The analysis of decay channels $J/\psi \to \gamma\gamma V(\rho, \phi)$

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Based on 7.8×10^6 J/ψ events collected by the BES experiment, J/ψ radiative decay channels $J/\psi \to \gamma\gamma V(\rho, \phi)$ have been studied. The $\eta(1430)$ resonance has been observed in these two channels respectively. Its mass and width are 1431 ± 17 MeV and 88 ± 28 MeV from the $J/\psi \to \gamma\gamma\rho$ mode, 1427 ± 13 MeV and 77 ± 46 MeV from the $J/\psi \to \gamma\gamma\phi$ mode. **Key words:** J/ψ,Resonance,Meson,Glueball

1. INTRODUCTION

Up to now, the structure of $\iota(1440)$ is not very clear. The existence of two overlapping pseudo-scalar states has been suggested, one of which around 1410 MeV decays into both $K\overline{K}\pi$ and $\eta\pi\pi$, and another one around 1470 MeV decays only to $K\overline{K}\pi$. It is therefore conceivable that the higher mass state is the $s\bar{s}$ member of the 2^1S_0 nonet[1]. Is the lower mass state a meson, glueball, or hybrid? It should be further investigated in different decay channels.

The radiative decay of $\iota(1440) \to \gamma\rho$ has been analysed in the process $J/\psi \to \gamma\gamma\rho(\rho \to \pi^+\pi^-)$ by Crystal-Ball[2], MarkIII[3] and DM2[4] respectively(see Tab. 1). From their analysis of the $\gamma\rho$ decay angular distribution, $\iota(1440)$ is mainly associated with a spin 0^- interpretation. However, spin 1^+ still cannot be excluded.

Table 1
Experimental results of $X(1440) \to \gamma\rho$

Mass(MeV)	Width(MeV)	$\mathrm{Br}(J/\psi \to \gamma X)Br(X \to \gamma\rho)(\times 10^{-4})$	Exp.
1390 ± 25	185^{+110}_{-80}	$1.9 \pm 0.5 \pm 0.4$	Cry. Ball
1432 ± 8	90 ± 26	$0.64 \pm 0.12 \pm 0.07$	MarkIII
1401 ± 18	174 ± 44	$0.9 \pm 0.2 \pm 0.14$	DM2

A pure $s\bar{s}$ meson can decay radiatively into $\gamma\phi$, but not $\gamma\rho$. A pure $(u\bar{u} + d\bar{d})$ meson can decay radiatively into $\gamma\rho$, but not $\gamma\phi$. A glueball can mix with both $s\bar{s}$ and $(u\bar{u}+d\bar{d})$, and therefore can decay into both $\gamma\phi$ and $\gamma\rho$. Here we report a study of $J/\psi \to \gamma\gamma\rho$ and $J/\psi \to \gamma\gamma\phi$ channels based on 7.8×10^6 J/ψ events collected by the BES experiment.

2. EVENT SELECTION

In this paper we mainly analyse the $J/\psi \to \gamma X(X \to \gamma V)$ channels, where V includes vectors ρ and ϕ. their decay modes are $\rho \to \pi^+\pi^-$ and $\phi \to K^+K^-$.

The BES detector has been fully described elsewhere [5]. For the above processes, two oppositely charged particles should be detected by the MDC (Main Drift Chamber). In order to exclude electronics noise, the energy deposited in BSC by each neutral particle is required to be $E_{sc} > 70MeV$. The photon is also required to be isolated from two charged tracks ($cos(\theta_{\gamma\pi(K)}) < 0.98$); this also rejects any radiative photon from charged particles. Photons are also required to come from the interaction point. Photons passing these cuts are called "good" photons. The photon with maximum energy among all of those "good" photons is selected as the J/ψ radiative photon.

2.1 The event selection of $J/\psi \to \gamma\gamma\rho(\rho \to \pi^+\pi^-)$

We define P_{miss} as the total momentum of all charged particles. A cut of $P_{miss} \leq 1.25GeV/c$ is required. This criterion rejects the background channel $J/\psi \to \rho\pi^0$ effectively.

If the weight of π identified by time of flight (TOF) is greater than that of K, we assume this track to be a π . Finally at least one π track is required per event.

In order to obtain a good $J/\psi \to \gamma\gamma\pi^+\pi^-$ event, we do a kinematic fit (4C-FIT) for all four particle final states which include two photons and two charged particles. If its $\chi^2 \leq 6$, this event will be called "good" event. The ρ signal is selected as $|M_{\pi^+\pi^-} - M_\rho| \leq 0.14GeV/c^2$. After our above cuts, the invariant mass spectrum of $\gamma\rho$ is shown in Fig. 1.

The detection efficiency is determined from a Monte Carlo simulation. After the same selections as real data, we obtain a detection efficiency of 4.8%. The total systematic error in this J/ψ decay mode is 19% .

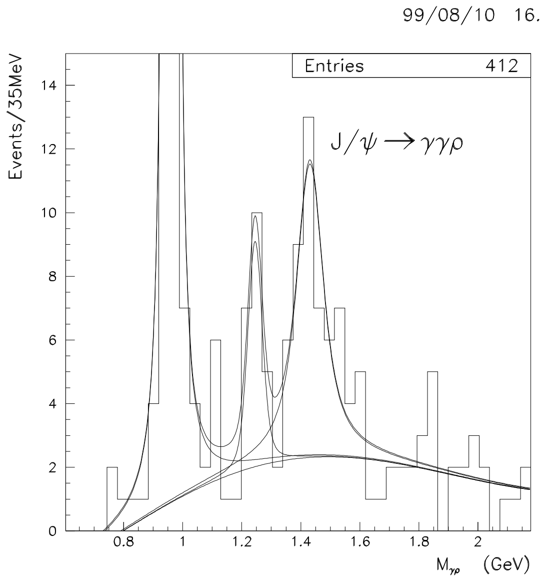

Figure 1. The Invariant Mass Spectrum of $\gamma\rho$. The upper curve is the resonance contribution, and the lower one is the shape of backgrounds.

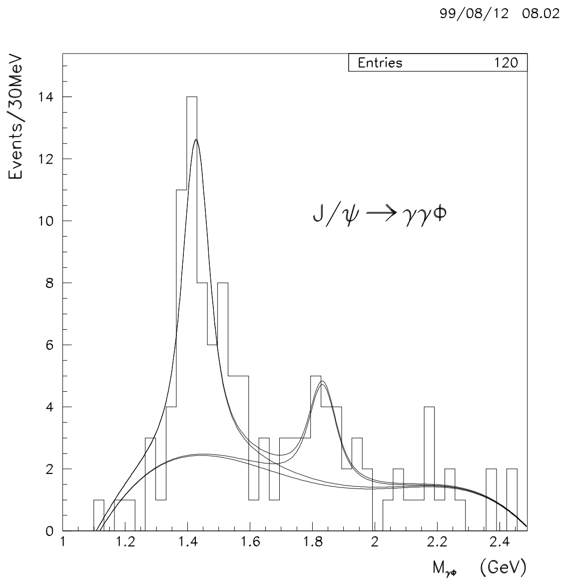

Figure 2. The Invariant Mass Spectrum of $\gamma\phi$. The upper curve is the resonance contribution, and the lower one is the shape of backgrounds.

Table 2
The resonance parameters of $J/\psi \to \gamma X(X \to \gamma\rho)$

Mass (MeV)	Width (MeV)	Br($J/\psi \to \gamma X)Br(X \to \gamma\rho)$ ($\times 10^{-4}$)	Events	Significance
961 ± 1	11 ± 3	$10.8 \pm 0.4 \pm 2.1$	269 ± 10	30.7σ
1245 ± 11	20 ± 16	$0.5 \pm 0.2 \pm 0.1$	13 ± 12	3.0σ
1431 ± 17	88 ± 28	$1.5 \pm 0.6 \pm 0.3$	38 ± 16	4.4σ

2.2 The event selection of $J/\psi \to \gamma\gamma\phi$ ($\phi \to K^+K^-$)

If the weight of K which is identified by TOF is greater than that of π, we assume this track as K. Eventually at least one K track is required. In order to suppress multi-photon backgrounds, P_{miss} should satisfy $P_{miss} \leq 1.25GeV/c$.

In order to get good $J/\psi \to \gamma\gamma K^+K^-$ events, we do a 4C-FIT for four final states, and $\chi^2 \leq 25$ has been required.

Table 3
The resonances parameters of $J/\psi \to \gamma X(X \to \gamma\phi)$

Mass (MeV)	Width (MeV)	Br($J/\psi \to \gamma X)Br(X \to \gamma\phi)$ ($\times 10^{-4}$)	Events	Significance
1427 ± 13	77$\pm$46	$1.7 \pm 0.7 \pm 0.4$	41 ± 16	6.4σ
1833 ± 29	80 ± 78	$0.6 \pm 0.5 \pm 0.1$	14 ± 11	2.8σ

By taking $M_{\gamma\gamma} \geq 0.6GeV/c^2$, the backgrounds $J/\psi \to \phi\eta$ and $J/\psi \to \phi\pi^0$ can be rejected . Requiring $|M_{K^+K^-} - M_\phi| \leq 0.02GeV/c^2$ as the ϕ signal, the final $\gamma\phi$ spectrum shown in Fig. 2 is obtained.

After the Monte Carlo simulation, we obtain a detection efficiency of 6.2%. The total systematic error in this J/ψ decay mode is 22%

3. RESULTS AND DISCUSSIONS

First we discuss results from $J/\psi \to \gamma\gamma\rho$. MarkIII observed three resonances [3] similar to our results. The first state, with a mass of 961 MeV in Tab. 2, can be interpreted as $\eta'(958)$. Our result is compatible with the PDG branching ratio ($Br(J/\psi \to \gamma\eta'(958), \eta'(958) \to \gamma\rho) = (13.0 \pm 1.1) \times 10^{-4}$. This result includes non-resonant $\pi^+\pi^-\gamma$). The state around 1245 MeV in Tab. 2 cannot be analysed in detail, because of low statistics. MarkIII also obtained this resonance in $J/\psi \to \gamma\gamma\rho$. They interpreted it as the signal of $f_1(1285)$, but they could not reject the possibility of $\eta(1295)$ [3]. The state X(1430) will be discussed below.

Consider next results from $J/\psi \to \gamma\gamma\phi$. The signal around 1833 MeV in Tab. 3 cannot be analysed in detail, because of low statistics .

Finally we discuss the X(1430) state observed in both $J/\psi \to \gamma\gamma\rho$ and $J/\psi \to \gamma\gamma\phi$ channels.

The WA102 collaboration [6] recently gave the result:

$$\frac{f_1(1420) \to \rho^0\gamma}{f_1(1420) \to K\overline{K}\pi} < 0.02 \ \ (95\% \ \ c.l.),$$

The PDG gives the world average of the branching ratio:

$$Br(J/\psi \to \gamma f_1(1420), f_1(1420) \to K\overline{K}\pi) = (8.3 \pm 1.5) \times 10^{-4}.$$

Combining these results we obtain:

$$Br(J/\psi \to \gamma f_1(1420), f_1(1420) \to \gamma\rho) < 1.7 \times 10^{-5}(95\% \ \ c.l.).$$

Our result for X(1430) from the $J/\psi \to \gamma\gamma\rho$ channel is ten times this upper limit. The X(1430) from our $J/\psi \to \gamma\gamma\rho$ analysis should therefore be $\eta(1430)$, not $f_1(1420)$.

The WA102 collaboration [6] also gives:

$$\frac{f_1(1420) \to \phi\gamma}{f_1(1420) \to K\overline{K}\pi} = 0.003 \pm 0.001 \pm 0.001.$$

Using the PDG value of the branching ratio mentioned above, we have

$$Br(J/\psi \to \gamma f_1(1420), f_1(1420) \to \gamma\phi) = (0.249 \pm 0.068 \pm 0.099) \times 10^{-5}.$$

This is two orders of magnitude smaller than our result for the X(1430) state. So this signal from $J/\psi \to \gamma\gamma\phi$ cannot be due to $f_1(1420)$. It must be due to $\eta(1430)$ dominantly.

We conclude that the X(1430) state from both $J/\psi \to \gamma\gamma\rho$ and $J/\psi \to \gamma\gamma\phi$ channels must be dominantly $\eta(1430)$. However, further investigation of the nature of this state will be necessary and possible from a BES sample now being taken with higher statistics.

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