong coupling to the $\pi^+\pi^- J/\psi$ final state [7], but relatively small coupling to open charm decay modes [8–12]. These properties perhaps indicate that the $Y(4260)$ state is not a conventional state of charmonium [13].

A similar situation has recently become apparent in the bottomonium system above the $B\bar{B}$ threshold, where there are indications of anomalously large couplings between the $\Upsilon(5S)$ state (or perhaps an unconventional bottomonium state with similar mass, the $Y_b(10890)$) and the $\pi^+\pi^-\Upsilon(1S, 2S, 3S)$ and $\pi^+\pi^- h_b(1P, 2P)$ final states [14, 15]. More surprisingly, substructure in these $\pi^+\pi^-\Upsilon(1S, 2S, 3S)$ and $\pi^+\pi^- h_b(1P, 2P)$ decays indicates the possible existence of charged bottomoniumlike states [16], which must have at least four constituent quarks to have a non-zero electric charge, rather than the two in a conventional meson. By analogy, this suggests there may exist interesting substructure in the $Y(4260) \to \pi^+\pi^- J/\psi$ 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 (CM) 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 in the $\pi^\pm J/\psi$ invariant mass spectrum, which we refer to as the $Z_c(3900)$. The analysis is performed with a 525 pb^{-1} data sample collected with the BESIII detector, which is described in detail in Ref. [17]. In the studies presented here, we rely only on charged particle tracking in the main drift chamber (MDC) and energy deposition in the electromagnetic calorimeter (EMC).

The GEANT4-based Monte Carlo (MC) simulation software, which includes the geometric description of the BESIII detector and the detector response, is used to optimize the event selection criteria, determine the detection efficiency, and estimate backgrounds. For the signal process, we use a sample of $e^+e^- \to \pi^+\pi^- J/\psi$ MC events generated assuming the $\pi^+\pi^- J/\psi$ is produced via $Y(4260)$ decays, and using the $e^+e^- \to \pi^+\pi^- J/\psi$ cross sections measured by Belle [3] and BaBar [5]. The $\pi^+\pi^- J/\psi$ substructure is modelled according to the experimentally observed Dalitz plot distribution presented in this analysis. ISR is simulated with KKMC [18] with a maximum energy of 435 MeV for the ISR photon, corresponding to a $\pi^+\pi^- J/\psi$ mass of 3.8 GeV/c^2.

For $e^+e^- \to \pi^+\pi^- J/\psi$ events, the J/ψ candidate is reconstructed with lepton pairs (e^+e^- or $\mu^+\mu^-$). Since this decay results in a final state with four charged particles, we first select events with four good charged tracks with net charge zero. For each charged track, the polar angle in the MDC must satisfy $|\cos\theta| < 0.93$, and the point of closest approach to the e^+e^- interaction point must be within ± 10 cm in the beam direction and within 1 cm in the plane perpendicular to the beam direction. Since pions and leptons are kinematically well separated in this decay, charged tracks with momenta larger than 1.0 GeV/c in the lab frame are assumed to be leptons, and the others are assumed to be pions. We use the energy deposited in the EMC to separate electrons from muons. For muon candidates, the deposited energy in the EMC should be less than 0.35 GeV; while for electrons, it should be larger than 1.1 GeV. The efficiencies of these requirements are determined from MC simulation to be above 99% in the EMC sensitive region.

In order to reject radiative Bhabha and radiative dimuon ($\gamma e^+e^-/\gamma\mu^+\mu^-$) backgrounds associated with a photon-conversion, the cosine of the opening angle of the pion candidates, which are true e^+e^- pairs in the case of background, is required to be less than 0.98. In the e^+e^- mode, the same requirement is imposed on the $\pi^\pm e^\mp$ opening angles. This restriction removes less than 1% of the signal events.

The lepton pair and the two pions are subjected to a four-constraint (4C) kinematic fit to the total initial four-momentum of the colliding beams in order to improve the momentum resolution and reduce the background. The χ^2 of the kinematic fit is required to be less than 60.

After imposing these selection criteria, the invariant mass distributions of the lepton pairs are shown in Fig. 1. A clear J/ψ signal is observed in both the e^+e^- and $\mu^+\mu^-$ modes. There are still remaining $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$, and other QED backgrounds, but these can be estimated using the events in the J/ψ mass sideband. The final selection efficiency is $53.8 \pm 0.3\%$ for $\mu^+\mu^-$ events and $38.4 \pm 0.3\%$ for e^+e^- events, where the errors are from the statistics of the MC sample. The main factors affecting the detection efficiencies include the detector acceptances for four charged tracks and the requirement on the quality of the kinematic fit adopted. The lower efficiency for e^+e^- events is due to final-state-radiation (FSR), bremsstrahlung energy loss of e^+e^- pairs and the EMC deposit energy requirement.

To extract the number of $\pi^+\pi^- J/\psi$ signal events, invariant mass distributions of the lepton pairs are fit using the sum of two Gaussian functions with a linear background term. The fits yield $M(J/\psi) = 3098.4 \pm 0.2$ MeV/c^2 with 882 ± 33 signal events in the $\mu^+\mu^-$ mode; and $M(J/\psi) = 3097.9 \pm 0.3$ MeV/c^2 with 595 ± 28 signal events in the e^+e^- mode.