New observations on light hadron spectroscopy at BESIII

Hongwei Liu[1] on behalf of the BESIII Collaboration
Institute of High Energy Physics
100049 Beijing, P. R. China

With samples of 225 million J/ψ events and 106 million ψ' events collected in the BESIII detector, $p\bar{p}$ mass threshold enhancement is evident in J/ψ radiative decays, which is consistent with BESII result. No significant narrow enhancement is observed in ψ' radiative decays. 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 and the angular distribution of the radiative photon is consistent with expectations for a pseudoscalar. In addition, in the $\pi^+\pi^-\eta'$ invariant mass spectrum, the $X(2120)$ and the $X(2370)$, are observed with statistical significance larger than 7.2σ and 6.4σ , 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.

1 Introduction

The Beijing Electron Positron Collider II (BEPCII) is a double ring collider, focusing on the τ-charm energy region, of which the designed luminosity is $1 \times 10^{33} cm^{-2}s^{-1}$ at the center of mass energy of 3770 MeV. The Beijing Spectrometer III (BESIII) is a general-purpose detector, which is the only experiment at BEPCII, and consists of four subdetectors: a main drift chamber, a time of flight system, a CsI(Tl) electromagnetic calorimeter, and a muon chamber. A superconducting solenoidal magnet locates between the calorimeter and the muon chamber and provides 1.0 T magnetic field. Up to now, BESIII has accumulated the word largest sample for J/ψ(225×10^6), ψ'(106×10^6), $\psi(3770)$ (2.9 fb^{-1}).

Multi-quark states, glueballs and hybrids have been searched for experimentally for a very long time, but none have been established. However, during the past three years, a lot of unexpected experimental evidence for hadrons cannot (easily) be explained by the conventional quark model. For example, at BESII:$p\bar{p}$ threshold enhancement was observed in $J/\psi \to \gamma p\bar{p}$,and X(1835) was observed in $J/\psi \to \gamma\pi^+\pi^-\eta'$. Taking advantage of the high luminosity provided by the BEPCII collider, BESIII collaboration has reported several new observations and many high precision measurements on light hadron spectroscopy such as the X(1835) resonance, $p\bar{p}$ mass threshold enhancement. In this talk, we will present the relative results of these new observations and measurements.

[1]liuhw@ihep.ac.cn

2 Observations

2.1 $p\overline{p}$ mass threshold study in J/ψ and $\psi^{'}$ radiative decays

A strong $p\overline{p}$ mass threshold enhancement was firstly observed by BESII experiment in the $J/\psi \to \gamma p\overline{p}$ [1]decay. One interesting feature of this enhancement is that no corresponding structure is reported in the relative channels, including B-meson decays [2], radiative decays of ψ' [3] and Υ [4], or the decay of $J/\psi \to \omega p\overline{p}$ [5].

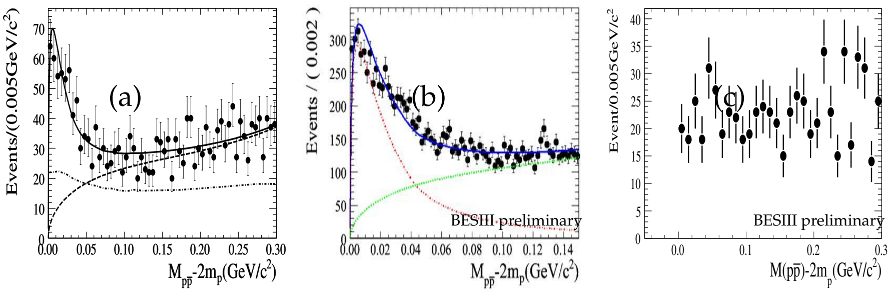

Figure 1: $p\overline{p}$ invariant mass distribution of :(a) $\psi' \to \pi^+\pi^- J/\psi(\gamma p\overline{p})$;(b) $J/\psi \to \gamma p\overline{p}$;(c) $\psi' \to \gamma p\overline{p}$. The dashed curve shows the fitted background polynomial. The dash-dotted curve in (a) represents how the acceptance varies with $M_{p\overline{p}}$.

FIG. 1 (a) and (b) show the $p\overline{p}$ invariant mass distribution of $\psi' \to \pi^+\pi^- J/\psi(\gamma p\overline{p})$ and direct $J/\psi \to \gamma p\overline{p}$. The strong threshold enhancement structure can be observed. The fitted resonance parameters are $M = 1861^{+6}_{-13}(\text{stat.})^{+7}_{-26}(\text{syst.})$ MeV/c^2 and $\Gamma < 38$ MeV/c^2 at the 90% C.L. for $\psi' \to \pi^+\pi^- J/\psi(\gamma p\overline{p})$. However, no significant threshold enhancement structure is found in $\psi' \to \gamma p\overline{p}$ decays, shown in FIG. 1 (c). The negative observations implies that the pure FSI effect alone cannot totally account for the strong threshold enhancement observed in the radiative decay of J/ψ.

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

The $X(1835)$ was firstly observed at BESII with a statistical significance of 7.7σ. Theoretical interpretations have been raised to settle the nature of this resonance, including the $p\overline{p}$ bound state [6], a glueball [7], a radial excitation of the η' meson [8], etc.

FIG. 2 Shown are the $\eta'\pi^+\pi^-$ invariant mass spectrum in $J/\psi \to \gamma\eta'\pi^+\pi^-$, where the η is detected in its (a) $\eta' \to \gamma\rho$ and (b)$\eta' \to \pi^+\pi^-\pi^0$ decay modes. The X(1835) resonance is clearly seen. Additional peaks are evident around 2.1 and 2.3 GeV/c^2, denoted as $X(2120)$ and $X(2370)$, as well as the $f_1(1510)$ and the distinct η_c. The fitting result of the combined mass spectrum is shown in FIG. 2 (c). The mass and width of $X(1835)$ are measured to be

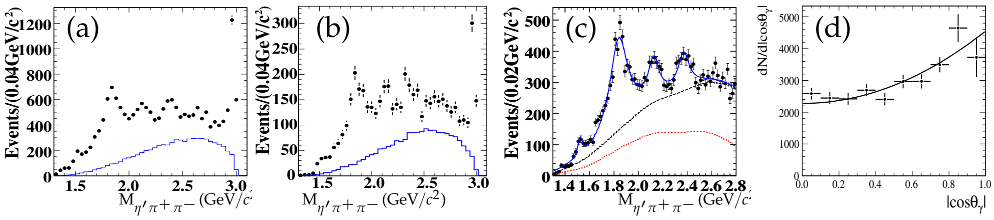

Figure 2: The invariant mass spectrum of $\eta'\pi^+\pi^-$ with (a) $\eta' \to \gamma\rho$, (b) $\eta' \to \eta\pi^+\pi^-$. (c) The fitting results of $\eta'\pi^+\pi^-$; (d) The $\cos^2\theta_\gamma$ distribution, where θ_γ is the polar angle of the photon in the J/ψ center of mass system. The solid circles are from data. The histograms are from $J/\psi \to \gamma\eta'\pi^+\pi^-$ phase space MC events.

$M = 1836.5 \pm 3.0(\text{stat.})^{+5.6}_{-2.1}(\text{syst.})$ MeV/c^2 and $\Gamma = 190 \pm 9(\text{stat.})^{+38}_{-36}(\text{syst.})$ MeV/c^2 with a significance of larger than 20σ. The statistical significance of the $X(2120)$ and $X(2370)$ are determined to be 7.2σ and 6.4σ respectively. For X(1835), the $\cos^2\theta_\gamma$ distribution is shown in FIG. 2 (d), where θ_γ is the polar angle of the photon in the J/ψ center of mass system. It agrees with $1 + \cos^2\theta_\gamma$, which is expected for a pseudoscalar.

2.3 Observation of $J/\psi \to \omega X(1870) \to \omega a_0(980)\pi$ in $J/\psi \to \omega\eta\pi^+\pi^-$

The $X(1860)$ in $J/\psi \to \gamma p\overline{p}$ and the X(1835) in $J/\psi \to \gamma\eta'\pi^+\pi^-$ stimulated the study of the decay patterns of these resonances. BESIII has finished the analysis of $J/\psi \to \omega\eta\pi^+\pi^-$ with J/ψ events.

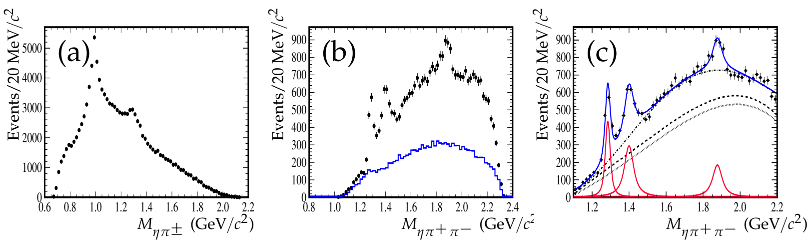

Figure 3: (a) The mass spectrum of $\eta\pi^\pm$; (b) The mass spectrum of $\eta\pi^+\pi^-$ in $a_0^\pm(980)$ mass window; (c) The $\eta\pi^+\pi^-$ mass spectrum fitting with $a_0^\pm(980)$. The dots are data. In (b), the histogram is from $J/\psi \to \omega\eta\pi^+\pi^-$ phase space MC events.

In the mass spectrum of $\eta\pi^\pm$, shown in FIG. 3 (a), the $a_0^\pm(980)$ peak is clearly seen. The mass spectrum of $\eta\pi^+\pi^-$ with $a_0^\pm(980)$ is shown in FIG. 3 (b). The $f_1(1285)$, $\eta(1405)$ and a clear peak around 1.8 GeV/c^2, denoted as $X(1870)$, can be seen. A fit with three resonances yields $M = 1877.3 \pm 6.3(\text{stat.})^{+6.3}_{-7.4}(\text{syst.})$ MeV/c^2 and $\Gamma = 57 \pm 12(\text{stat.})^{+19}_{-4}(\text{syst.})$ MeV/c^2 for $X(1870)$ with a statistical significance of 7.2σ. Additionally, the branching ratio of the

$\eta(1405)$ hadronic decay is measured to be smaller than the production in the radiative decays of J/ψ [9], which indicates $\eta(1405)$ may couple strongly to gluons.

3 Summary

In this talk, studies of $X(1860)$ in $J/\psi \to \gamma p\bar{p}$, $X(1835)$ and two new resonances in $J/\psi \to \gamma\eta'\pi^+\pi^-$, and $X(1870)$ in $J/\psi \to \omega\eta\pi^+\pi^-$ are reported. Whether these three peaks are from the same source still needs further experimental and theoretical studies. At BESIII, many precision measurements with high discovery potential have been possible and more physics results are expected.

Acknowledgments

We would like to thank the accelerator people at BEPCII for their hard work which makes our high luminosity possible. We would also like to thank the great computational and software support of the IHEP staff.

References

[1] J. Z. Bai *et al.* [BES Collaboration], Phys. Rev. Lett. **91**, 022001 (2003). [hep-ex/0303006].

[2] M. Z. Wang *et al.* [Belle Collaboration], Phys. Rev. Lett. **92**, 131801 (2004). [hep-ex/0310018].

[3] M. Ablikim *et al.* [BES Collaboration], Phys. Rev. Lett. **99**, 011802 (2007). [hep-ex/0612016].

[4] S. B. Athar *et al.* [CLEO Collaboration], Phys. Rev. **D73**, 032001 (2006). [hep-ex/0510015].

[5] M. Ablikim *et al.* [BES Collaboration], Eur. Phys. J. **C53**, 15-20 (2008). [arXiv:0710.5369 [hep-ex]].

[6] A. Datta, P. J. O'Donnell, Phys. Lett. **B567**, 273-276 (2003). [hep-ph/0306097].

[7] N. Kochelev, D. -P. Min, Phys. Lett. **B633**, 283-288 (2006). [hep-ph/0508288].

[8] T. Huang, S. -L. Zhu, Phys. Rev. **D73**, 014023 (2006). [hep-ph/0511153].

[9] K. Nakamura *et al.* (Particle Data Group), J. of Phys. G **37**, 075021 (2010).