RECENT RESULTS ON LIGHT HADRON SPECTROSCOPY AT BES

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BESII has reported a $p\bar{p}$ near-threshold enhancement in $J/\psi \to \gamma p\bar{p}$ and a new particle as X(1835) in $J/\psi \to \gamma\pi^+\pi^-\eta'$. The κ particle were also found in $J/\psi \to K^+K^-\pi^+\pi^-$(neutral one) and $J/\psi \to K^\pm K_s^0\pi^\mp\pi^0$(charged one). BESIII has collected more than 100M ψ' events and 220M J/ψ events. With these data samples, $p\bar{p}$ near-threshold enhancement and X(1835) are analyzed carefully and the BESII result are confirmed.

1 Introduction of BES at BEPC

The BES detector is a large solid-angle magnetic spectrometer at the Beijing Electron Positron Collider(BEPC). 58M J/ψ events were collected at BESII [1]. BESIII [2] is upgraded from BESII, it begins physics run since March 2009. There are more than 100M ψ' and 220M J/ψ events have been collected. The $p\bar{p}$ mass threshold structure and X(1835) were first observed and measured at BESII, the evidence for the existence of κ was also reported. Here we report the observation of κ at BESII and the confirmation of $p\bar{p}$ mass threshold structure and X(1835) at BESIII.

2 Analysis of charged κ at BESII

σ and κ are first found in the analysis of $\pi\pi$ and πK scattering data, which can not be filled into any nonets of ordinary $q\bar{q}$ mesons. Evidences for the κ have been reported recently by the E791 experiment [3] and the FOCUS experiment [4]. In 2006, BESII reported the existence of κ particle in the analysis of $J/\psi \to \bar{K}^*(892)^0K^+\pi^- \to K^+K^-\pi^+\pi^-$ [5]. Because of the isospin symmetry, there should be charged κ particle. Here, we try to find the charged κ in $J/\psi \to \bar{K}^*(892)^\pm\kappa^\pm \to K^\pm K_s^0\pi^\mp\pi^0$ with 58M J/ψ data collected with BESII [6]. A partial wave analysis, which is based on the covariant helicity amplitude analysis, is performed for the charged κ analysis. The final fit of $K\pi$ spectrum is shown in Fig. 1(a), where points with error bars are data, and the light shaded histogram is the final fit. In the figure, the dark shaded histogram shows the contribution of the charged κ. Fig. 1(b) shows the final fit for the $K^*(892)\pi$ spectrum. Three different parameterizations are used to fit the κ. They are

$$BW_\kappa = \frac{1}{m_\kappa^2 - s - im_\kappa\Gamma_\kappa}, \Gamma_\kappa = cons., \tag{1}$$

$$BW_\kappa = \frac{1}{m_\kappa^2 - s - i\sqrt{s}\Gamma_\kappa(s)}, \Gamma_\kappa(s) = \frac{g_\kappa^2.k_\kappa}{8\pi s}, \tag{2}$$

$$BW_\kappa = \frac{1}{m_\kappa^2 - s - i\sqrt{s}\Gamma_\kappa(s)}, \Gamma_\kappa(s) = \alpha.k_\kappa, \tag{3}$$

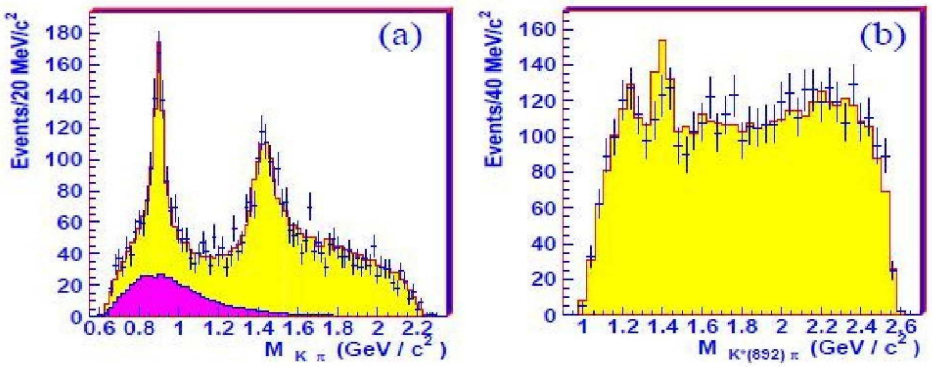

Figure 1: (a) Final fit results for the $K\pi$ spectrum. Points with error bars are data, the light shaded histogram is the final global fit, and the dark shaded histogram is the contribution of the kappa. (b) Final fit of $K^*(892)\pi$ spectrum. Points with error bars are data, the light shaded histogram is the final global fit. The two peaks in the lower mass region are fitted by $K_1(1270)$(lower one) and $K_1(1400)$(higher one) seperately.

Table 1: Masses, widths and pole positions of the charged κ. In the table, the first errors are statistical, and the second are systematic. BW (1) means equation (1) in the fit, BW (2) and BW (3) have similar meanings.

	BW(1)	BW(2)	BW (3)
Mass (MeV/c^2)	$810 \pm 68^{+15}_{-24}$	$884 \pm 40^{+11}_{-22}$	$1165 \pm 58^{+120}_{-41}$
Width (MeV/c^2)	$536 \pm 87^{+106}_{-47}$	$478 \pm 77^{+71}_{-41}$	$1349 \pm 500^{+472}_{-176}$
pole (MeV/c^2)	$(849 \pm 77^{+18}_{-14})$ $-i(256 \pm 40^{+46}_{-22})$	$(849 \pm 51^{+14}_{-28})$ $-i(288 \pm 101^{+64}_{-30})$	$(839 \pm 145^{+24}_{-7})$ $-i(297 \pm 51^{+50}_{-18})$

where k_κ is the magnitude of the momentum of the K in the $K\pi$, or the κ center of mass system, and α is a constant which will be determined by fit. Parameters in the Breit-Wigner function are determined by mass and width scans. The final results are listed in the Table 1, where the first errors are statistical, and the second are systematic. The mass and width parameters obtained by different parameterizations are quite different, but their poles are almost the same. This situation is quite similar to what we found in the study of the neutral κ. The corresponding results for the neutral κ [5] are shown in Table 2. The results for the charged κ are consistent with those of the neutral κ.

3 Conformation of $p\bar{p}$ mass threshold structure at BESIII

An anomalously strong $p\bar{p}$ mass threshold enhancement was observed by the BESII experiment in the radiative decay process $J/\psi \to \gamma p\bar{p}$ [7]. An interesting feature of this enhancement is that corresponding structures are not observed in near-threshold $p\bar{p}$ cross section measurements, in

Table 2: Masses, widths and pole positions of the neutral κ. BW (1) means equation (1) in the fit, BW (2) and BW (3) have similar meaning

	BW(1)	BW(2)	BW (3)
Mass (MeV/c^2)	$745 \pm 26^{+14}_{-91}$	$874 \pm 25^{+12}_{-55}$	$1140 \pm 39^{+47}_{-80}$
Width (MeV/c^2)	$622 \pm 77^{+61}_{-78}$	$518 \pm 65^{+27}_{-87}$	$1370 \pm 156^{+406}_{-148}$
pole (MeV/c^2)	$(799 \pm 37^{+16}_{-90})$ $-i(290 \pm 33^{+25}_{-38})$	$(836 \pm 38^{+18}_{-87})$ $-i(329 \pm 66^{+28}_{-46})$	$(811 \pm 74^{+17}_{-83})$ $-i(285 \pm 20^{+18}_{-42})$

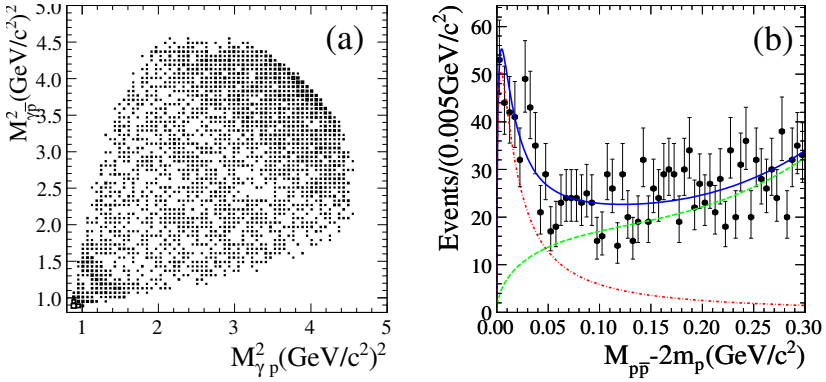

Figure 2: Analysis of $\psi' \to \pi^+\pi^- J/\psi, J/\psi \to \gamma p\bar{p}$ at BESIII (a)Dalitz plot. (b)Fitting of $p\bar{p}$ near-threshold structure, the solid curve is the fit result; the dashed curve shows the fitted background function.

B-meson decays [8,9], in radiative ψ' or $\Upsilon \to \gamma p\bar{p}$ decays [10,11]. This experimental observation stimulated a number of theoretical speculations. One of these is the intriguing suggestion that it is an example of a $p\bar{p}$ bound state, sometimes called baryonium, which has a long history and has been the subject of many experimental searches.

With 100M ψ' data collected at BESIII, $\psi' \to \pi^+\pi^- J/\psi(J/\psi \to \gamma p\bar{p})$ is used to study the $p\bar{p}$ mass threshold structure. Fig. 2(a) shows the Dalitz plot. There is obvious structure near the threshold of the $p\bar{p}$ mass spectrum. The enhancement is fitted with an acceptance weighted Breit-Wigner function of the form $BW(M) \propto \frac{q^{2L+1}k^3}{(M^2-M_0^2)^2+M_0^2\Gamma^2}$(Fig. 2(b)), where Γ is a constant(determined from fit), q is the proton momentum in the $p\bar{p}$ rest-frame, L is the $p\bar{p}$ orbital angular momentum, and k is the photon momentum. The fitting gives the mass and width as $m = 1861^{+6}_{-13}(stat)^{+7}_{-26}(syst)MeV/c^2$ and $\Gamma < 38MeV/c^2(90\%C.L.)$. The result is consistent with BESII. $\psi' \to \gamma p\bar{p}$ is also studied and no such an enhancement observed, which indicated pure FSI interpretation of the narrow and strong $p\bar{p}$ threshold enhancement in J/ψ radiative decay is disfavored.

4 Confirmation of X(1835) at BESIII

X(1835) was observed in the $\pi^+\pi^-\eta'$ invariant-mass spectrum with a statistical significance of 7.7σ at BESII [12]. A fit with a Breit-Wigner function yields a mass $M = 1833.7 \pm 6.1(stat) \pm 2.7(syst)MeV/c^2$, a width $\Gamma = 67.7 \pm 20.3(stat) \pm 7.7(syst)MeV/c^2$, and a production branching fraction $B(J/\psi \to \gamma X) \times B(X \to \pi^+\pi^-\eta') = [2.2 \pm 0.4(stat) \pm 0.4(syst)] \times 10^{-4}$. The mass and width of X(1835) are not compatible with any known meson resonance.

With 220M J/ψ events collected at BESIII, $J/\psi \to \gamma\pi^+\pi^-\eta'(\eta' \to \gamma\rho, \eta\pi^+\pi^-)$ is studied to verify the BESII observation. Fig. 3(a) shows the invariant mass spectrum of $\pi^+\pi^-\eta'$ for $J/\psi \to \gamma\pi^+\pi^-\eta'(\eta' \to \gamma\rho)$. A significant peak at $M \sim 1835$ MeV/c^2 is observed. If it is fitted with one resonance plus a polynomial background shape, the statistical significance of the resonance is about 18σ. Fig. 3(b) is the invariant mass spectrum of $\pi^+\pi^-\eta'$ for $J/\psi \to \gamma\pi^+\pi^-\eta'(\eta' \to \eta\pi^+\pi^-)$. There is also a significant peak at $M \sim 1835$ MeV/c^2. The fitting shows the statistical significance is about 9σ. Extensive studies of potential background processes using both data and MC is made, none can produce a peak around 1835 MeV/c^2 in the $\pi^+\pi^-\eta'$ mass spectrum. Fig.3(c) shows the $\pi^+\pi^-\eta'$ invariant-mass spectrum for the combined $J/\psi \to \gamma\pi^+\pi^-\eta'(\eta' \to \gamma\rho)$ and $J/\psi \to \gamma\pi^+\pi^-\eta'(\eta' \to \pi^+\pi^-\eta)$. This spectrum is fitted with a Breit-Wigner function convolved with a Gaussian mass resolution function. The mass and width obtained from the fit are $M = 1842.4 \pm 2.8(stat)$ MeV/c^2 and $\Gamma = 99.2 \pm 9.2$ (stat) MeV/c^2 with a statistical significance of 21σ. These values are consistent with the published BESII results [12]. More

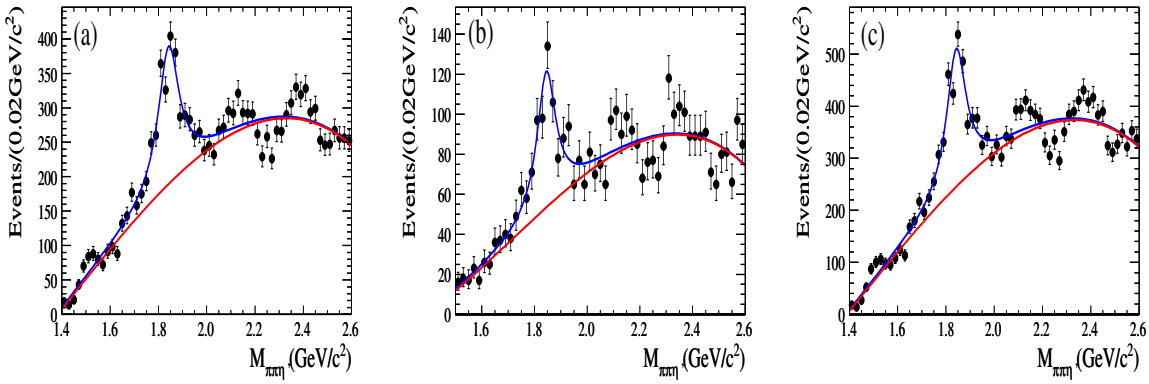

Figure 3: Fitting the invariant mass spectrum of $\pi^+\pi^-\eta'$ in $J/\psi \to \gamma\pi^+\pi^-\eta'$ at BESIII. (a)$\eta' \to \gamma\rho$; (b)$\eta' \to \pi^+\pi^-\eta$;(c)The combined invariant mass spectrum of $\eta' \to \gamma\rho$ and $\eta' \to \pi^+\pi^-\eta$. The mass spectrum is fitted with a resonance plus polynomial background shape.

studies will be performed on the high $\pi^+\pi^-\eta'$ mass region of $2.1 \sim 2.5$ GeV/c^2.

5 Summary

Charged κ is observed at BESII with $J/\psi \to K^\pm K_s^0 \pi^\mp \pi^0$. Partial Wave Analysis has been performed on the charge κ, and the mass and width are measured. An anomalous strong, near-threshold enhancement in the $p\bar{p}$ invariant mass distribution is observed in the decay process of $\psi' \to \pi^+\pi^- J/\psi(J/\psi \to \gamma p\bar{p})$. If it is fitted with an S-wave Breit-Wigner resonance function, the peak mass is $M = 1865 \pm 5$ (stat) MeV/c^2 and the width is $\Gamma < 33$ MeV/c^2 at the 90% confidence level. The resonance, $X(1835)$ is confirmed in two decay modes of η' for $J/\psi \to \pi^+\pi^-\eta'$. The BESIII results are consistent with those published by BESII.

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