RECENT RESULTS ON LIGHT HADRON SPECTROSCOPY AT BESIII

Y. CHEN

(for the BESIII Collaboration)

*Institute of High Energy Physics, Academy of Science,
 Beijing 100049, P. R. China
chenye@ihep.ac.cn*

Several measurements on light hadron spectroscopy have been achieved with Beijing Spectrometry III (BESIII). BESII results such as a near threshold enhancement on the $p\bar{p}$ invariants mass spectrum namely X(1860) and a resonance X(1835) have been confirmed with 225 million J/ψ data accumulated from June 12, 2009 to July 28, 2009. Along with some other preliminary BESIII results including observations of X(1870), X(2120) and X(2370); the first direct measurement of $a_0(980)/f_0(980)$ mixing; and an improved measurement on the matrix element of decay $\eta' \rightarrow \pi\pi\eta$ have been reported at the 4th international workshop on charm physics.

Keywords: Light hadron spectroscopy; J/ψ decay

PACS numbers: 13.20Gd, 14.40Be, 13.75Cs, 12.39Mk

1. Introduction

Study of the spectroscopy is a way to get a better understanding of the internal structure. We choose to study the $\tau - \text{charm}$ collider because e^+e^- collider is a gluon rich process and it could provide an environment with relatively low background. Using the 225 million J/ψ data sample accumulated at BESIII, we are dedicated to make more precise measurements on the established spectrum of the light hadrons, search for the non-conventional hadrons, understand how hadrons are formed¹. This talk presents five decay channel analysis performed at BESIII which would be described in the following sections.

2. $p\bar{p}$ invariant mass spectrum enhancement

An anomalous near threshold enhancement in $p\bar{p}$ invariant mass spectrum, X(1860), has been observed at BESII² and recently confirmed by BESIII³. The mass of this particle is measured to be $1.859^{+3}_{-10}(\text{stat.})^{+5}_{-25}(\text{syst.}) \text{ GeV}$ and the total width is $\Gamma < 30 \text{ MeV}/c^2$ at the 90% confidence level². This enhancement is recently confirmed again by CLEO collaboration⁴.

The discovery of X(1860) invokes intensive studies on light hadron spectroscopes both experimentally^{5,6,7,8} and phenomenologically^{9,10,11,12,13,14,15}. Experiment results shows that this enhancement is not seen from other quarkonia decay such as $J/\psi \rightarrow \pi^0 p \bar{p}$ ², $\Upsilon(2S) \rightarrow \gamma p \bar{p}$ ⁵, $\psi \rightarrow \gamma p \bar{p}$ ⁶ and $J/\psi \rightarrow \omega p \bar{p}$ ⁷. Phenomenologically, people interpret the originality of X(1860) as baryonium, multiquarks candidate or mainly from pure final state interaction etc. Meanwhile, people intent to associate this enhancement with a broad enhancement observed from B meson decays^{16,17} or a new resonance X(1835) observed at BESII¹⁸. BESIII study the $p \bar{p}$ invariant mass spectrum using both the decay channel of $\psi \rightarrow \pi \pi J/\psi$, $J/\psi \rightarrow \gamma p \bar{p}$ ³ and also $J/\psi \rightarrow \gamma p \bar{p}$. From the left plot of Fig. 1, we see the the structure of X(1860) has been clearly confirmed.

3. Confirmation of X(1835) and observation of two new structures in $J/\psi \rightarrow \gamma \pi \pi \eta'$

X(1835) was observed at BESII in the decay of $J/\psi \rightarrow \gamma \pi \pi \eta'$, the mass is measured to be $1833.7 \pm 6.1(stat.) \pm 2.7(syst.) MeV$ and the width is measured to be $67.7 \pm 20.3(stat) \pm 7.7(stat) MeV$ ¹⁸. Confirmation of X(1835) is straightforward and necessary at BSEIII; other motivation of this study would be that LQCD predicts the 0^{-+} glueball mass is around $2.3 GeV$. It would be important and interesting to study the $J/\psi \rightarrow \gamma \pi \pi \eta'$. The right plot of Fig 1 shows the invariant mass spectrum of $J/\psi \rightarrow \gamma \pi \pi \eta'$ with two η' decay modes $\eta' \rightarrow \gamma \rho$ and $\eta' \rightarrow \pi \pi \eta$. We see X(1835) and η_c are observed along with two additional structures around $2.1 GeV$ and $2.3 GeV$. Signal of $f_1(1510)$ is also clearly seen as well¹⁹.

From above, we conclude that X(1835) resonance is confirmed at BESIII with a significance of 20σ . The width is significantly larger than that measured at BESII with one resonance in the fit. Meanwhile, X(2120) and X(2370), are observed with significance larger than 7.2σ and 6.4σ , respectively¹⁹.

Fig. 1. Left: $p \bar{p}$ invariant mass spectrum from the $\psi' \rightarrow \pi \pi J/\psi (J/\psi \rightarrow \gamma p \bar{p})$, solid curve is the fitting result, the dashed curve is the background, the dash-dotted line is the efficiency curve; Right: invariant mass spectrum of $\pi \pi \eta'$ fitting with four resonances model. the red dash-dot line is contribution of non- η' events and the $\pi^0 \pi \pi \eta'$ background for two η' decay modes and the solid black line is including an additional empirical function to describe the phase-space contribution.

4. Observation of $X(1870) \rightarrow a_0\pi$ in $J/\psi \rightarrow \omega\pi\pi\eta$ at BESIII.

We also study the decay channel of $J/\psi \rightarrow \omega\pi\pi\eta$. Fig. 2 demonstrates a fit with three resonances model. Study shows that the $f_1(1285)$, $\eta(1410)$ and $X(1870)$ are primarily decay via $a_0(980)\pi^\pm$. Whether the $X(1870)$ is the $X(1835)$, $\eta_2(1870)$ or a new resonance, further study is needed.

5. $a_0(980)$ - $f_0(980)$ mixing

There are long-history controversial views on the nature of $a_0(980)/f_0(980)$. People interpret them as $q\bar{q}$ measons, four quarks states, hybrids and $K\bar{K}$ molecules etc. Study of the mixing of $a_0(980)$ and $f_0(980)$ will shed new light on this mystery. A narrow peak has been predicted around 8 MeV between the charged and neutral kaon thresholds (987 ~ 995 MeV)^{21,22,23} which motives us to do this study.

A direct measurement of the $a_0(980)$ - $f_0(980)$ mixing has been firstly carried out at BESIII. The $f_0(980)$ to $a_0(980)$ transition is measured via $J/\psi \rightarrow \phi f_0(980) \rightarrow \phi a_0(980) \rightarrow \phi\eta\pi^0$. Evidence for $f_0(980) \rightarrow a_0(980)$ is found with a significance of 3.4σ , see the left plot of Fig. 3. For the case of $a_0^0(980) \rightarrow f_0(980)$ transition, it is measured in the processes $\chi_{c1} \rightarrow \pi^0 a_0^0(980) \rightarrow \pi^0 f_0(980) \rightarrow \pi^0\pi\pi$, and the significance is 1.9σ , shown on the right plot of Fig. 3. Measurements and upper limits of both branching ratios and mixing intensities are determined as well²⁰. Following the mixing intensity of ξ_{fa} and ξ_{af} is presented respectively,

$$\xi_{fa} = \frac{Br(J/\psi \rightarrow \phi f_0(980) \rightarrow \phi a_0(980) \rightarrow \phi\eta\pi^0)}{Br(J/\psi \rightarrow \phi f_0(980) \rightarrow \phi\pi\pi)} \\ = (0.60 \pm 0.20(stat.) \pm 0.12(sys.) \pm 0.26(para.))\%$$

and

$$\xi_{af} = \frac{Br(\chi_{c1} \rightarrow \pi^0 a_0(980) \rightarrow \pi^0 f_0(980) \rightarrow \pi^0\pi\pi)}{Br(\chi_{c1} \rightarrow \pi^0 a_0(980) \rightarrow \pi^0\pi^0\eta)} \\ = (0.31 \pm 0.16(stat.) \pm 0.14(sys.) \pm 0.03(para.))\%.$$

Fig. 2. $J/\psi \rightarrow \omega\pi\pi\eta$. $\pi\pi\eta$ invariant mass spectrum with three resonances model, the dashed line is the background component described by polynomial function.

Fig. 3. (a) Fitting result of the $\eta\pi^0$ mass spectrum recoiling against the ϕ signal. (b) Fitting result of the $\pi^+\pi^-$ mass spectrum in the χ_{c1} mass window. The dotted lines shows the mixing signal. The dash-dotted lines indicate underlying $a_0(980)$ of $f_0(980)$ from other processes. The dashed lines denote the polynomial background.

Table. I Experimental and theoretical values of the parameters of the matrix element squared for $\eta' \rightarrow \pi\pi\eta$.

Par.	VES ²⁵	Theory ²⁷	BESIII ²⁴
a	-0.127 ± 0.018	-0.116 ± 0.001	-0.047 ± 0.012
b	-0.106 ± 0.032	-0.042 ± 0.034	-0.069 ± 0.021
c	0.015 ± 0.018	-	0.019 ± 0.012
d	-0.082 ± 0.019	0.010 ± 0.019	-0.073 ± 0.013

Par.	CLEO ²⁶	VES ²⁸	BESIII ²⁴
$Re(\alpha)$	-0.021 ± 0.025	-0.072 ± 0.014	-0.033 ± 0.006
$Im(\alpha)$	0.000(fixed)	0.000 ± 0.100	0.000 ± 0.050
c	0.000(fixed)	0.020 ± 0.019	0.018 ± 0.010
d	0.000(fixed)	-0.066 ± 0.034	-0.059 ± 0.013

6. Matrix element measurement of the decay $\eta' \rightarrow \eta\pi\pi$

A new level of precision measurement on the matrix element for the decay of $\eta' \rightarrow \eta\pi\pi$ has also been performed based on the largest sample of η' decay to data. Two representations of parametrization for the decay amplitudes are adopted including the general decomposition and the linear decomposition. Table. I demonstrates the experimental and theoretical values of the parameters of the matrix

element squared for $\eta' \rightarrow \pi\pi\eta$ in the general parametrization (upper) and in the linear parametrization (lower)²⁴.

Acknowledgments

The speaker would like to thank all the BESIII colleagues for their contribution to make this talk possible. And many thanks to the organizers of Charm2010.

References

1. "Physics at BESIII", edited by K. T. Chao and Y. F. Wang, Int. J. Mod. Phys. A **24**, suppl. 1 (2009).
2. J.Z. Bai *et al.* (BES Collaboration), Phys. Rev. Lett. **91**, 022001 (2003).
3. M. Ablikim *et al.* (BESIII Collaboration), Chinese Physics C **34**, 4 (2010).
4. J. P. Alexander *et al.* (CLEO Collaboration), Phys. Rev. D **82**, 092002 (2010).
5. S. A. Athar *et al.* (CLEO Collaboration), Phys. Rev. D, 032001 (2006).
6. M. Ablikim *et al.* (BES Collaboration), Phys. Rev. Lett. **99**, 011802 (2007).
7. M. Ablikim *et al.* (BES Collaboration), Eur. Phys. J. C **53**, 15 (2008).
8. For review, S. Jin, Int. J. Mod. Phys. A **20**, 5145 (2005).
9. A. Datta and P. J. O'Donnell, Phys. Lett. B **567**, 273 (2003).
10. M. L. Yan, S. Li, B. Wu, B. Q. Ma, Phys. Rev. D **72**, 034027 (2005).
11. S. L. Zhu, Int. J. Mod. Phys. A **20**, 1548 (2005).
12. B. S. Zou, H. C. Chiang, Phys. Rev. D **69**, 034004 (2004).
13. D. V. Bugg, Phys. Lett. B **598**, 8(2004).
14. A. Sibirtsev, J. Haidenbauer, S. Krewald, M. G. Meissner, A. W. Thomas, Phys. Rev. D **71**, 054010 (2005).
15. For review, C. S. Gao and S. L. Zhu, Commun. Theor. Phys. **42**, 844(2004); E. Klempt and A. Zaitsev, Phys. Rept. **454**, 1 (2007).
16. K. Abe *et al.* (BELLE Collaboration), Phys. Rev. Lett. **94**, 182002 (2005).
17. B. Aubert *et al.* (BABAR Collaboration), Phys. Rev. D **74**, 051101 (2006).
18. M. Ablikim *et al.* (BES Collaboration), Phys. Rev. Lett. **95**, 262001 (2005).
19. M. Ablikim *et al.* (BESIII Collaboration), arXiv: 1012.3510, [hep-ex](2010).
20. M. Ablikim *et al.* (BESIII Collaboration), arXiv: 1012.5131, [hep-ex](2010).
21. C. Hanhart, B. Kubis and J. R. Peláez, Phys. Rev. D **76**, 074028 (2007).
22. J. J. Wu, Q. Zhao and B. S. Zou, Phys. Rev. D **75**, 114012, (2007).
23. J.J. Wu and B. S. Zou, Phys. Rev. D **78**, 074017(2008).
24. M. Ablikim *et al.* (BESIII Collaboration), arXiv:1012.1117, [hep-ex](2010).
25. V. Dorofeev *et al.*, Phys. Lett. B **651**, 22 (2007).
26. R. A. Briere *et al.* (CLEO Collaboration), Phys. Rev. Lett. **84**, 26(2000).
27. B. Borosoy and R. Nissler, Eur. Phys. J A **26**, 383 (2005).
28. D. V. Amelin *et al.* , Phys. Atom. Nucl. **68**, 373 (2005).