Experimental Study on $J/\psi \to \gamma K^+K^-$ and $J/\psi \to \gamma\pi^0\pi^0$, $J/\psi \to \gamma\eta\eta$, $J/\psi \to \gamma\eta\eta'$, $J/\psi \to \gamma\eta'\eta'$

Yucan ZHU
Representing BES Collaboration
Institute of High Energy Physics, Academia Sinica
Beijing 100039, People's Republic of China

Abstract

The decay $J/\psi \to \gamma K^+K^-$ has been analysed with the data collected by BES at Beijing electron-positron collider (BEPC). Two resonances are found in 1.7 GeV region. One is a scalar with mass $1781 \pm 8^{+10}_{-31}$(MeV) and width $85 \pm 24^{+22}_{-19}$(MeV), and the other is a tensor with mass $1696 \pm 5^{+9}_{-34}$(MeV) and width $103 \pm 18^{+30}_{-11}$(MeV). The branching ratios $Br(J/\psi \to \gamma f_J)Br(f_J \to K^+K^-)$ are $(0.8\pm0.1)10^{-4}$ for $J = 0$ and $(2.5\pm0.4)10^{-4}$ for $J = 2$, respectively. We also studied J/ψ radiative decays to $\pi^0\pi^0$, $\eta\eta$, $\eta\eta'$ and $\eta'\eta'$. The evidence for the existence of $\xi(2230)$ in these channels is shown.

1 Study on $J/\psi \to \gamma K^+K^-$

There have been considerable recent interests in the $f_J(1710)$ and its role in the glueball spectroscopy. Phenomenologically, since the $f_J(1710)$ was first discovered by the Crystal Ball Collaboration in $J/\psi \to \gamma\eta\eta$ [1], it has been observed in other channels of J/ψ decay[2, 3], the pp central production[4], π^-p induced reactions [5, 6], in which the productions of glueballs are expected to be enhanced, while there is no evidence of the $f_J(1710)$ in $\gamma\gamma$ collisions[7] where the glueball production should be suppressed. Moreover, the $f_J(1710)$ has not been observed in the K^-p reaction[8], which suggests that it be unlikely an $s\bar{s}$ state. The recent investigation[9] shows that the nature of this state depends critically on whether its spin-parity is 0^{++} or 2^{++}; a scalar $f_J(1710)$ is likely a glueball state. The calculations on QCD lattice predict[10, 11] that the lightest glueball should be a scalar with mass $1.5 \sim 1.7$ GeV, which is consistent with the mass of $f_J(1710)$.

The spin of the $f_J(1710)$ has not been well determined experimentally. In this report, we present an analysis of the recent $J/\psi \to \gamma K^+K^-$ data from BES experiment at BEPC. The preliminary selection of the γK^+K^- events chooses those that have two opposite charged tracks and more than one photon. Some criteria are used to remove Bhabha and Dimu events. Other backgrounds, such as $J/\psi \to K^{*\pm}K^\mp$, $J/\psi \to \rho^\pm\pi^\mp$, $J/\psi \to \rho^0\pi^0$, $J/\psi \to \gamma f_2(1270)$ and $J/\psi \to \gamma\eta(1440)$ are greatly rejected by requiring the kinematic variable $|U| = |E_{miss} - |\mathbf{P}_{miss}|| < 0.1$, $P^2_{t\gamma} \equiv 4|\mathbf{P}_{miss}|^2 \sin^2(\theta_{m\gamma}/2) < 0.0035$ GeV^2 and $\chi^2_{\gamma\pi^+\pi^-} < \chi^2_{\gamma K^+K^-}$. Where E_{miss} and $\mathbf{P}_{miss}$ are the missing energy and missing momentum of all charged particles respectively, $\theta_{m\gamma}$ is the angle between the missing momentum and the photon direction.

The K^+K^- invariant mass spectrum is shown in Fig. 1, wherein the resonance structure in 1.5 and 1.7 GeV region is clearly seen. For the process $J/\psi \longrightarrow VX(X \longrightarrow P\bar{P})$, The moment is defined as

$$T_r = \int W(\theta_V, \Omega) R_e[D^j_{0,-m}(0, \theta_V, 0) {D^l_{m,0}}^*(\Omega)] d\cos\theta_V d\Omega, \qquad (1)$$

where $W(\theta_V, \Omega)$ is the angular distribution, r denotes (j, l, m), and P represents a pseudoscalar particle. Previous work by BES at BEPC [12] indicates that there exists a spin 0 and a spin 2 component in the mass region of $f_J(1710)$. The higher spin components are

Table 1: The masses, widths, and branching ratios of $X_{0^{++}}$ and $X_{2^{++}}$.

Spin	Mass(MeV)	Width(MeV)	$Br(J/\psi \to \gamma X)(X \to K^+K^-)(10^{-4})$
0^{++}	$1781 \pm 8^{+10}_{-31}$	$85 \pm 24^{+22}_{-19}$	$0.8 \pm 0.1^{+0.3}_{-0.1}$
2^{++}	$1696 \pm 5^{+9}_{-34}$	$103 \pm 18^{+30}_{-11}$	$2.5 \pm 0.4^{+0.9}_{-0.4}$
$f_2'(1525)$	$1516 \pm 5^{+9}_{-15}$	$60 \pm 23^{+13}_{-20}$	$1.6 \pm 0.2^{+0.6}_{-0.2}$

excluded as the results from PQCD[13] show that the contributions from the high spin (> 2) components are very small. In our present work, the helicity amplitudes of 0^{++} and 2^{++} components are included in 10 independent theoretical moments [14] for this process. The invaraint mass spectrum K^+K^-(from $1.44 - 1.86$ GeV/c^2) is divided into 14 bins with the bin width of 30MeV. The helicity parameters are obtained for each bin by using the optimum method. The contributions to the γK^+K^- mass spectrum from 0^{++} and 2^{++} components are shown in Fig. 2 and Fig. 3 respectively, which are renormalized to the observed mass spectrum. The $f_2'(1525)$ is well reproduced in Fig. 3, and a second 2^{++} resonance $X_{2^{++}}$ appears in the lower part of the $f_J(1710)$ mass region. Fig. 2 shows the presence of a 0^{++} resonance $X_{0^{++}}$ in the higher part of $f_J(1710)$ mass region. The masses, widths and branching ratios of 0^{++} and 2^{++} are given in table 1, in which the errors come from the Breit-Wigner fit and the uncertainties of the background shape and the bin widths respectively. The hadronic decay $J/\psi \to \omega K^+K^-$ is also useful to study the identification of the $f_J(1710)$ because the $f_2'(1525)$ in this channel is bellow the threshold. It is expected that this can be carried out with the upgraded BES and more J/ψ events in the near future.

In summary, a scalar and a tensor are separated from the broad resonance around 1.7 GeV. The scalar $X_{0^{++}}(1780)$ in the $f_J(1710)$ mass region is clearly established in our analysis. Further investigation on the other channels, such as $J/\psi \to \gamma 4\pi$ and the $J/\psi \to \gamma\pi\pi$ will be helpful to understand the nature of the scalar and tensor.

2 Preliminary Study of $\xi(2230)$ to $\pi^0\pi^0$, $\eta\eta$, $\eta\eta'$ and $\eta'\eta'$

$\xi(2230)$ has been found by BES collaboration at BEPC in $J/\psi \to \gamma p\bar{p}$ and $J/\psi \to \gamma\pi^+\pi^-$ after comfirmed in $J/\psi \to \gamma K^+K^-$ and $J/\psi \to \gamma K_sK_s$. The measured masses, widths and branching ratios were given[15].

However, the knowledge about $\xi(2230)$ is still limited by the experimental results. Therefore, the study of other decay modes, such as $J/\psi \to \gamma\pi^0\pi^0$, $\gamma\eta\eta'$, $\gamma\eta\eta$ $\gamma\eta'\eta'$ etc, is very important in understanding the nature of $\xi(2230)$.

BES Collaboration has recently studied $\xi(2230)$ in J/ψ radiative decays to $\pi^0\pi^0$, $\eta\eta$, $\eta\eta'$ and $\eta'\eta'$. Here, some preliminary results are obtained. Fig. 4 shows the invariant mass spectra of $\pi^0\pi^0$, $\eta\eta$, $\eta\eta'$ and $\eta'\eta'$ and table 2 shows the fitted results.

Table 2: The masses, widths, and statistical significance of $\xi(2230)$.

Decay Mode	Mass(MeV)	Width(MeV)	Statistical Significance
$\pi^0\pi^0$	2244 ± 35	20 (fixed)	3.7σ
$\eta\eta'$	2249 ± 18	20 (fixed)	3.5σ
$\eta\eta$	2243 ± 14	20 (fixed)	3.2σ
$\eta'\eta'$	2225 ± 13	20 (fixed)	3.1σ

Acknowledgment

This work was supported partly by the National Science Foundation of China under Contract No. 19290401. We would like to thank the staff of the BEPC accelerator and the IHEP Computing Center. We are grateful to L.S. Kisslinger and Z.P. Li of Carnegie Mellon University, K.T. Chao of Peking University for many useful discussions.

References

[1] C. Edwards et al., Phys. Rev. Lett. 48 (1982) 458.

[2] J.E. Augustin et al., Phys. Rev. Lett. 60 (1988) 2238.

[3] R.M. Baltrusaitis et al., Phys. Rev. D 35 (1987) 2077; T. Bolton, Ph.D thesis, MIT (1988); L.P. Chen, Ph.D thesis, SLAC-Repot-386 (1991); D. V. Bugg, *et al.* Phys. Lett. B 353 (1995) 378.

[4] T.A. Armstrong et al., Phys. Lett. B 167 (1986) 133; Phys. Lett. B 227 (1989) 186.

[5] A. Etkin et al., Phys. Rev. D 25 (1982) 1786.

[6] B. Bolonkin et al., Nucl. Phys. B 309 (1988) 426.

[7] H. Aihara et al., Phys. Rev. Lett. 57 (1986) 404.

[8] D. Aston et al., Nucl. Phys. B 301 (1988) 525;

[9] F. Close, G. Farrar, and Zhenping Li, to be published.

[10] G. Bali et al., Phys. Lett. B 309 (1993) 378.

[11] D. Weingarten, Nucl. Phys. B (Proc. Suppl.) 34 (1994) 29; J. Sexton *et al.*, Phys. Rev. Lett. 75 (1995) 4563.

[12] Z.P. Zheng, The Report from the BES at BEPC. AIP Conference Proceedings 302, Lepton and photon Interactions, XVI international Sysmposim, Itheca, NY1993, p530; Z.D. Cheng, MS thesis, IHEP Beijing (1992).

[13] A. Billoire *et al.*, Phys. Lett. B 80 (1979) 381.

[14] H. Yu, Q.X. Shen, Y.C. Zhu, Z.P. Zheng and Z.D. Cheng, High Energy Phys. and Nucl. Phys. 17 (1993) 143.

[15] BES collaboration, Phys. Rev. Lett. 76 (1996) 3502.

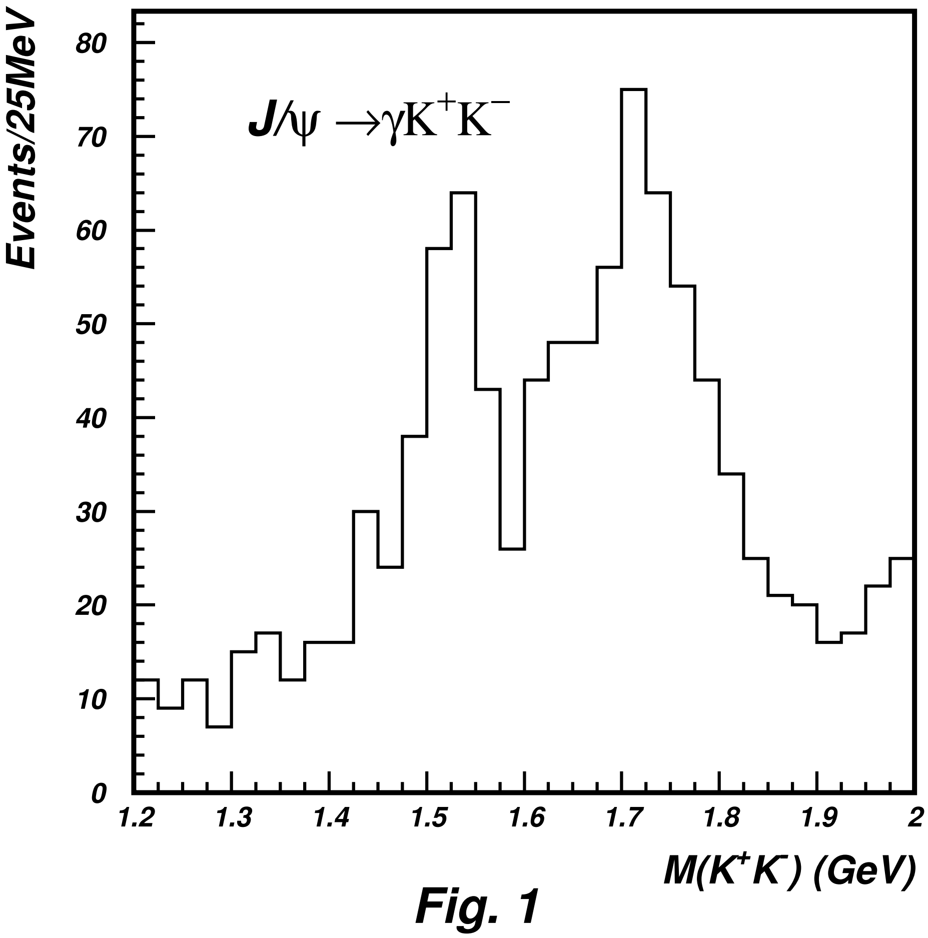

Events/25MeV
80
70
60
50
40
30
20
10
0
$J/\psi \to \gamma K^+K^-$
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
$M(K^+K^-)$ (GeV)

Fig. 1

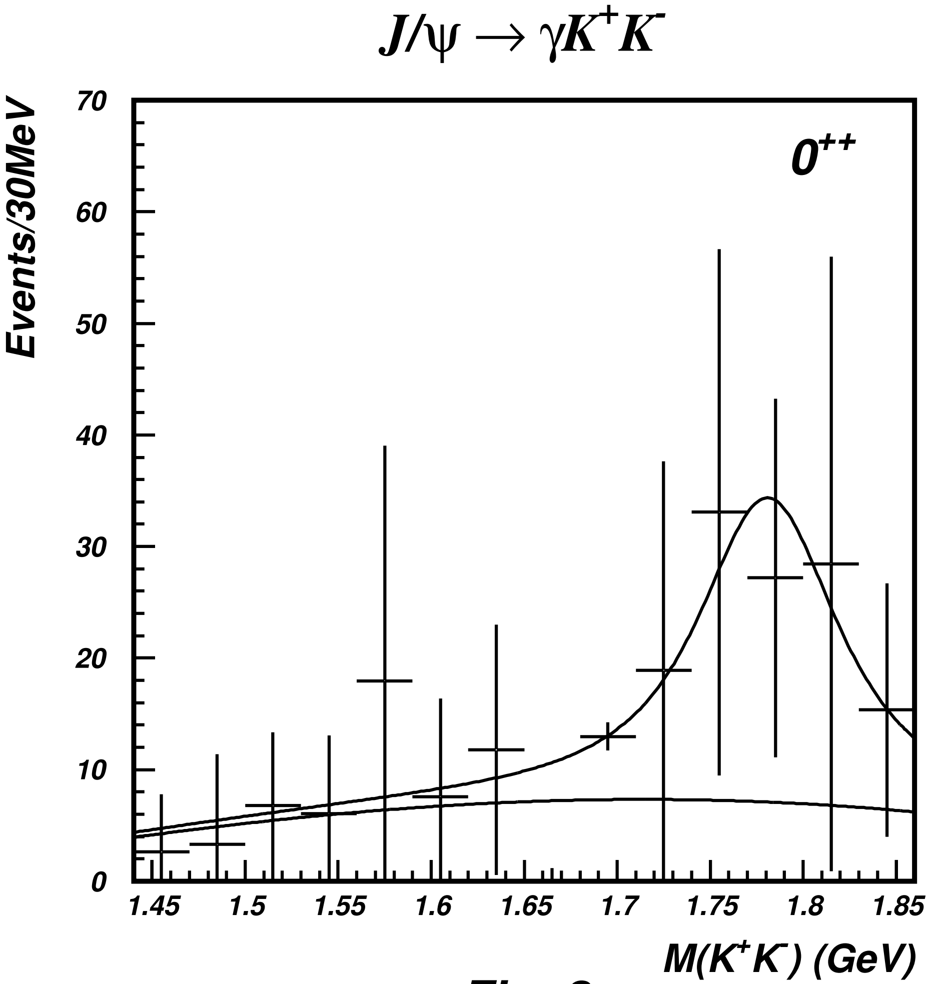

J/ψ → γK+K-
Events/30MeV
0++
M(K+K-) (GeV)
0
10
20
30
40
50
60
70
1.45
1.5
1.55
1.6
1.65
1.7
1.75
1.8
1.85

Fig. 2

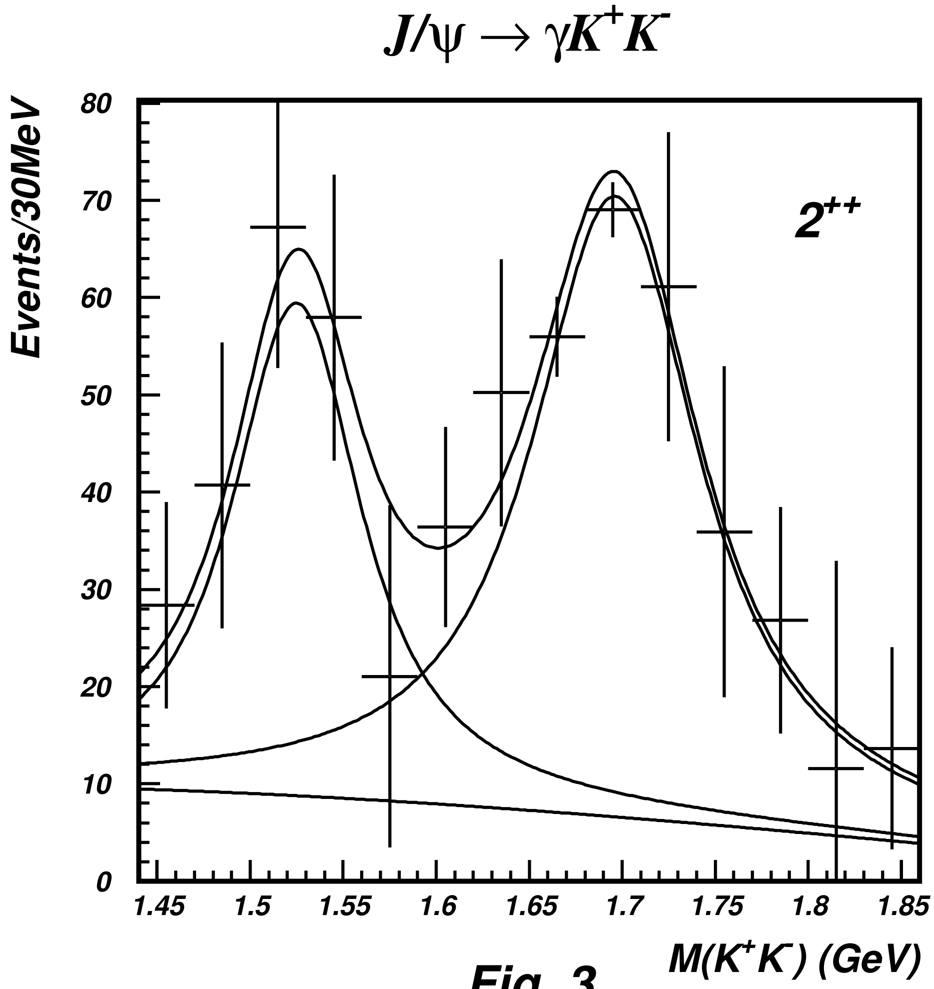
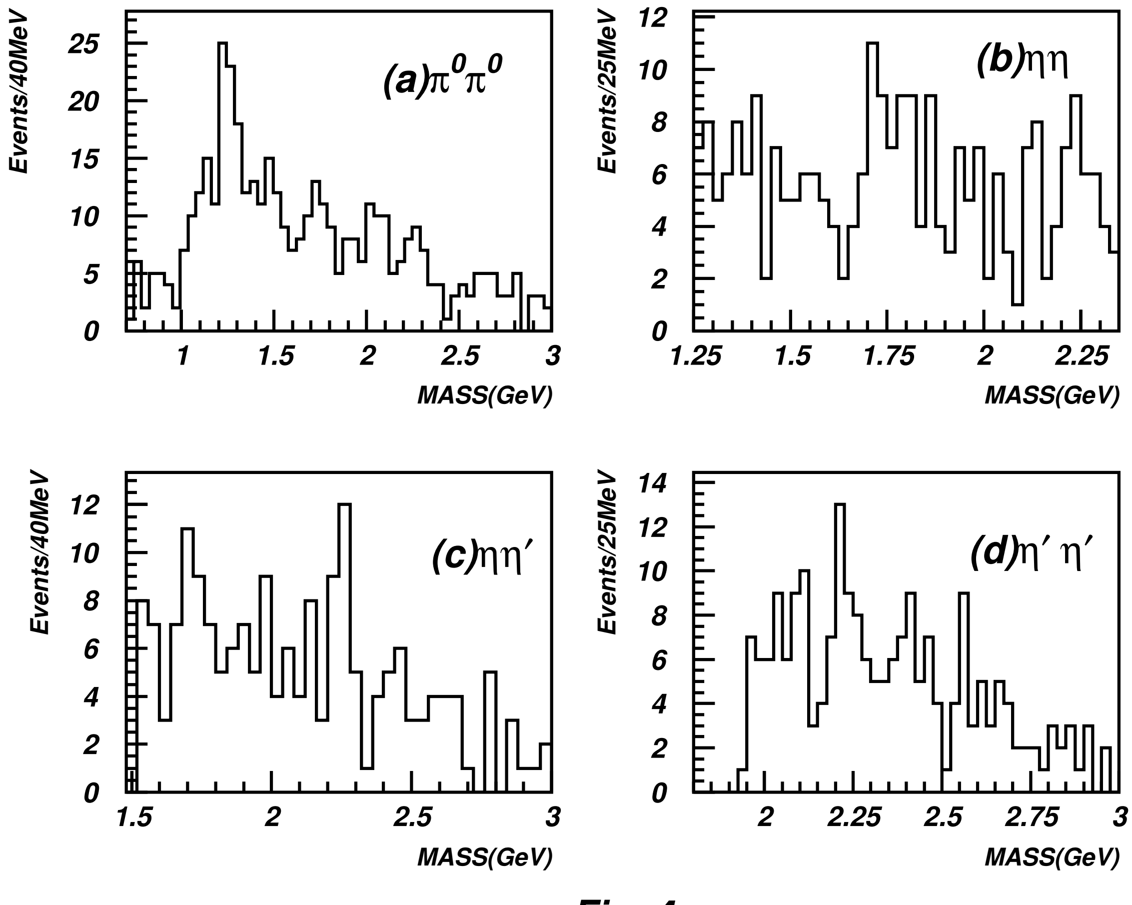


Fig. 3



Events/40MeV
(a)π⁰π⁰
MASS(GeV)
Events/25MeV
(b)ηη
MASS(GeV)
Events/40MeV
(c)ηη′
MASS(GeV)
Events/25MeV
(d)η′ η′
MASS(GeV)

Fig. 4