The Analysis of Decay Channels
$J/\psi \to \gamma\gamma V(\rho, \phi, \omega)$
—- BES Analysis Memo —-

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Abstract

The radiative decays of the J/ψ is one of the best ways to search for the glueball,if glueballs really exist. By using the 24M J/ψ data from run number 13700 to 16835 collected by BESII, we analyzed the $J/\psi \to \gamma\gamma\rho$ and $J/\psi \to \gamma\gamma\phi$ channels which are consistent with BESI data. We confirmed the signal at 1416MeV in $\gamma\rho$ Invariant Mass Spectrum, and another signal at 1412MeV in the $\gamma\phi$ Invariant Mass Spectrum. Furthermore, we also analysed $J/\psi \to \gamma\gamma\omega$ and find there may exist a signal around 1412MeV. These rusult are very meanful to understand the structure of $\iota/\eta(1440)$.

1 Introduction

1.1 The physical results in the world so far.

Decay Mode	Mass (MeV)	Width (MeV)	$B(J/\psi \to \gamma\eta).B(\eta \to \gamma V)$ ($*10^{-4}$)	Experiment
$\eta(1440) \to \gamma\rho^0$	1390 ± 25	185 ± 110	$1.9 \pm 0.5 \pm 0.4$	Cry.Ball[1]
	1432 ± 8	90 ± 26	$0.64 \pm 0.12 \pm 0.07$	MarkIII[2]
	1401 ± 18	174 ± 44	$0.9 \pm 0.2 \pm 0.14$	DM2[3]
	1431 ± 17	88 ± 28	$1.1 \pm 0.5 \pm 0.3$	BESI[4]
$\eta(1440) \to \gamma\phi$			< 1.6	MarkIII
$\eta(1440) \to \gamma\phi$	1424 ± 15	73 ± 58	$2.0 \pm 1.0 \pm 0.6$	BESI
$\eta(1440) \to \gamma\omega$			< 2.3	MarkIII

1.2

The $\iota/\eta(1440)$ is the candidate for the 0^{-+} glueball. Up to now, the structure of $\iota/\eta(1440)$ is not very clear. The existence of two overlapping pseudo-scalar mesons has been suggested, one at 1410 MeV which decays into $K\overline{K}$ and $\eta\pi\pi$, and the other at 1470 MeV which decays only to $K\overline{K}$. It is conceivable that the higher mass state is $s\overline{s}$ member of the 2^1S_0[5]. Is the lower mass state a meson, glueball, or hybrid? It should be further investigated in different decay channels.

It[6] points out that the glueball can be distinguished from $q\overline{q}$ and hybrid by analysis of $J/\psi \to \gamma\gamma\rho$ and $J/\psi \to \gamma\gamma\phi$. For a glueball, it should have the same mass value regardless of where it comes from ($\gamma\rho$ or $\gamma\phi$), but for the $q\overline{q}$ and $q\overline{q}g$ states, it has been predicted that the mass peak position from $\gamma\phi$ should higher than that from $\gamma\rho$ about 300 MeV.

Furthormore, although the analysis of $J/\psi \to \gamma\gamma\omega$ has ever been done by MarkIII, they only gave the upper limit. The theory[7] predicts if $\iota/\eta(1440)$ is a $q\overline{q}$ state which decays in a flavour independent way, the width relationship between $\gamma\rho$, $\gamma\phi$, and $\gamma\omega$ is $\Gamma_{\gamma\rho}$:$\Gamma_{\gamma\phi}$: $\Gamma_{\gamma\omega}$=9:2:1; But if it is a glueball the ratios should be 1:1:1. Therefore the analysis is a very meanful supplement of $J/\psi \to \gamma\gamma V$.

2 $J/\psi \to \gamma\gamma\rho$ event selection.

- $N_{chrg} = 2$, $\sum Q_{totch} = 0$, $N_{neu} \leq 10$.

  $\sqrt{x^2 + y^2} < 0.015, |z| < 0.15$

- For charged tracks: MFIT=2 or -19 for every event

  $P_{miss} < 1.25GeV$

  Use 4c-fit to four tracks (regarded 2 as π and 2 as γ) . We need

  $\chi^2 \leq 6$

  $\chi^2 < \chi^2_{\gamma\gamma k^+ k^-}$

  $\chi^2 < \chi^2_{\gamma\pi^+\pi^-}$

  $\chi^2 < \chi^2_{\gamma\gamma\gamma\pi^+\pi^-}$

  Particle identification by the weight information in TOF, we need at least one π track in one event

  TOFW(π)>TOFW(K), TOFW(π)>TOFW(p)

  $|M_{\pi^+\pi^-} - M_\rho| \leq 0.14GeV$

- For neutral tracks, we need at least two neutral tracks is good photon.

  $N_\gamma \geq 2$

  The select conditions for good photons are as below:

  The energy deposit in SC of photon $E_\gamma \geq 50MeV$

  The angular relation between the direction of γ cluster after reconstruction and the direction of line from the collsion point to the first fired point in SC

  $\Delta \leq 0.4$

- In order to reject the effect of the radiative photon from charged particle, we required:

  $cos\theta_{\gamma q} \leq 0.98$

  The number of hitted layers by photons in SC should be greater than two, and the first fired layer should be less than five

The acceptance is determined from Monte Carlo simulation. The results are about 13.3% for $J/\psi \to \gamma\gamma\rho$ case.

3 $J/\psi \to \gamma\gamma\phi$ event selection.

The only difference from the above channel is that for charged tracks:

- Use 4c-fit to fit the four tracks (regarded 2 as π and 2 as γ). We need

  $\chi^2 \leq 25$

  $\chi^2 < \chi^2_{\gamma\gamma\pi^+\pi^-}$

  $\chi^2 < \chi^2_{\gamma\gamma\gamma k^+k^-}$

  $\chi^2 < \chi^2_{\gamma k^+k^-}$

- Particle identification by the weight information in TOF, we need two K track in one event

- $M_{\gamma\gamma} \geq 0.6$ so that background $J/\psi \to \phi\eta$ and $J/\psi \to \phi\pi^0$ can be rejected

- $|M_{K^+K^-} - M_\phi| \leq 0.02$

The acceptance is determined from Monte Carlo simulation. The results are about 13.4% for $J/\psi \to \gamma\gamma\phi$ case.

4 Backgroud Analysis

Background Channel	Generating Number	$J/\psi \to \gamma\gamma\rho$	$J/\psi \to \gamma\gamma\phi$
$J/\psi \to \rho^0\pi^0$	$20 * 10^4$	0	0
$J/\psi \to \pi^+\pi^-\pi^0$	$45 * 10^4$	0	0
$J/\psi \to \gamma\eta'$	$3 * 10^4$	0	0
$J/\psi \to \rho\eta$	$1 * 10^4$	0	0
$J/\psi \to \rho\eta'$	$1 * 10^4$	0	0
$J/\psi \to \phi\eta$	$1 * 10^4$	0	0
$J/\psi \to \phi\eta'$	$1 * 10^4$	0	0
$J/\psi \to \omega\pi^0$	$3 * 10^4$	0	0
$J/\psi \to \omega\pi^0\pi^0$	$8 * 10^4$	0	0
$J/\psi \to \omega\eta$	$3 * 10^4$	0	0
$J/\psi \to \omega\eta'$	$3 * 10^4$	0	0
$J/\psi \to \gamma\eta\pi^+\pi^-$	$1 * 10^4$	0	0

5 Check $J/\psi \to \gamma\gamma(\rho, \phi)$ with BESII data

BESII BW Fit results compared with BESI data

Decay Mode	Mass (MeV)	Width (MeV)	Experiment
$\eta(1440) \to \gamma\rho^0$	1431 ± 17	88 ± 28	BESI
	1416 ± 4	101 ± 78	Ours
$\eta(1440) \to \gamma\phi$	1424 ± 15	73 ± 58	BESI
	1412 ± 5	104 ± 16	Ours

5 CHECK $J/\psi \to \gamma\gamma(\rho, \phi)$ WITH BESII DATA

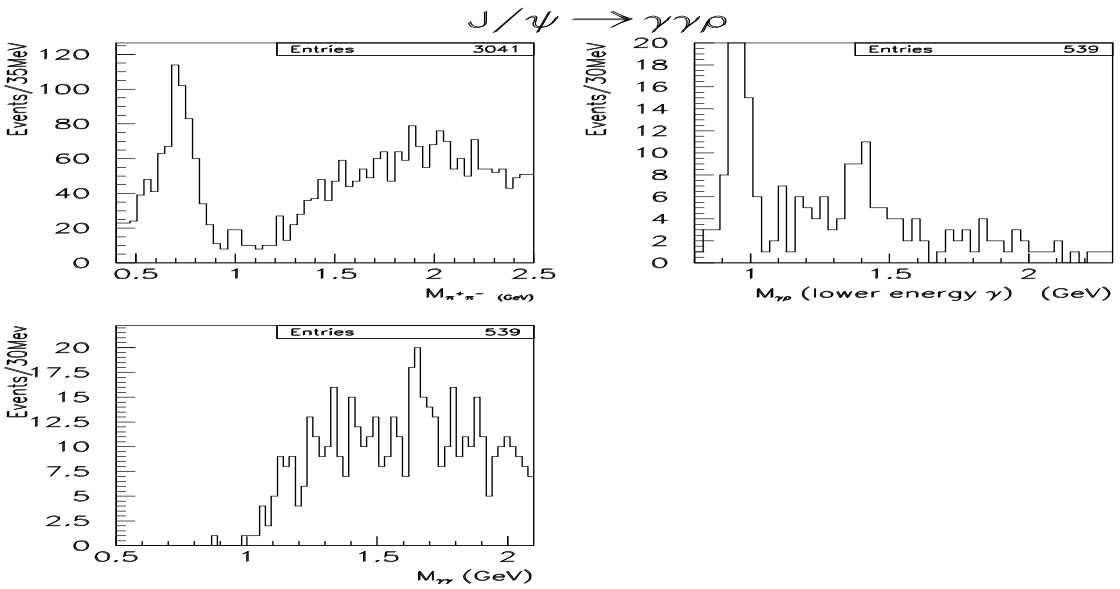

Figure 1: The Invariant Mass Spectrum with BESI data

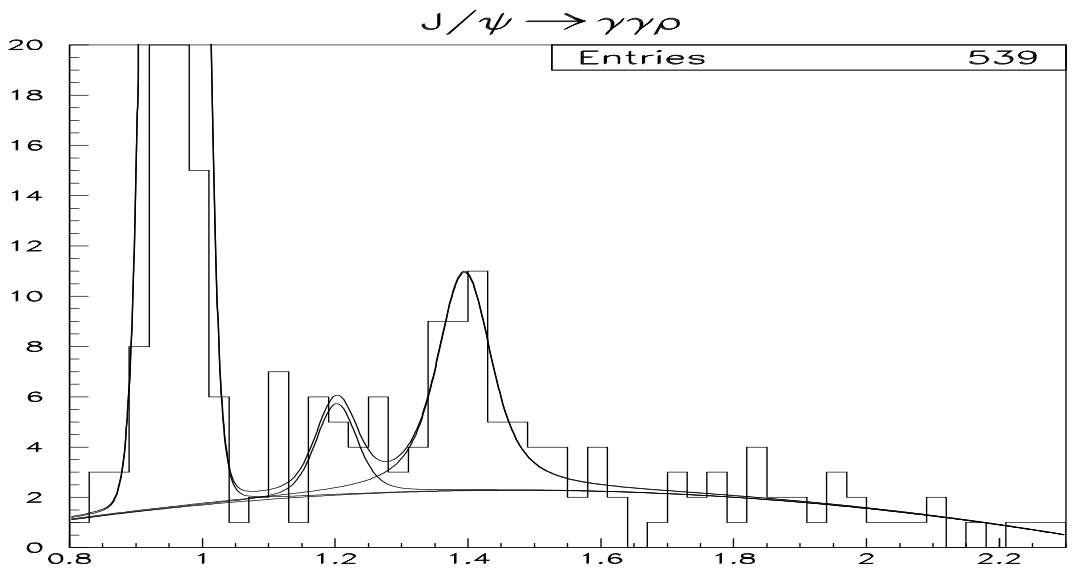

Figure 2: The BW Fit of $\gamma\rho$ Invariant Mass Spectrum with BESI data

5 CHECK $J/\psi \to \gamma\gamma(\rho, \phi)$ WITH BESII DATA

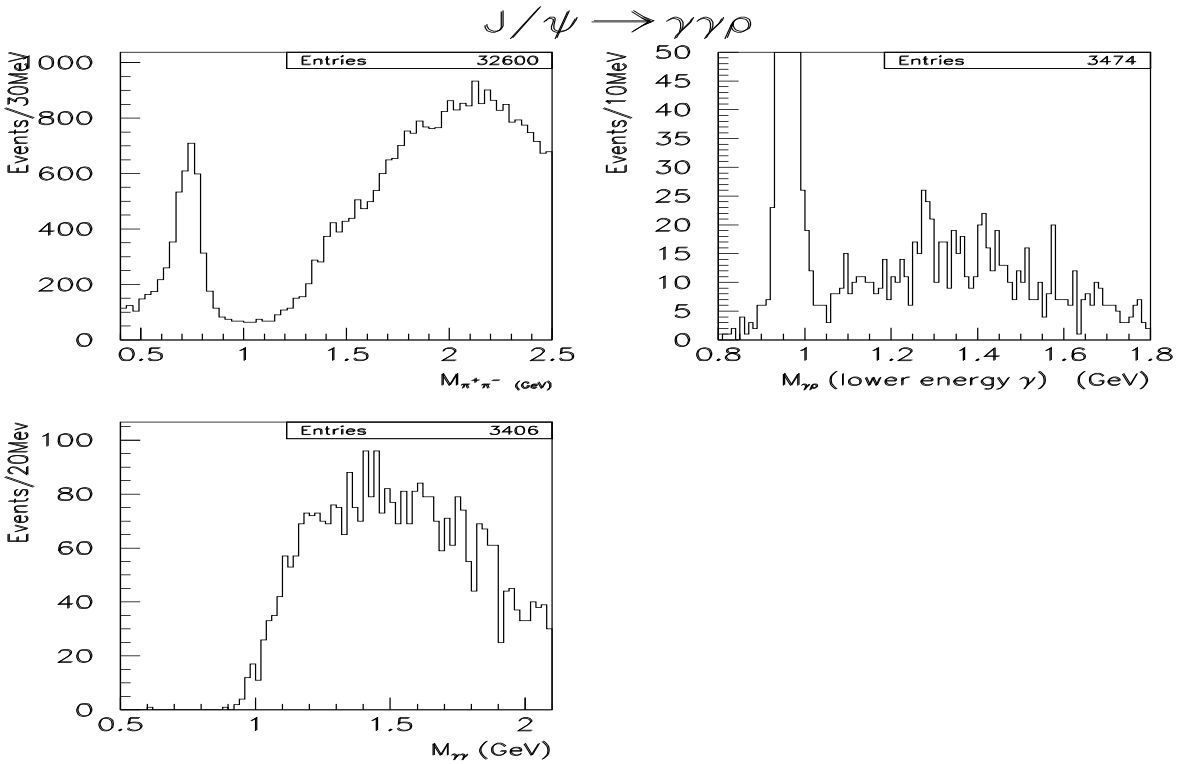

Figure 3: The Invariant Mass Spectrum with BESII data

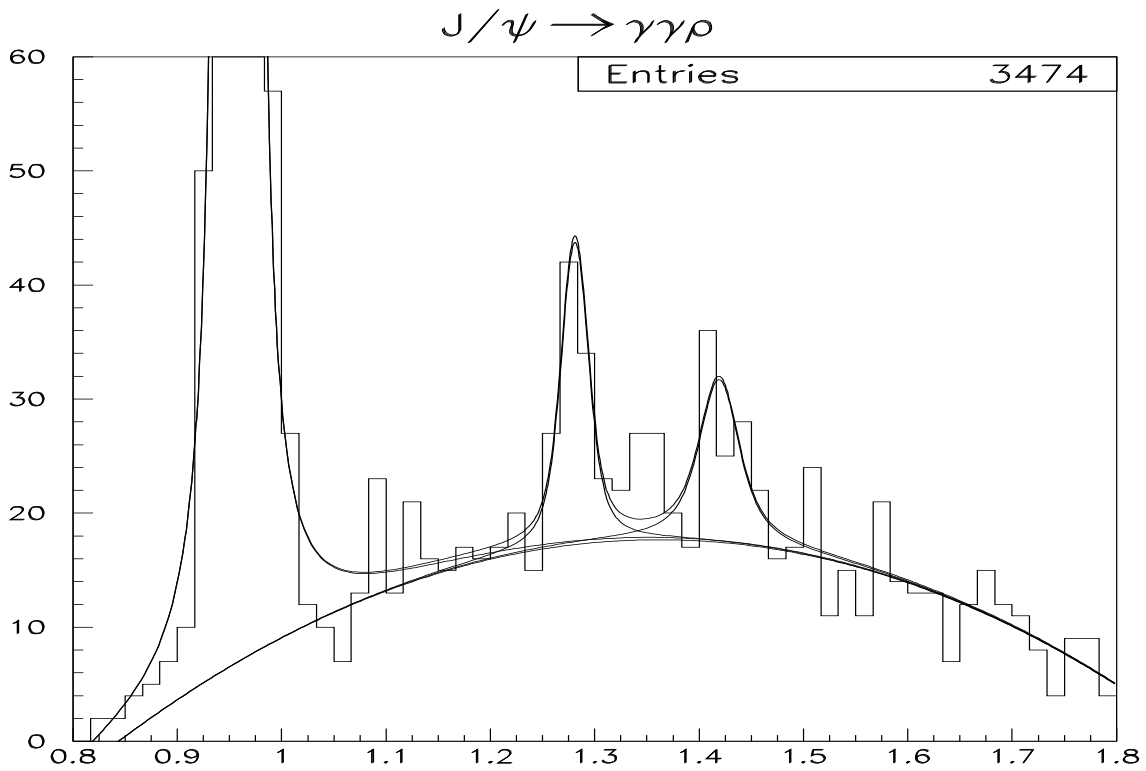

Figure 4: The BW Fit of $\gamma\rho$ Invariant Mass Spectrum with BESII data

5 CHECK $J/\psi \to \gamma\gamma(\rho, \phi)$ WITH BESII DATA

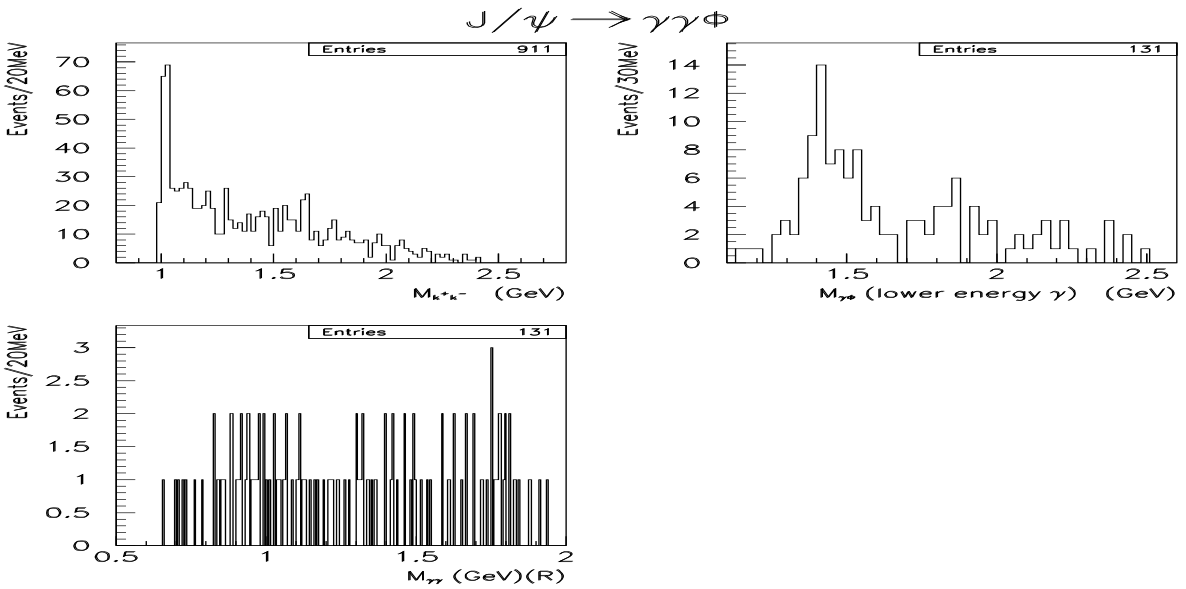

Figure 5: The Invariant Mass Spectrum with BESI data

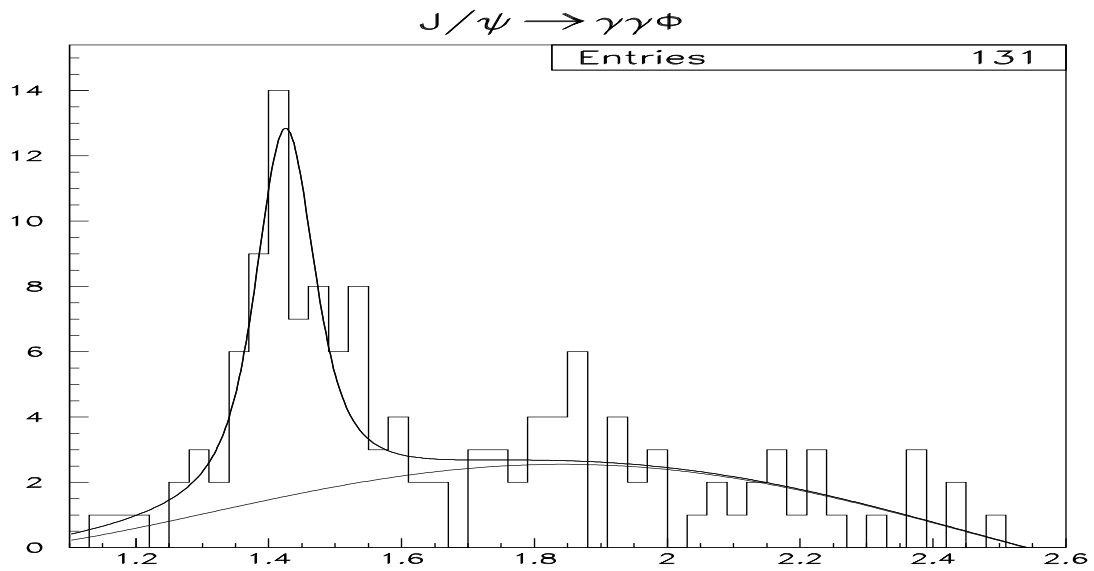

Figure 6: The BW Fit of $\gamma\phi$ Invariant Mass Spectrum with BESI data

5 CHECK $J/\psi \to \gamma\gamma(\rho, \phi)$ WITH BESII DATA

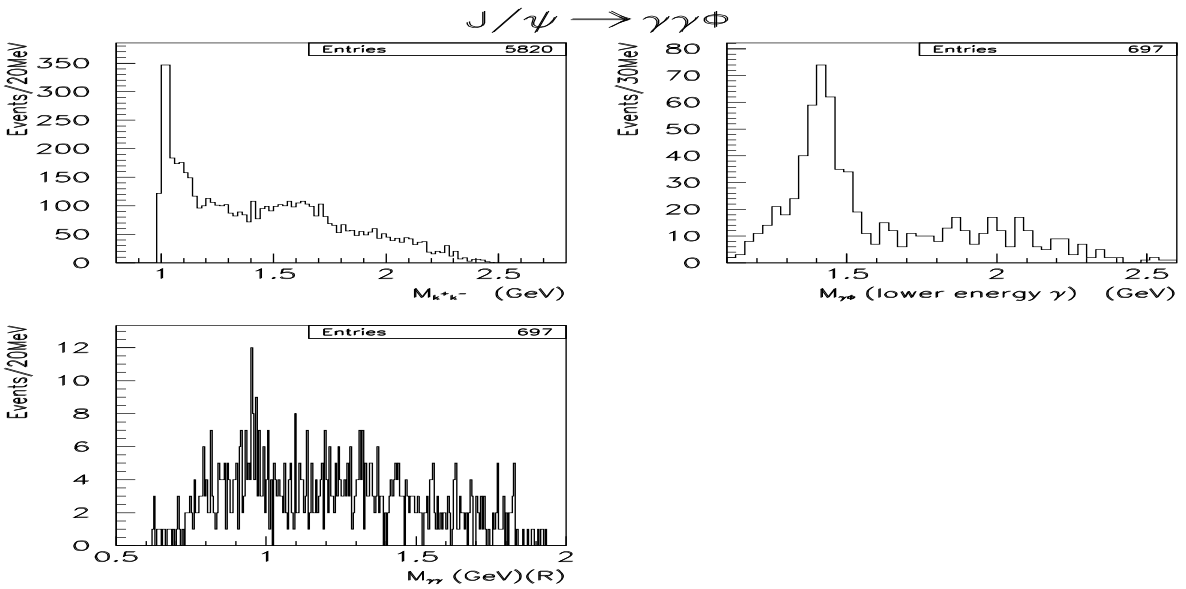

Figure 7: The Invariant Mass Spectrum with BESII data

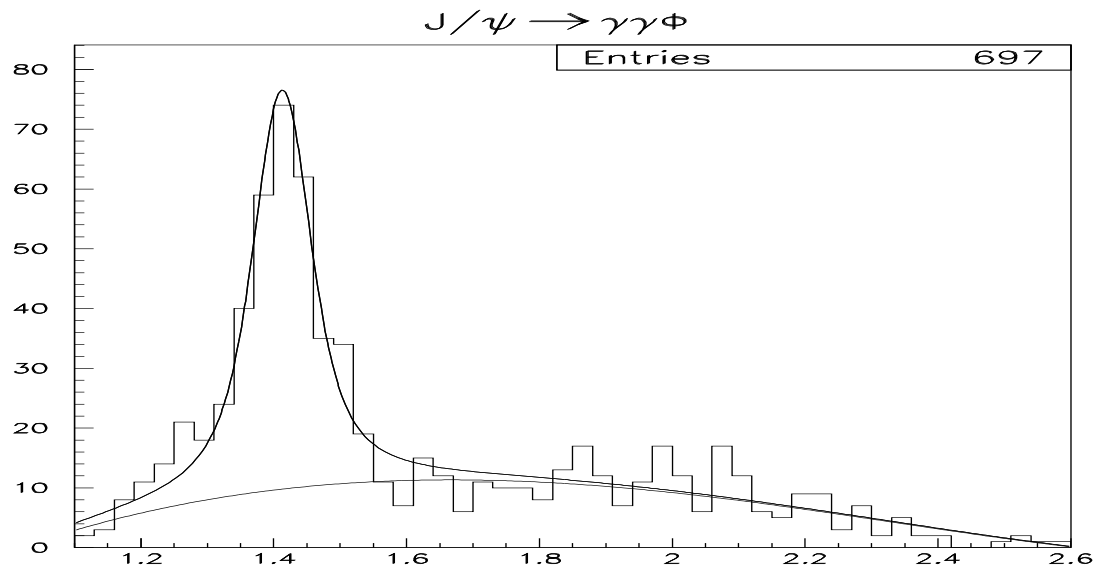

Figure 8: The BW Fit of $\gamma\phi$ nvariant Mass Spectrum with BESII data

6 $J/\psi \to \gamma_1\gamma_2\omega$ Event Selection

6.1

$N_{chrg} = 2$, $\sum Q_{totch} = 0$, $N_{neu} \leq 10$.

6.2 For Charged Tracks:

- $\sqrt{x^2 + y^2} \leq 0.015m$, $|z| \leq 0.15m$
- MFIT=2 or -19 for every event
- $|cos\theta| \leq 0.8$,
- $P_{xy} \geq 0.06$GeV
- $P_{miss} \leq 1.0GeV$
- Particle identification by the weight information in TOF, we need two π track in one event

  $W_\pi > W_k$ and $W_\pi > W_p$
- Use 4c-fit to fit the six tracks (regarded 2 as π and 4 as γ). We need

  $\chi^2 \leq 20$

  $\chi^2 < \chi^2_{\gamma\gamma\gamma\gamma k^+ k^-}$

6.3 For neutral tracks, we need at least four neutral tracks are good photons

$N_\gamma \geq 4$

(1) The selective conditions for good photons are as below:

a. $E_{sc} \geq 50MeV$

b. The angular relation between the direction of γ cluster after reconstruction and the direction of line from the collision point to the first fired point in SC

$\Delta \leq 0.4$

c. $cos\theta_{\gamma q} \leq 0.98$

d. The number of hitted layers by photons in SC should be greater than two

(2) To search for two of four photons which are decayed from π^0, We define:
$(\Delta M)_{min} = \sqrt{[(M_{\gamma\gamma} - \pi^0)/\sigma_{M_{\pi^0}}]^2 + [(M_{\pi^+\pi^-\pi^0} - \omega)/\sigma_{M_\omega}]^2}$

6.4 The Invariant Mass Restriction

$|M_{\pi^+\pi^-\pi^0} - M_\omega| \leq 0.039$

$|M_{\gamma\gamma} - M_{\pi^0}| \leq 0.018$

In order to reject the backgroud $J/\psi \to \omega\eta$ and $J/\psi \to \omega\pi^0$, we need:

$|M_{\gamma_1\gamma_2} - M_{\pi^0}| \geq 0.016$,

$|M_{\gamma_1\gamma_2} - M_\eta| \geq 0.031$

The acceptance is determined from Monte Carlo simulation. The results are about 2.1% for $J/\psi \to \gamma_1\gamma_2\omega$ channel

7 Discussion

- The BESII results of $J/\psi \to \gamma\gamma\rho$ and $J/\psi \to \gamma\gamma\phi$ are consistent with BESI's.
- In the analysis of radiative decay $J/\psi \to \gamma\gamma\omega$, the η' signal has been seen in $\gamma\omega$ Invariant Mass Spectrum, which comes from $J/\psi \to \gamma\eta'(\eta' \to \gamma\omega)$, therefore our study is reliable. In the meanwhile, We find that there may exist a signal near 1412MeV in $\gamma\omega$ Invariant Mass Spectrum. With the increasing BESII data, We will continue this study and check existence of the "signal" with high statistics.
- We clearly see the π^0 and η signals in $M_{\gamma_1\gamma_2}$. They come from $J/\psi \to \omega\pi^0$ and $J/\psi \to \omega\eta$. We can do further study in $J/\psi \to VP$ decay channels, which are

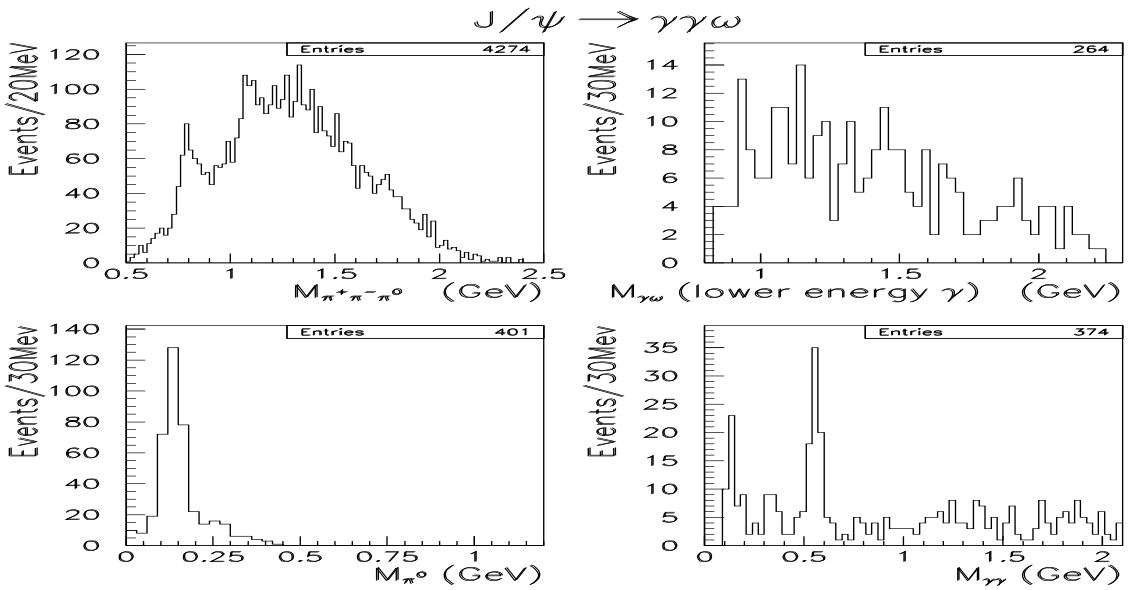

Figure 9: The Invariant Mass Spectrum with BESI data

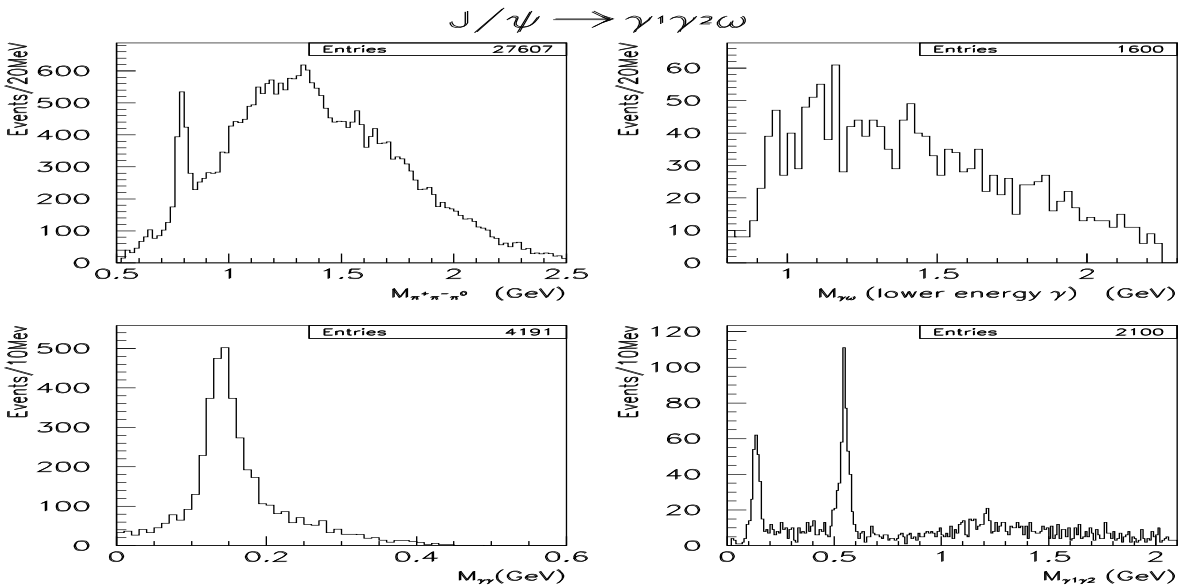

Figure 10: The Invariant Mass Spectrum with BESII data

very meaningful to study "$\rho\pi$ puzzle"

8 Reference

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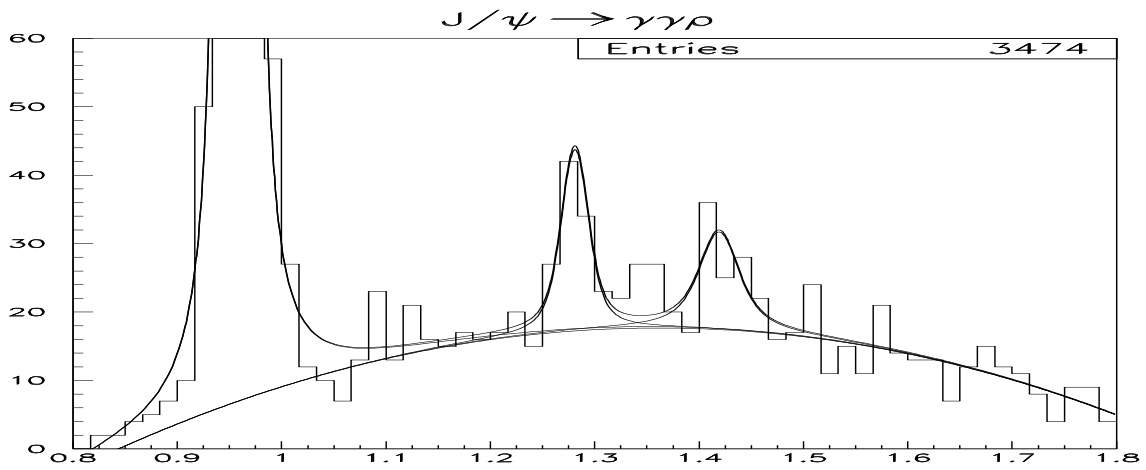

Figure 11: The BW Fit of $\gamma\rho$ Invariant Mass Spectrum with BESII data

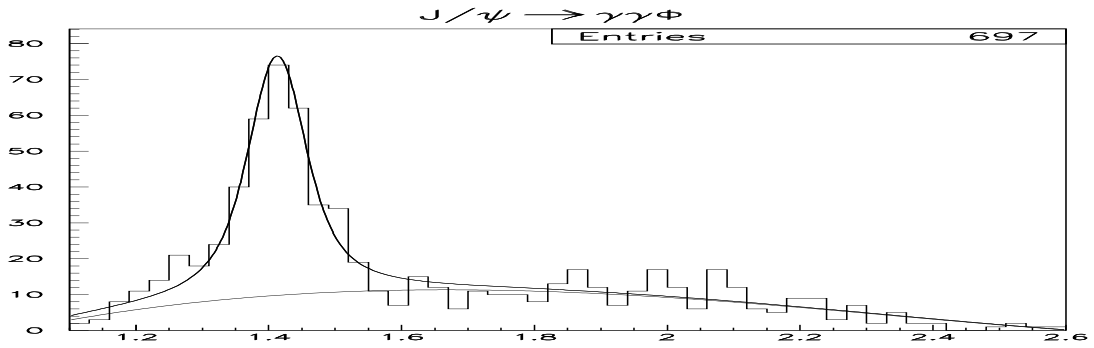

Figure 12: The BW Fit of $\gamma\phi$ Invariant Mass Spectrum with BESII data

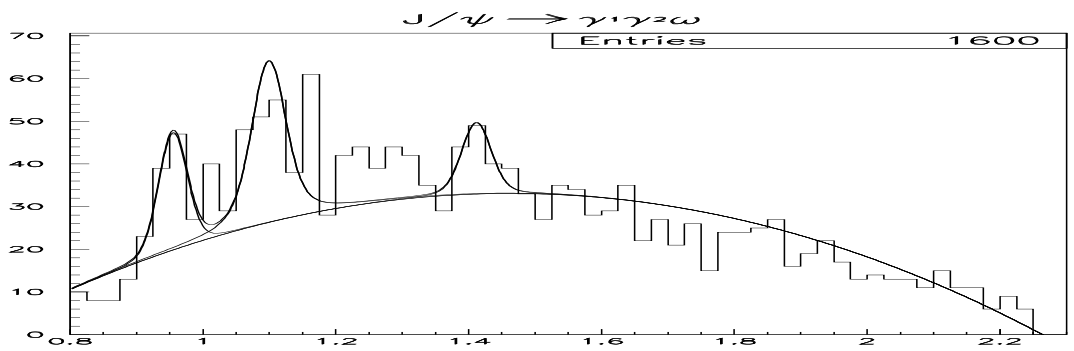

Figure 13: The BW Fit of $\gamma\omega$ Invariant Mass Spectrum with BESII data