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OBSERVATION OF THE $X(1840)$ AT BESIII

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Observation of the $X(1840)$ in the $3(\pi^+\pi^-)$ invariant mass in $J/\psi \to \gamma 3(\pi^+\pi^-)$ at BESIII is reviewed. With a sample of 225.3×10^6 J/ψ events collected with the BESIII detector at BEPCII, the $X(1840)$ is observed with a statistical significance of 7.6σ. The mass, width and product branching fraction of the $X(1840)$ are determined. The decay $\eta' \to 3(\pi^+\pi^-)$ is searched for, and the upper limit of the branching fraction is set at the 90% confidence level.

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1. Introduction

Within the standard model framework, the strong interaction is described by Quantum Chromodynamics (QCD), which suggests the existence of the unconventional hadrons, such as glueballs, hybrid states and multiquark states. The establishment of such states remains one of the main interests in experimental particle physics.

Decays of the J/ψ particle are ideal for the study of the hadron spectroscopy and the searching for the unconventional hadrons. In the decays of the J/ψ particle, several observations in the mass region 1.8 GeV/c^2 - 1.9 GeV/c^2 have been presented in different experiments[1–8], such as the $X(p\bar{p})$[1–3], $X(1835)$[4,5], $X(1810)$[6,7] and $X(1870)$[8].

2. Observation of the $X(1840)$

Recently, the paper Ref. 9 presented the observation of a new structure, the $X(1840)$. Using a sample of 225.3×10^6 J/ψ events[10] collected with BESIII detector[11] at BEPCII[12], the decay of $J/\psi \to \gamma 3(\pi^+\pi^-)$ was analyzed, and the $X(1840)$ was observed in the $3(\pi^+\pi^-)$ mass spectrum with a statistical significance of 7.6σ.

The $3(\pi^+\pi^-)$ invariant mass spectrum is shown in Fig. 1, where the $X(1840)$ can be clearly seen. The parameters of the $X(1840)$ are extracted by an unbinned maximum likelihood fit. In the fit, the background is described by two contributions: the contribution from $J/\psi \to \pi^0 3(\pi^+\pi^-)$ and the contribution from other

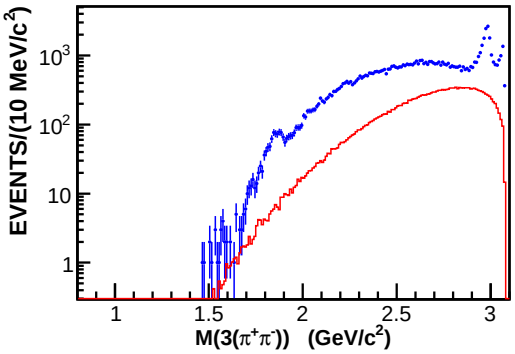

Fig. 1. Distribution of the invariant mass of $3(\pi^+\pi^-)$. The dots with error bars are data; the histogram is phase space events with an arbitrary normalization.

sources. The contribution from $J/\psi \to \pi^0 3(\pi^+\pi^-)$ is determined from MC simulation and fixed in the fit (shown by the dash-dotted line in Fig. 2). The other contribution is described by a third-order polynomial. The signal is described by a Breit-Wigner function modified with the effects of the detection efficiency, the detector resolution, and the phase space factor. The fit result is shown in Fig. 2. The mass and width of the $X(1840)$ are $M = 1842.2 \pm 4.2^{+7.1}_{-2.6}$ MeV/c^2 and $\Gamma = 83 \pm 14 \pm 11$ MeV, respectively; the product branching fraction of the $X(1840)$ is $\mathcal{B}(J/\psi \to \gamma X(1840)) \times \mathcal{B}(X(1840) \to 3(\pi^+\pi^-)) = (2.44 \pm 0.36^{+0.60}_{-0.74}) \times 10^{-5}$. In these results, the first errors are statistical and the second errors are systematic.

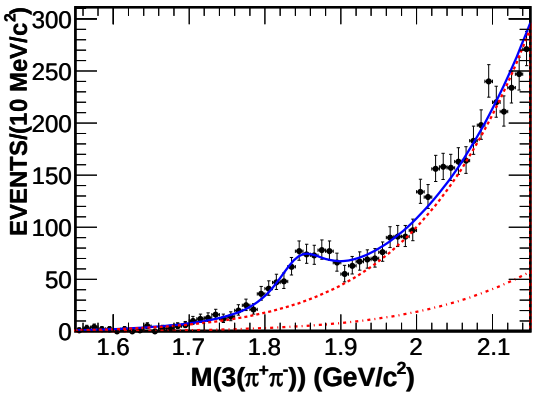

Fig. 2. The fit of mass spectrum of $3(\pi^+\pi^-)$. The dots with error bars are data; the solid line is the fit result. The dashed line represents all the backgrounds, including the background events from $J/\psi \to \pi^0 3(\pi^+ pi^-)$ (dash-dotted line, fixed in the fit) and a third-order polynomial representing other backgrounds.

Figure 3 shows the comparisons of the $X(1840)$ with other observations at BESIII[9]. The comparisons indicate that at present one can not distinguish whether the $X(1840)$ is a new state or the signal of a $3(\pi^+\pi^-)$ decay mode of an existing state.

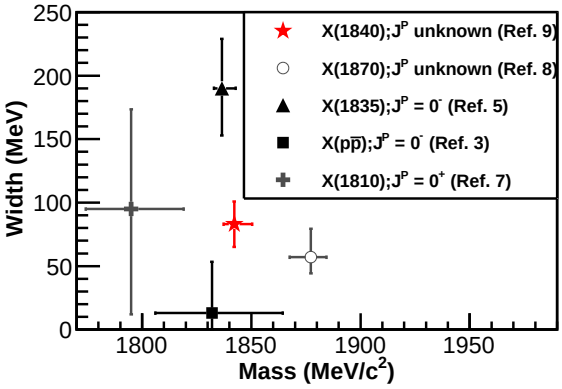

Fig. 3. Comparisons of observations at BESIII. The error bars include statistical, systematic, and, where applicable, model uncertainties.

3. Search for the decay of $\eta' \to 3(\pi^+\pi^-)$

With the same data sample, the decay of $\eta' \to 3(\pi^+\pi^-)$ was searched for[9]. The mass spectrum of the $3(\pi^+\pi^-)$ is shown in Fig. 1, where no events are observed in the η' mass region. With the Feldman-Cousins frequentist approach[13], the upper limit of the branching fraction is set to be $\mathcal{B}(\eta' \to 3(\pi^+\pi^-)) < 3.1 \times 10^{-5}$ at the 90% confidence level, where the systematic uncertainty is taken into account.

4. Summary

With a sample of 225.3×10^6 J/ψ events collected at BESIII, the decay of $J/\psi \to \gamma 3(\pi^+\pi^-)$ was analyzed. The $X(1840)$ was observed in the $3(\pi^+\pi^-)$ invariant mass spectrum. The mass, width and product branching fraction of the $X(1840)$ are $M = 1842.2 \pm 4.2^{+7.1}_{-2.6}$ MeV/c^2, $\Gamma = 83 \pm 14 \pm 11$ MeV and $\mathcal{B}(J/\psi \to \gamma X(1840)) \times \mathcal{B}(X(1840) \to 3(\pi^+\pi^-)) = (2.44 \pm 0.36^{+0.60}_{-0.74}) \times 10^{-5}$, respectively. The decay $\eta' \to 3(\pi^+\pi^-)$ was searched for. No events were observed in the η' mass region and the upper limit of the branching fraction was set to be $\mathcal{B}(\eta' \to 3(\pi^+\pi^-)) < 3.1 \times 10^{-5}$ at the 90% confidence level.

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