PROCEEDINGS OF SCIENCE

New Observations on Light Hadron Spectroscopy at BESIII

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With samples of 220 million J/ψ events and 110 million ψ' events collected in the BESIII detector, $p\bar{p}$ mass threshold enhancement is studied. The enhancement is evident in J/ψ radiative decay, which is consistent with BESII result. No significant narrow enhancement is observed in ψ' radiative decay. For $J/\psi \to \gamma\pi^+\pi^-\eta'$ decay, the $X(1835)$, which was previously observed by BESII, is confirmed with a statistical significance that is larger than 20σ. In addition, in the $\pi^+\pi^-\eta'$ invariant mass spectrum, the $X(2120)$ and the $X(2370)$, are observed with statistical significances larger than 7.2σ and 6.7σ, respectively. A new process $J/\psi \to \omega X(1870) \to \omega a_0\pi$ is also observed in $J/\psi \to \omega\pi^+\pi^-\eta$ decay.

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1. Introduction

An anomalously strong $p\bar{p}$ mass threshold enhancement, the $X(1860)$, was observed by the BESII experiment in the radiative decay process $J/\psi \to \gamma p\bar{p}$ [1]. An interesting feature of this enhancement is that corresponding structures are not observed in near-threshold $p\bar{p}$ cross section measurements, or in B-meson decays [2], or in radiative ψ' [3] or $\Upsilon \to \gamma p\bar{p}$ decays [4], or in $J/\psi \to \omega p\bar{p}$ decays [5]. One of theoretical speculations [6] is the intriguing suggestion that it is a $p\bar{p}$ bound state, sometimes called baryonium [6]. It also stimulated a study of $J/\psi \to \gamma\pi^+\pi^-\eta'$, in which a resonance, the X(1835), was observed in the $\pi^+\pi^-\eta'$ invariant-mass spectrum with a statistical significance of 7.7σ at BESII [7]. The possible interpretations include a $p\bar{p}$ bound state [6], a glueball [8], a radial excitation of the η' meson [9], etc.

The high statistics data samples of $\sim 220\times10^6$ J/ψ and $\sim 110\times10^6$ ψ' events accumulated by the upgraded Beijing Spectrometer (BESIII) in 2009, located at the Beijing Electron-Positron Collider (BEPCII) at the Beijing Institute of High Energy Physics, provide an opportunity to confirm the existence of above resonances, look for 0^{-+} glueballs in $J/\psi \to \gamma\pi^+\pi^-\eta'$ decays, and search for possible related states in other decay modes, such as $J/\psi \to \omega\pi^+\pi^-\eta$ decays.

2. $p\bar{p}$ Mass Threshold Study in J/ψ and ψ' radiative decays

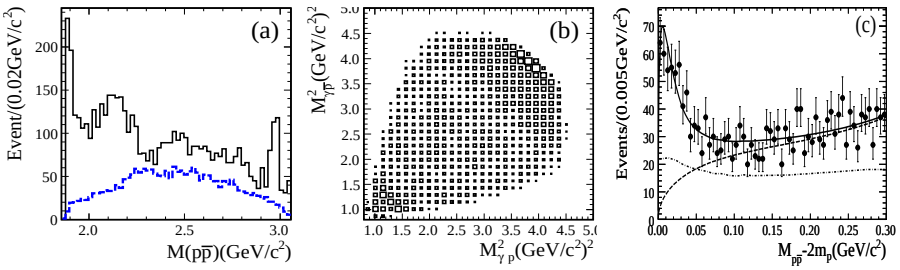

Figure 1: The selected $\psi' \to \pi^+\pi^- J/\psi(J/\psi \to \gamma p\bar{p})$ events: (a) The $p\bar{p}$ invariant mass spectrum. (b) An $M^2(\gamma p)$ (horizontal) *versus* $M^2(\gamma\bar{p})$ (vertical) Dalitz plot for the selected events. (c) $p\bar{p}$ mass spectrum fitting in the threshold region, the solid curve is the fit result, the dashed curve shows the fitted background function, and the dash-dotted curve indicates how the acceptance varies with $M_{p\bar{p}}$.

Fig. 1(a) shows the $p\bar{p}$ invariant mass distribution for surviving events of $\psi' \to \pi^+\pi^- J/\psi(J/\psi \to \gamma p\bar{p})$. The distribution's features include the η_c peak, a broad enhancement around $M_{p\bar{p}} \sim 2.2$ GeV/c^2, and a prominent low-mass peak at the $p\bar{p}$ mass threshold, similar to that reported by BESII [1]. The Dalitz plot in Fig. 1(b) shows that a band corresponding to the threshold enhancement is evident in the upper right corner. Fitting with an acceptance weighted $S-$wave Breit-Wigner function plus the background shape shown in Fig. 1(c), yields a peak mass of $M = 1861^{+6}_{-13}$ (stat)$^{+7}_{-26}$ (syst) MeV/c^2 and a width of $\Gamma < 38$ MeV/c^2 at the 90%*C.L.*

The decay channel of $J/\psi \to \gamma p\bar{p}$ is also studied, the $p\bar{p}$ mass spectrum, as shown in Fig. 2(a)) has similar structure as Fig. 1(a)). In Fig. 2(b), the fitting in the $p\bar{p}$ mass spectrum with $S-$wave BW function can yield a peak mass of $M = 1861.6 \pm 0.8$ (stat) MeV/c^2 and a width of $\Gamma < 8$ MeV/c^2 at the 90%*C.L.* In the study of $\psi' \to \gamma p\bar{p}$, there is no significant narrow threshold enhancement as

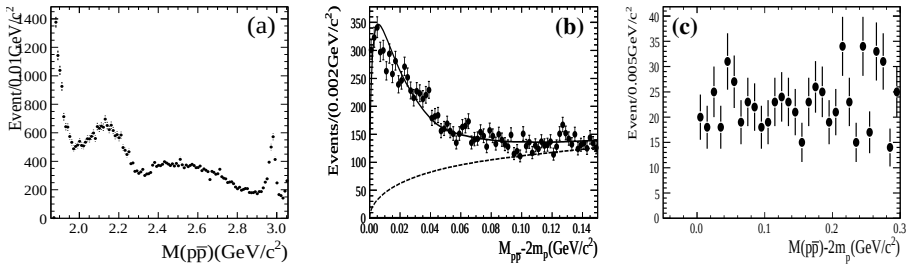

Figure 2: The $p\bar{p}$ invariant mass spectrum (a) and fitting in the threshold region (b) for the selected $J/\psi \to \gamma p\bar{p}$ events, where the solid curve is the fit result; the dashed curve shows the fitted background function. (c) is the $p\bar{p}$ invariant mass spectrum in the threshold region for the selected $\psi' \to \gamma p\bar{p}$ events .

shown in Fig. 2(c). It indicates that the strong $p\bar{p}$ threshold enhancement observed in J/ψ radiative decay disfavors the interpretation of pure final state interactions (FSI).

3. Confirmation of $X(1835)$ and two new structures in $J/\psi \to \gamma\pi^+\pi^-\eta'$ decays

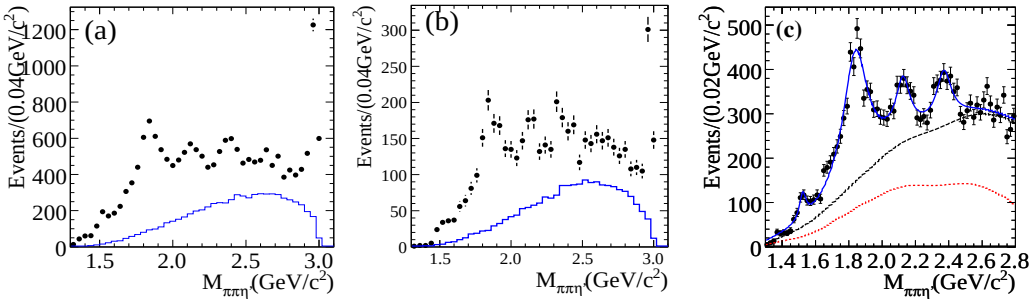

Figure 3: Invariant mass spectrum of $\pi^+\pi^-\eta'$ after final selection for $J/\psi \to \gamma\pi^+\pi^-\eta'(\eta' \to \gamma\rho^0)$ (a) and $J/\psi \to \gamma\pi^+\pi^-\eta'(\eta' \to \pi^+\pi^-\eta, \eta \to \gamma\gamma)$ (b), where the solid circles are data and the histogram are from $J/\psi \to \gamma\pi^+\pi^-\eta'$ phase space MC events(with arbitrary normalization). (c) is mass spectrum fitting with four resonances, the dash-dot line is contributions of non-η' events and the $\pi^0\pi^+\pi^-\eta'$ background for two η' decay modes and the dash line is contributions of background and non-resonant $\pi^+\pi^-\eta'$ process.

For $J/\psi \to \gamma\pi^+\pi^-\eta'$ with the decay modes of $\eta' \to \gamma\rho$ and $\eta' \to \pi^+\pi^-\eta$, the $X(1835)$ resonance is clearly seen in the $\pi^+\pi^-\eta'$ invariant mass spectrum of Fig. 3(a) and (b). Additional peaks are evident around 2.1 and 2.4 GeV/c^2, the $X(2120)$ and $X(2370)$, as well as $f_1(1510)$ and a distinct signal for the η_c. The spectrum fits for the combined two η' decay modes have been made using four efficiency-corrected Breit-Wigner functions convolved with a Gaussian mass resolution plus non-resonant $\pi^+\pi^-\eta'$ contribution and background representations shown in Fig.3(c). The statistical significance of the $X(1835)$ is larger than 20σ, while the $X(2120)$ and $X(2370)$, are larger than 7.2σ and 6.7σ, respectively. The mass and width are 1838.1 ± 2.8 and 179.5 ± 9.1 MeV/c^2 for the $X(1835)$, 2124.8 ± 5.6 and 101 ± 14 MeV/c^2 for the $X(2120)$, 2371.0 ± 6.4 and 108 ± 15 MeV/c^2 for the $X(2370)$ respectively. For the $X(1835)$, the mass is consistent with the BESII result, but the width is significantly larger.

4. Observation of $X(1870) \to a_0\pi$ in $J/\psi \to \omega\pi^+\pi^-\eta$ decays

For $J/\psi \to \omega\pi^+\pi^-\eta$ decays, as shown in Fig.4, in the $\pi^+\pi^-\eta$ mass spectrum of Fig.4.(b), besides the η', there are clear $f_1(1285)$, $\eta(1405)$ a structure the $X(1870)$. Fig.4.(c) shows all of the three structures decay primarily via $a_0(980)\pi$, and the fitting yields the mass and width are 18373 ± 11 and 82 ± 19 MeV$/c^2$ for the $X(1870)$ with significance of 7.7σ

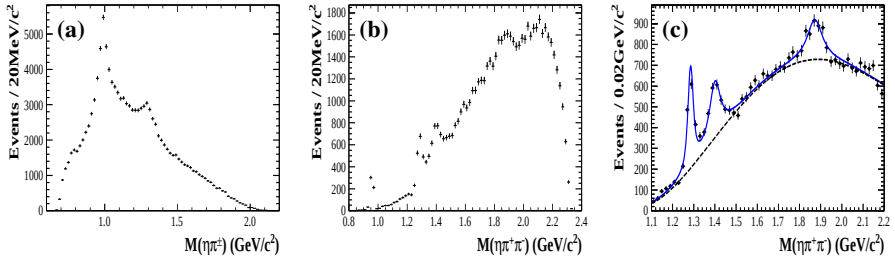

Figure 4: The selected $J/\psi \to \omega\pi^+\pi^-\eta$ events: (a) The combined $\eta\pi^+$ and $\eta\pi^-$ mass spectrum; (b) The $\eta\pi^+\pi^-$ mass spectrum; (c) The $\eta\pi^+\pi^-$ mass spectrum fitting with a_0 selection;.

5. Summary

In summary, the $p\bar{p}$ mass threshold enhancement $X(1860)$ is confirmed in J/ψ radiative decay, and no obvious similar structure is observed in ψ' radiative decay. The X(1835) is confirmed in $J/\psi \to \gamma\pi^+\pi^-\eta'$, and two new resonances, $X(2120)$ and $X(2370)$ are observed with significance larger than 7.2σ and 6.7σ respectively. A new process $J/\psi \to \omega X(1870) \to \omega a_0\pi$ is observed. Whether or not the X(1860), X(1835) and X(1870) are the same resonance, still needs further study and PWA is a important technique not only to determine the spin-parities of above three resonances, but also to make more precise measurements on masses, widths and Branch ratios by considering possible interferences among them.

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