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

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Content

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
$\eta(1440) \to \gamma\rho$	1390 ± 25	185 ± 110	$1.9 \pm 0.5 \pm 0.4$	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
	1431 ± 17	88 ± 28	$1.1 \pm 0.5 \pm 0.3$	BESI
$\eta(1440) \to \gamma\phi$			< 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 $\iota/\eta(1440)$ is the candidate for the 0^{-+} glueball

–Up to now, the structure of $\iota/\eta(1440)$ is suggested as the existence of two overlapping pseudo-scalar mesons, 1410 MeV and 1470 MeV

–It is conceivable that the higher mass state is $s\bar{s}$ member of the 2^1S_0. Is the lower mass state a meson, glueball, or hybrid?

1.3 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, in the($\gamma\rho$ or $\gamma\phi$) Invariant Mass Spectrum, it should have the same BW Fit mass value.

–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.

1.4 The motivation of $J/\psi \to \gamma\gamma\omega$ analysis

–It is a very meaningful suppplement of $J/\psi \to \gamma\gamma V$

–Although the analysis of $J/\psi \to \gamma\gamma\omega$ has ever been done by MarkIII, they only gave the upper limit.

–The theory 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

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

  $\chi^2 \leq 6$

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

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

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

  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 are good photons.

  $N_\gamma \geq 2$

  The select conditions for good photon are shown as below:

  The energy deposit in SC of photon $E_\gamma \geq 0.05GeV$

  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 numbers of hitted layers by photon in SC should be greater than two

The acceptance is determined from Monte Carlo Simulation. The result is 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

  $\chi^2 \leq 25$

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

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

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

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

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

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

The acceptance is determined from Monte Carlo Simulation. The result is 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	33 ± 17	Ours
$\eta(1440) \to \gamma\phi$	1424 ± 15	73 ± 58	BESI
	1412 ± 5	104 ± 16	Ours

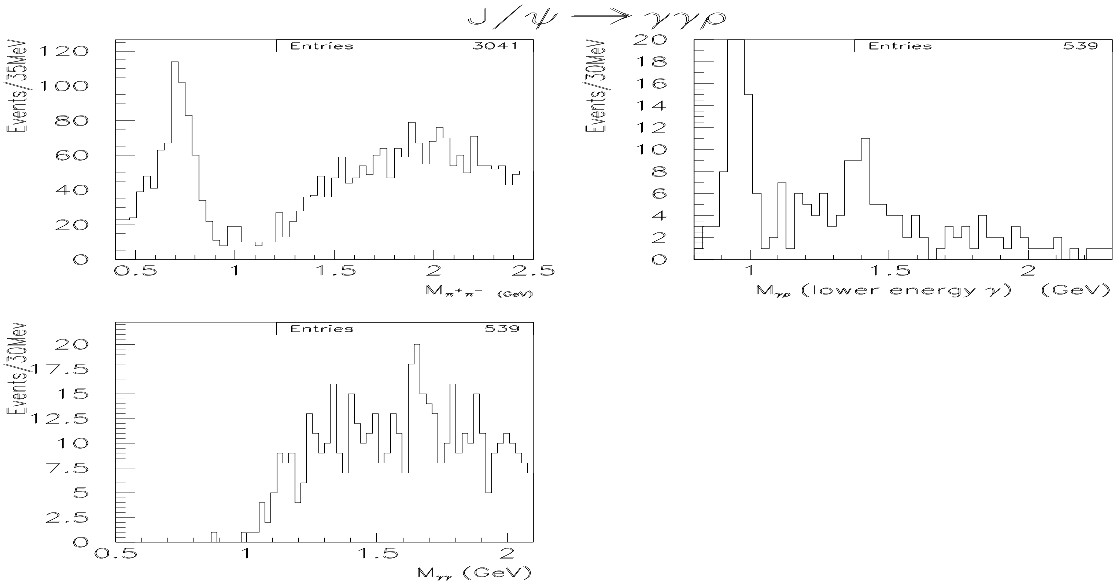

Figure 1: The Invariant Mass Spectrum with BESI data

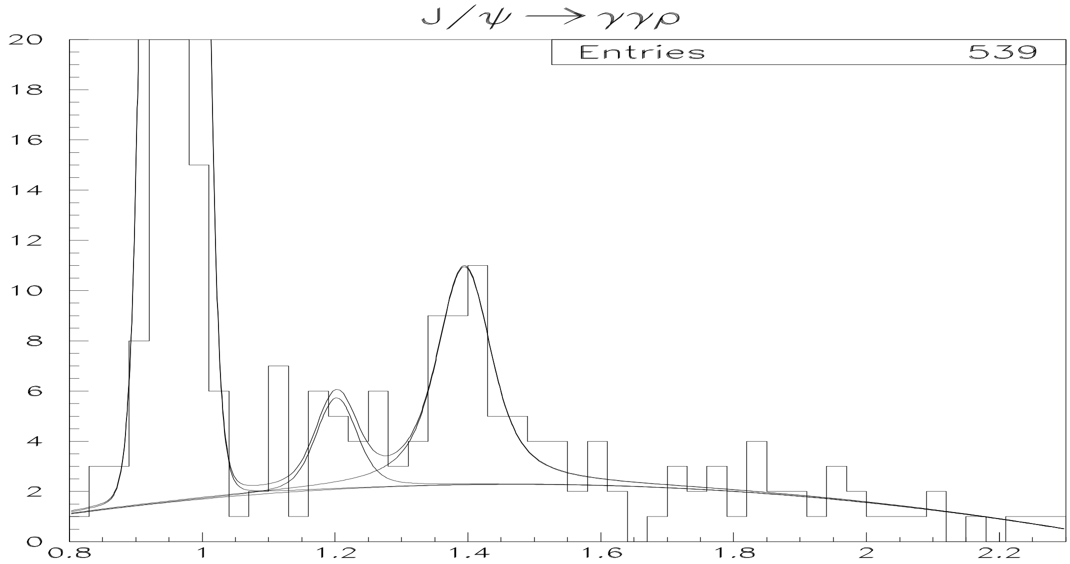

Figure 2: The BW Fit of $\gamma\rho$ Invariant Mass Spectrum with BESI data

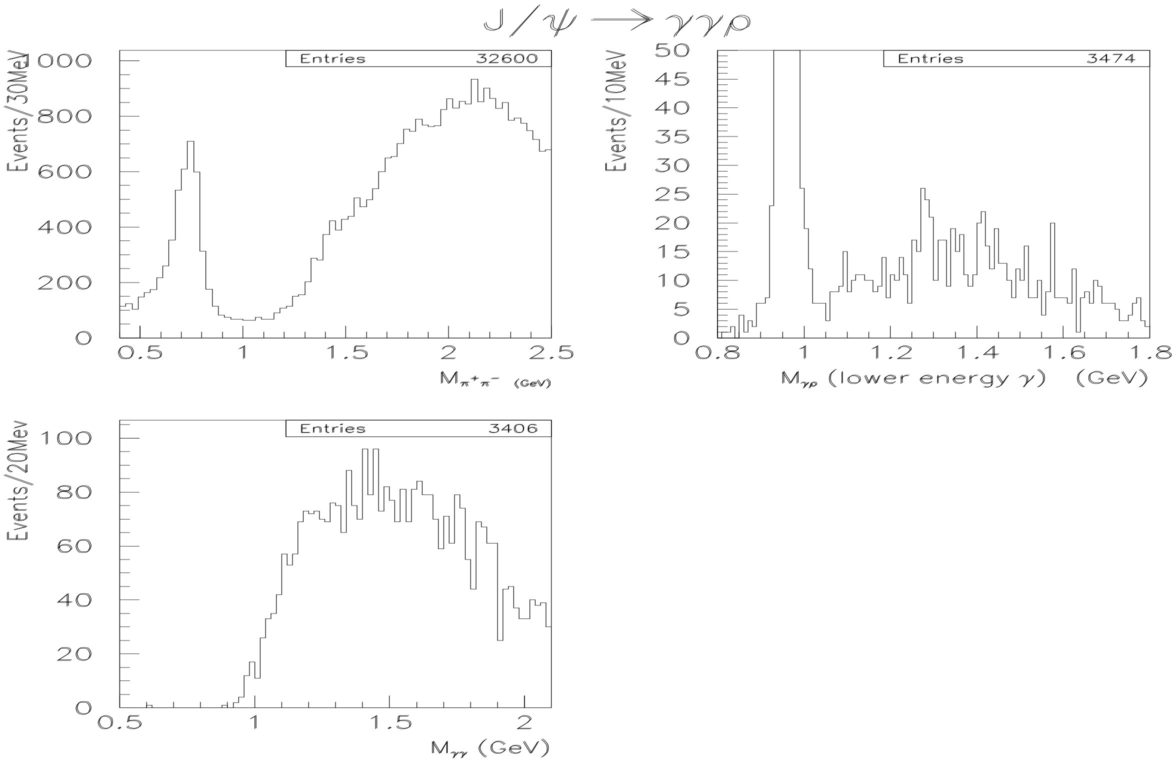

Figure 3: The Invariant Mass Spectrum with BESII data

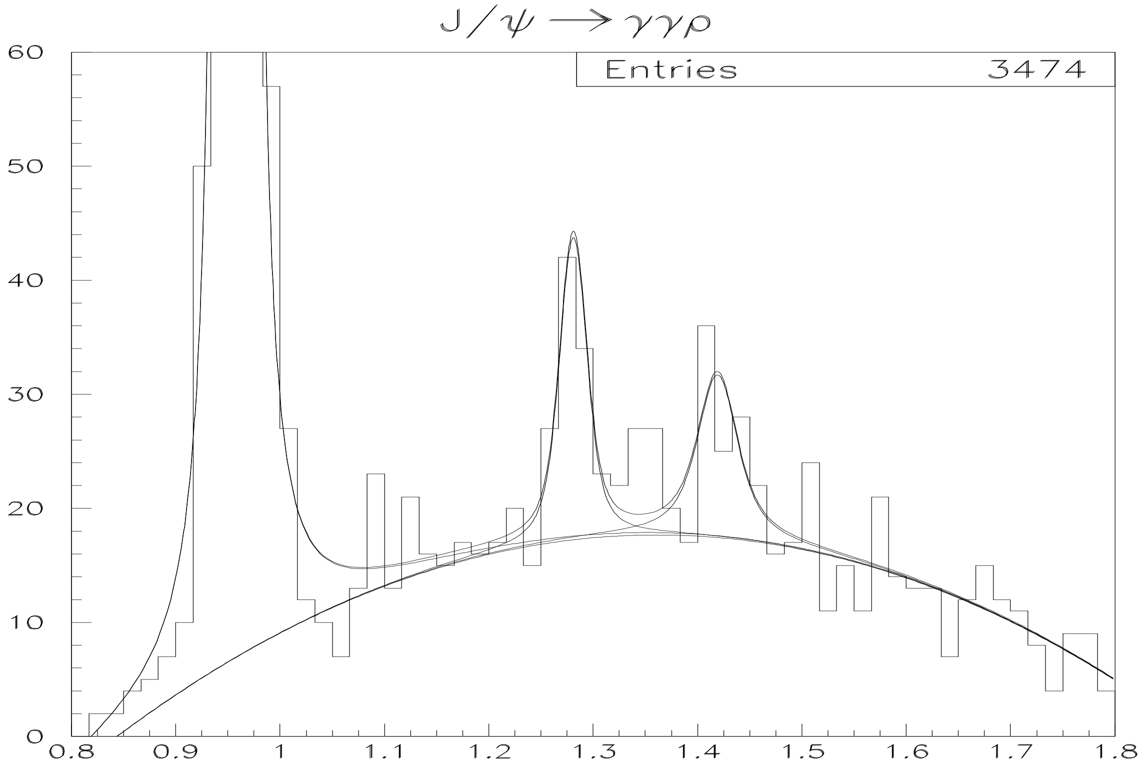

Figure 4: The BW Fit of $\gamma\rho$ Invariant Mass Spectrum with BESII data

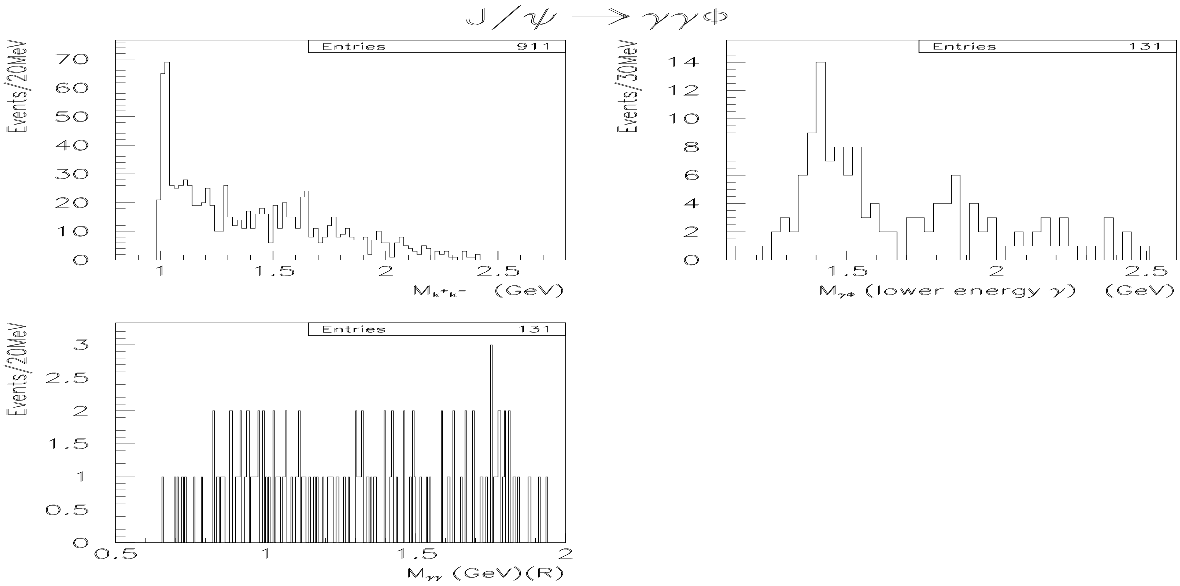

Figure 5: The Invariant Mass Spectrum with BESI data

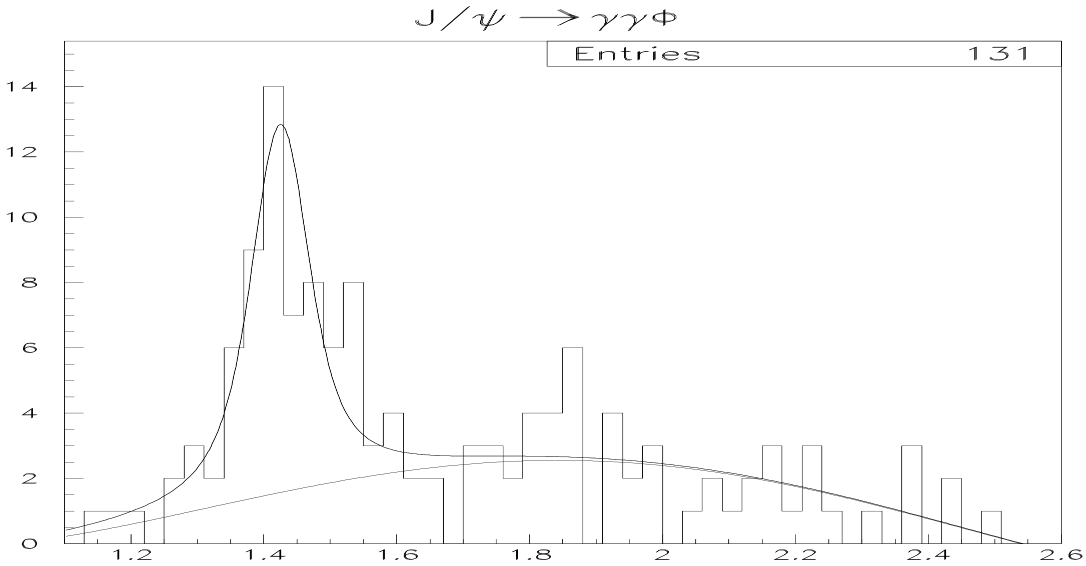

Figure 6: The BW Fit of $\gamma\phi$ Invariant Mass Spectrum with BESI data

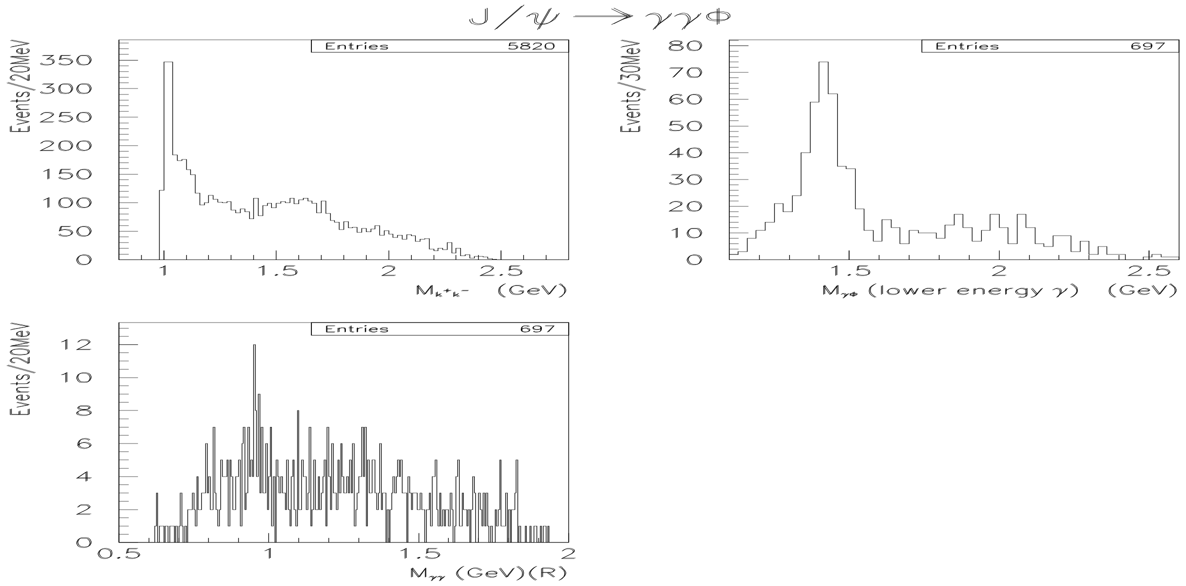

Figure 7: The Invariant Mass Spectrum with BESII data

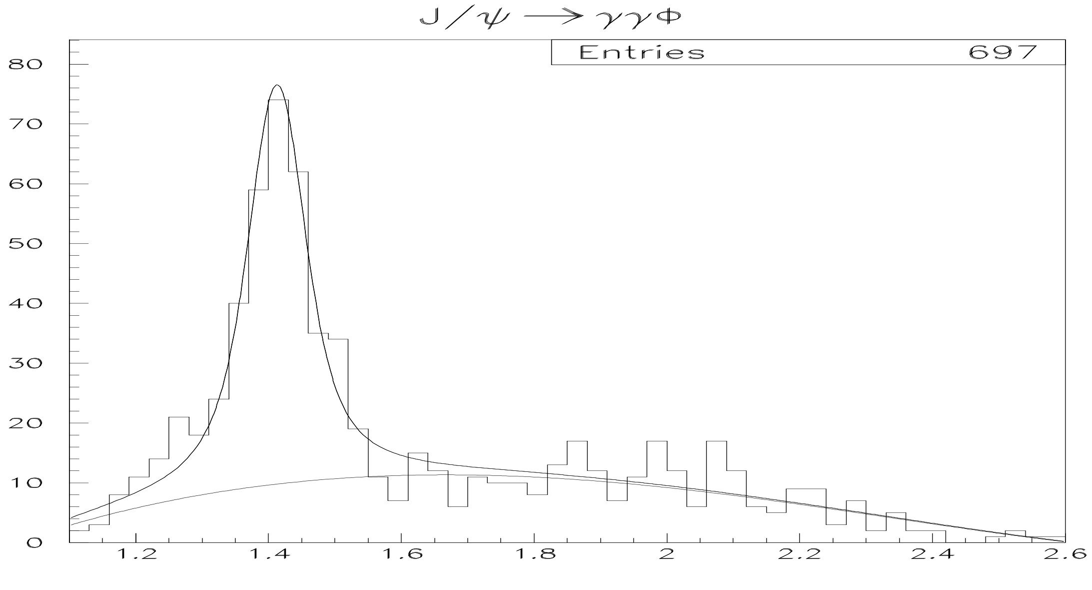

Figure 8: The BW Fit of $\gamma\phi$ nvariant Mass Spectrum with BESII data

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$0.06GeV
- $P_{miss} \leq 1.0GeV$
- 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

  $\chi^2 \leq 20$

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

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 photon are shown as below:

a. $E_{sc} \geq 0.05GeV$

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:

$$(\Delta M)_{min} = \sqrt{[(M_{\gamma\gamma} - M_{\pi^0})/\sigma_{M_{\pi^0}}]^2 + [(M_{\pi^+\pi^-\pi^0} - M_\omega)/\sigma_{M_\omega}]^2}$$

6.4 The Invariant Mass Restriction

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

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

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

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

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

The acceptance is determined from Monte Carlo Simulation. The result is about 2.1% for $J/\psi \to \gamma_1\gamma_2\omega$ case

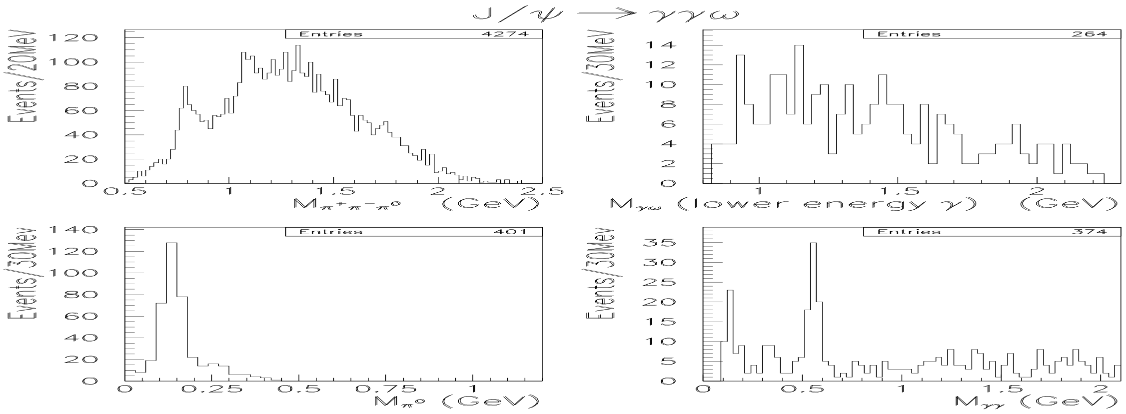

Figure 9: The Invariant Mass Spectrum with BESI data

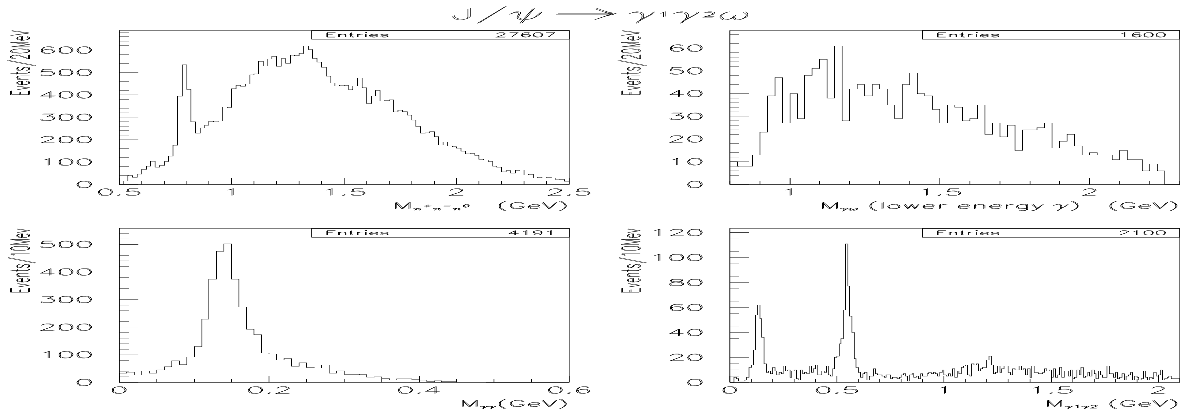

Figure 10: The Invariant Mass Spectrum with BESII data

7 Discussion

- The BESII results of $J/\psi \to \gamma\gamma\rho$ and $J/\psi \to \gamma\gamma\phi$ are consistent with BESI's , so confirm the firstly observed signal in BESI in the $\gamma\phi$ Invariant Mass Spectrum which was also the first corresponding physical report in the world

- Considering pure meson of $(u\bar{u} + d\bar{d})$ state mainly decays to $\gamma\rho$, not to $\gamma\phi$ and pure meson of $s\bar{s}$ state mainly decay to $\gamma\phi$, not to $\gamma\rho$, but a glueball can mix with either $(u\bar{u} + d\bar{d})$ or $s\bar{s}$, the hyphothesis that X(1440) includes glueball constituent is supported by our study result

- 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 1418MeV 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 very meaningful to study "$\rho\pi$ puzzle"