LIGHT HADRON SPECTROSCOPY AT BESIII

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Based on the world largest data sample of J/ψ, which collected by BESIII detector, the psudo-scalars ($\eta(1440)/\eta(1405)/\eta(1475)$), scalar glueball candidates ($f_0(1370)$, $f_0(1500)$, and $f_0(1710)$), and X(18**) have been reviewed and discussed.

1 Introduction

BEPCII is a double-ring electron-positron collider working at center-of-mass (c.m.) energies from 2.0 to 4.6 GeV. The BESIII detector is described in detail in Ref. [1]. The cylindrical BESIII detector covers 93% of the full solid angle. It consists of a helium-gas-based Main Drift Chamber (MDC), a plastic scintillator Time-of-Flight system (TOF), a CsI(Tl) Electromagnetic Calorimeter (EMC), and a muon counter. The charged particle momentum and photon energy resolutions at 1 GeV are 0.5% and 2.5%, respectively. BESIII started data taking for physics since 2009, up to now, the world largest data samples at J/ψ, ψ', $\psi(3770)$, $\psi(4040)$, $Y(4260)$,..., are already collected, for the details please refer to Tab. 1.

2 Psuedoscalar: $\eta(1440/1405/1475)$

The $\eta(1440)$ was first observed in $p\bar{p}$ annihilation at rest into $\eta(1440)\pi^+\pi^-$, $\eta(1440) \to K\bar{K}\pi$ [4], and then in J/ψ radiative decays into $K\bar{K}\pi$ [5] and $\gamma\rho$ [6]. Further studies by different experiments reported two pseudoscalars in this mass region, $\eta(1405)$ and $\eta(1475)$. The former decays mainly through $a_0(980)\pi$ (or direct $K\bar{K}\pi$), and the latter mainly to $K^*(892)\bar{K}$.

If the $\eta(1295)$ is established, according to the quark-model, The $\eta(1475)$ could be the first radial excitation of the η', with the $\eta(1295)$ being the first radial excitation of the η [7,8]. However, due to the strong kinematical suppression the data are not sufficient to exclude a sizeable $s\bar{s}$ admixture also in the $\eta(1405)$ [9]. Also, the $\eta(1405)$ is an excellent candidate for a 0^{-+} glueball in the fluxtube model [10], although it is not favored by lattice gauge theories, which predict the 0^{-+} glueball should be above 2 GeV [11,12].

However, the issue remains controversial as to whether these two pseudoscalars really exist. According to Ref. [13] the splitting of a single state could be due to nodes in the decay ampli-

Table 1: Data Sets for BESIII

Energy point	Int. Lum.
J/ψ	1.3×10^9
ψ'	5×10^8
$\psi(3770)$	$2.9\ fb^{-1}$
$\psi(4040)$	$0.5\ fb^{-1}$
$4230/4260 MeV$	$2.3\ fb^{-1}$
$4360 MeV$	$0.5\ fb^{-1}$
$4600 MeV$	$0.5\ fb^{-1}$
$\psi(4415)$	$1\ fb^{-1}$
$4470/4530 MeV$	$0.1\ fb^{-1}$
around Λ_C threshold	$0.04\ fb^{-1}$
$4420 MeV$	$1\ fb^{-1}$
R scan: 2$\sim$ 3 GeV, 19 points	$\sim 0.5 fb^{-1}$
R scan: 3.85$\sim$ 4.59 GeV, 104 points	$\sim 0.8 fb^{-1}$
$3554 MeV$ (for τ mass)	$24\ pb^{-1}$
$4100 \sim 4400 MeV$ (coarse scan)	$0.5\ fb^{-1}$
On-going data taking	

tudes which differ in $\eta\pi\pi$ and $K^*(892)\bar{K}$. Based on the isospin violating decay $J/\psi \to \gamma 3\pi$ observed by BESIII [14] the splitting could also be due to a triangular singularity mixing $\eta\pi\pi$ and $K^*(892)\bar{K}$ [15,16]. With the one-state assumption, the relationship between its $\gamma\phi$, $\gamma\rho$, and $\gamma\omega$ decay modes is predicted to be $Br(\gamma\phi) : Br(\gamma\rho) : Br(\gamma\omega)$ =1 : 3.8 : 0.42 [15]. Figure 1 (b) shows the invariant mass distribution of $\gamma\rho$ at BES2 [6], which based on the 58×10^6 J/ψ events. Recently, BESIII obtained the preliminary results of $\eta(1475) \to \gamma\phi$ [17] as show in Fig. 1 (c) and (d). Due to the interference effect between $\eta(1475)$ and $X(1835)$, there are two possible solutions (destructive and constructive) with equal fit goodness, by comparing to the result of the $Br(\eta(1440) \to \gamma\rho)$ from Ref. [6], the calculated ratios of $Br(\gamma\rho) : Br(\gamma\phi)$ are $(6.6 \pm 2.1) : 1$ and $(9.9 \pm 2.8) : 1$ for constructive and destructive cases respectively, which its a little bit larger than that of the prediction in Ref. [15].

3 Scalar Glueball Candidates: $f_0(1370)$, $f_0(1500)$, and $f_0(1710)$

The $f_0(1370)$ and $f_0(1500)$ decay mostly into pions (2π and 4π), while the $f_0(1710)$ decays mainly into the $K\bar{K}$ final states. The $K\bar{K}$ decay branching ratio of the $f_0(1500)$ is small [18,19,20]. As we know, different theoretical models have different explanations for the candidates of the scalar glueball, Ref. [21] prefer the $f_0(1370)$ with a significant glue content, Ref. [22] suggest the $f_0(1500)$ is mainly glue, and Ref. [23]'s results indicate that $f_0(1710)$ has a larger overlap with the pure gauge glueball than other related scalar mesons.

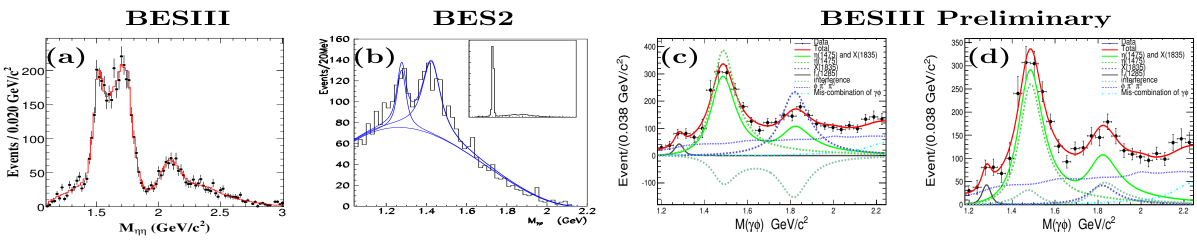

Figure 1 – The invariant mass of (a) $\eta\eta$ in $J/\psi \to \gamma\eta\eta$. (b) $\gamma\rho$ in $J/\psi \to \gamma\gamma\rho$, the insert shows the full mass scale where the $\eta(958)$ is clearly observed. (c) and (d) Fit to $M(\gamma\phi)$ in $J/\psi \to \gamma\gamma\phi$ for destructive-interference and constructive-interference solution respectively. Dots with error bars are data, red line is fit model, green line is $\eta(1475)$ together with $X(1835)$, black line is $f_1(1285)$, blue dotted line is for the backgrounds.

Based on a sample of 2.25×10^8 J/ψ events collected with the BESIII detector at BEPCII, a full partial wave analysis (PWA) on $J/\psi \to \gamma\eta\eta$ was performed using the relativistic covariant tensor amplitude method [24]. Figure 1 (a) shows the comparisons between real data and PWA projections. The measured branching fraction is $Br(J/\psi \to \gamma f_0(1710) \to \gamma\eta\eta) = (2.35^{+0.13+1.24}_{-0.11-0.74}) \times 10^{-4}$. From PDG [18] we can find branching fractions of other decay modes for $f_0(1710)$, such as $Br(J/\psi \to \gamma f_0(1710) \to \gamma K\bar{K}) = (8.5^{+1.2}_{-0.9}) \times 10^{-4}$, $Br(J/\psi \to \gamma f_0(1710) \to \gamma\pi\pi) = (4.0 \pm 1.0) \times 10^{-4}$, and $Br(J/\psi \to \gamma f_0(1710) \to \gamma\omega\omega) = (3.1 \pm 1.0) \times 10^{-4}$. If we sum up all of these dominated decay modes of $f_0(1710)$, it will be comparable with the theoretical glueball prediction in Ref. [23] which $Br(J/\psi \to \gamma G(0^{++})) = 3.8(9) \times 10^{-3}$. However, it still difficult to say $f_0(1710)$ is a glueball, more study should be needed.

4 Status of $X(18^{**})$

A Strong enhancement near the $p\bar{p}$ threshold, $X_{p\bar{p}}$, was first observed by BESII [25] in the decay $J/\psi \to \gamma p\bar{p}$, and confirmed by BESIII [26,27] and CLEO [28]. In a partial wave analysis of $J/\psi \to \gamma p\bar{p}$, BESIII determined the J^{PC} of the $X_{p\bar{p}}$ to be 0^{+} [29]. The mass of the $X_{p\bar{p}}$ is consistent with the $X(1835)$ mass measured in $J/\psi \to \gamma\pi^+\pi^-\eta'$ [30], but the width of the $X_{p\bar{p}}$ is significantly narrower. Since the discovery of the $X(1835)$, many possible interpretations have been proposed, such as a $p\bar{p}$ bound state [31,32,33,34,35], a glueball [36,37], or a second radial excitation of the η' meson [38,39]. In the search for the $X(1835)$ in other J/ψ hadronic decays, BESIII reported a 0^{++} state, $X(1810)$, in $J/\psi \to \omega\phi$ [40], $X(1840)$ in $J/\psi \to \gamma 3(\pi^+\pi^-)$ [41], and $X(1870)$ in $J/\psi \to \omega\eta\pi^+\pi^-$ [42]. Figure 2 (a) summarized the mass and width of the $X(18^{**})$ in different decay modes reported at BESIII.

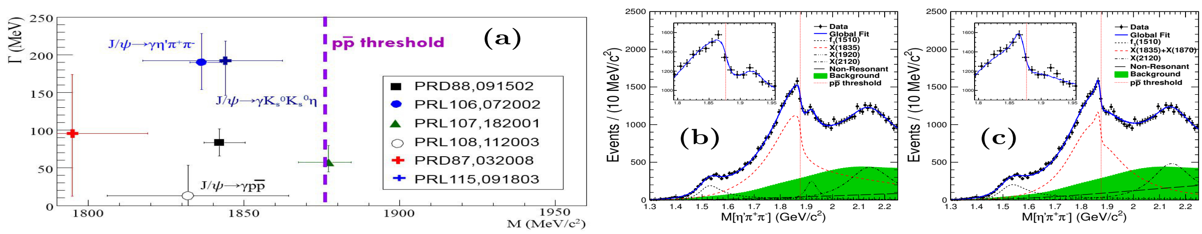

Figure 2 – (a) The mass and width distribution of the states near the $p\bar{p}$ threshold which have been measured in BESIII. (b) and (c) Fit results of $\eta'\pi^+\pi^-$, the Flatté formula and a coherent sum of two Breit-Wigner amplitudes are used respectively. The dashed dotted vertical line shows the position of $p\bar{p}$ mass threshold, the dots with error bars are data, the solid curves are total fit results, the dashed curves are the state around 1.85 GeV in (b), and the sum of $X(1835)$ and $X(1870)$ in (c), the short-dashed curves are the $f_1(1510)$, the dash-dotted curves are the $X(2120)$, the dash-dot-dot-dotted curves are $X(1920)$ in (b), the long-dashed curves are non-resonant $\eta'\pi^+\pi^-$ fit results, the shaded histograms are background events. The inset shows the data and the global fit between 1.8 GeV and 1.95 GeV.

In order to understand the nature of $X(1835)$ and $X(p\bar{p})$, recently, the $\eta'\pi^+\pi^-$ line shape of $X1835$ has been studied [43]. Two models have been used to characterize the $\eta'\pi^+\pi^-$ line shape around 1.85 GeV, one which explicitly incorporates the opening of a decay threshold in the mass spectrum (Flatte formula) (Fig. 2 (b)), and another which is the coherent sum of two resonant amplitudes (Fig. 2 (c)). Both fits show almost equally good agreement with data, and suggest the existence of either a broad state around 1.85 GeV with strong couplings to $p\bar{p}$ final states or a narrow state just below the $p\bar{p}$ mass threshold. Although it cannot distinguish between the fits, either one supports the existence of a $p\bar{p}$ molecule-like state or bound state with greater than 7σ significance.

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