New States and Hadron Spectroscopy at BESII

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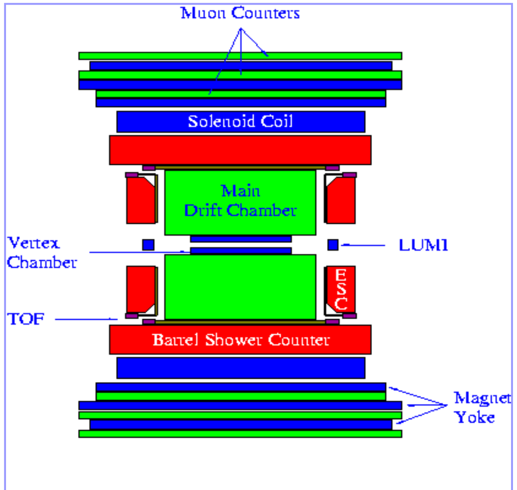
Focus on following results:

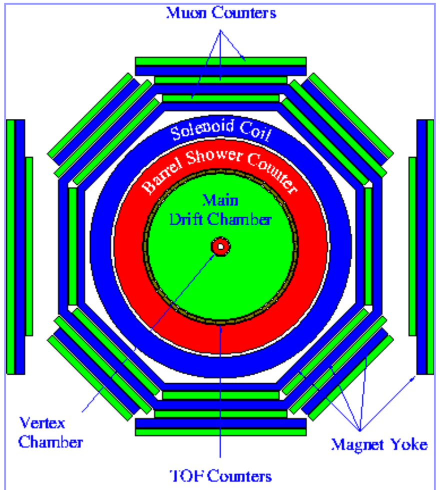
- The observation of X(1835) at BES
- The $\omega\phi$ threshold enhancement in $J/\psi \to \gamma\omega\phi$
- Study of $J/\psi \to \gamma\omega\omega$
- Scalars: σ, κ, $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $f_0(1710)$, $f_0(1790)$ …

Introduction

BESII Detector



Side view of the BES detector

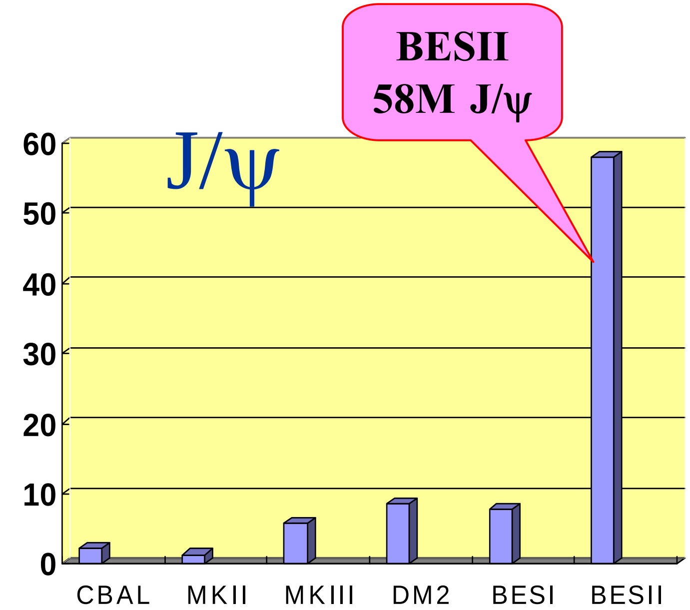


End view of the BES detector

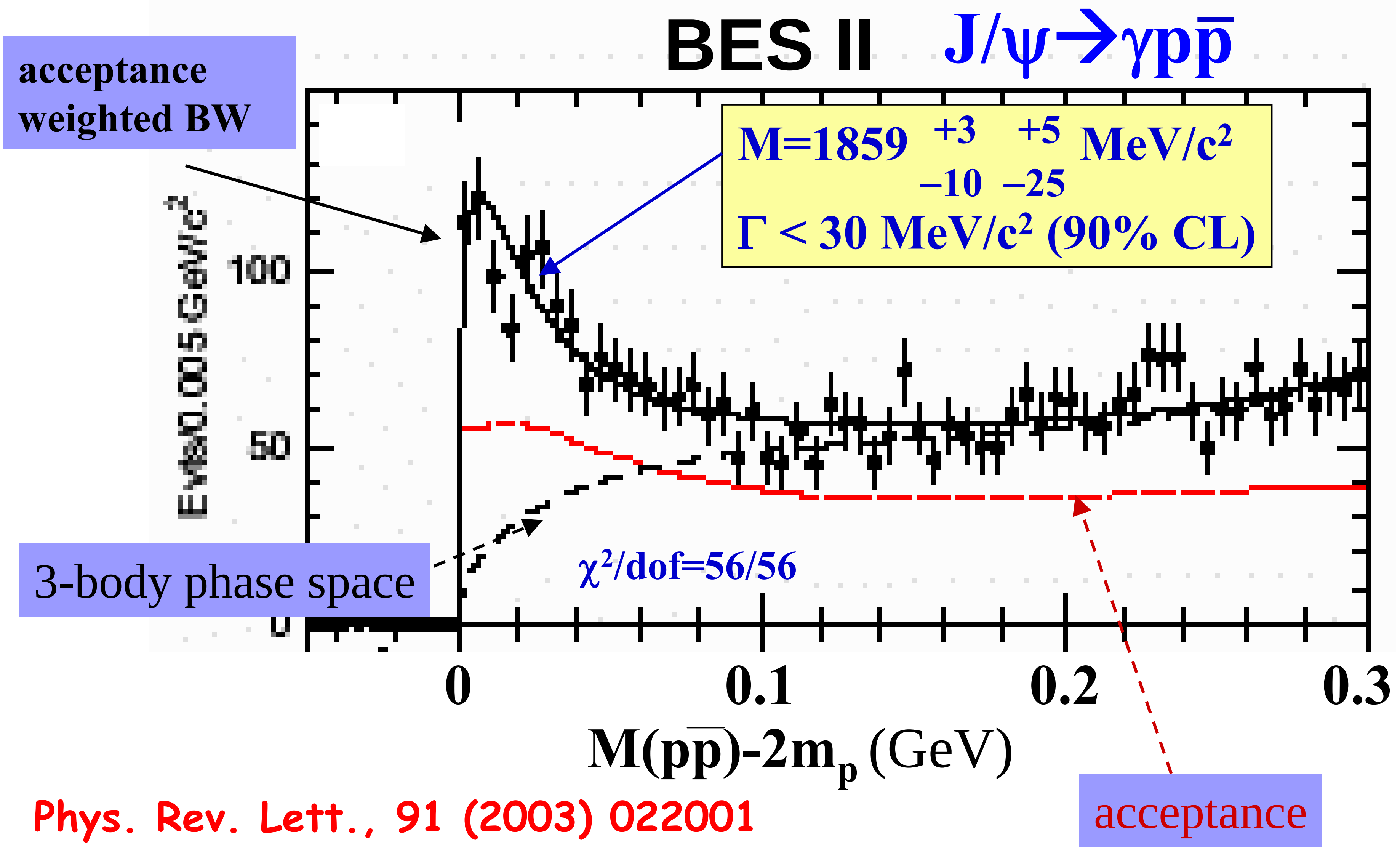
VC: σ_{xy} = 100 μm
MDC: σ_{xy} = 220 μm
$\sigma_{dE/dx}$ = 8.5 %
$\Delta p/p = 1.78\sqrt{(1+p^2)}$
μ counter: $\sigma_{r\phi}$ = 3 cm
σ_z = 5.5 cm

TOF: σ_T = 180 ps
BSC: $\Delta E/\sqrt{E}$ = 21 %
σ_ϕ = 7.9 mr
σ_z = 2.3 cm
B field: 0.4 T

World J/ψ Sample (×10^6)



Observation of an anomalous enhancement near the threshold of $p\bar{p}$ mass spectrum at BES II



Phys. Rev. Lett., 91 (2003) 022001

$p\bar{p}$ bound state (baryonium)?

There is lots & lots of literature about this possibility

E. Fermi, C.N. Yang, Phys. Rev. 76, 1739 (1949)
…
I.S. Sharpiro, Phys. Rept. 35, 129 (1978)
C.B. Dover, M. Goldhaber, PRD 15, 1997 (1977)
…
A. Datta, P.J. O'Donnell, PLB 567, 273 (2003)]
M.L. Yan *et al.*, hep-ph/0405087

deute

attracti … ce?

+

Observations of this structure in other decay modes are desirable.

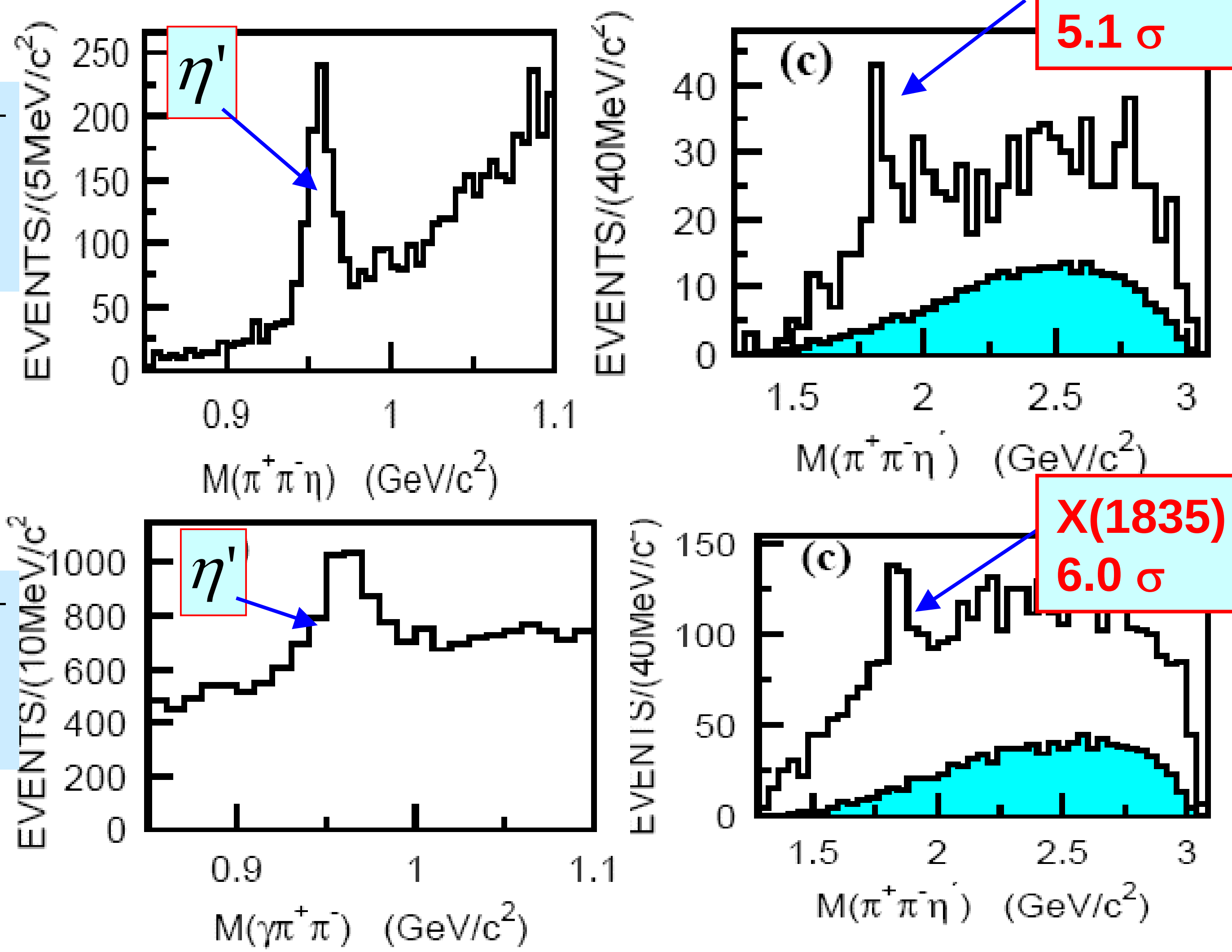
singlets with
$M_d = 2m_p - \varepsilon$

singlets with
$M_b = 2m_p - \delta$?

Observation of X(1835) in $J/\psi \to \gamma \pi^+ \pi^- \eta'$

$$J/\psi \to \gamma \eta' \pi^+ \pi^-$$
$$\eta' \to \eta \pi^+ \pi^-$$

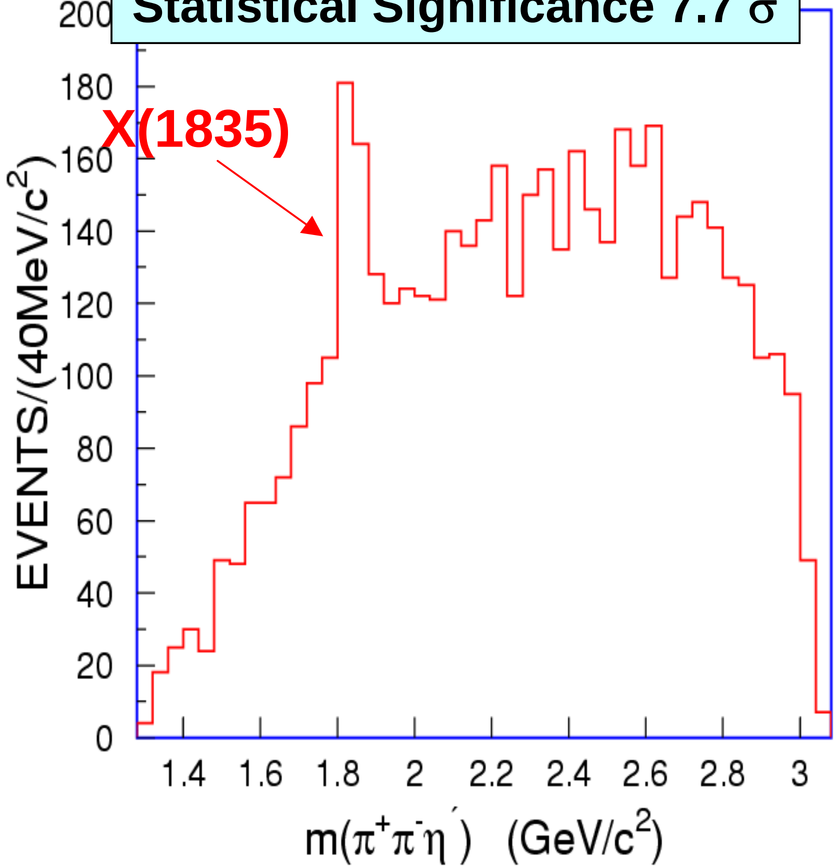
$$J/\psi \to \gamma \eta' \pi^+ \pi^-$$
$$\eta' \to \gamma \rho$$

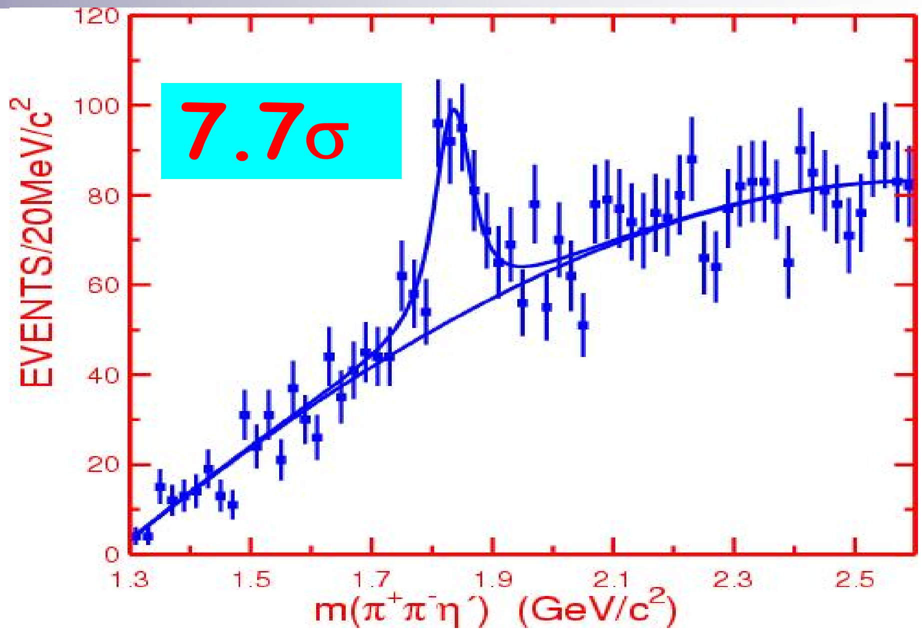


Combine two channels

$$J/\psi \rightarrow \gamma \pi^+ \pi^- \eta'$$

Statistical Significance 7.7 σ





$$N_{obs} = 264 \pm 54$$

$$M = 1833.7 \pm 6.1 \pm 2.7 \text{ MeV/c}^2$$

$$\Gamma = 67.7 \pm 20.3 \pm 7.7 \text{ MeV/c}^2$$

$$B(J/\psi \rightarrow \gamma X) B(X \rightarrow \pi^+ \pi^- \eta') = (2.2 \pm 0.4 \pm 0.4) \times 10^{-4}$$

Phys. Rev. Lett., 95 (2005) 262001

X(1835) could be the same structure as X(1860) indicated by $p\bar{p}$ mass threshold enhancement

- X(1835) mass is consistent with the mass of the S-wave resonance X(1860) indicated by the $p\bar{p}$ mass threshold enhancement.

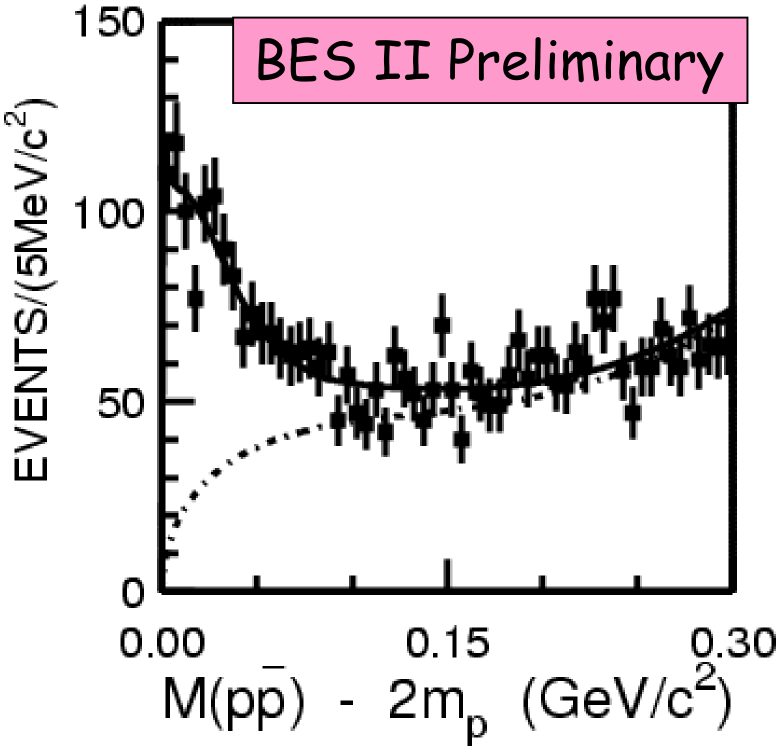
  Its width is 1.9σ higher than the upper limit of the width obtained from $p\bar{p}$ mass threshold enhancement.

- On the other hand, if the FSI effect is included in the fit of the $p\bar{p}$ mass spectrum, the width of the resonance near $p\bar{p}$ mass threshold will become larger.

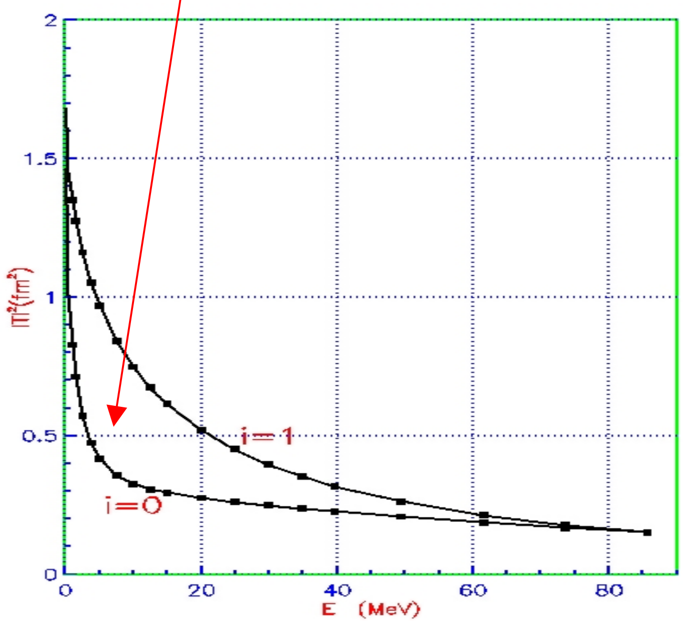
Fit to J/ψ → γp$\bar{p}$ including FSI

M = 1830.6 ± 6.7 MeV

Γ = 0 ± 93 MeV



Include FSI curve from A.Sirbirtsev et al.(hep-ph/0411386) in the fit (I=0)

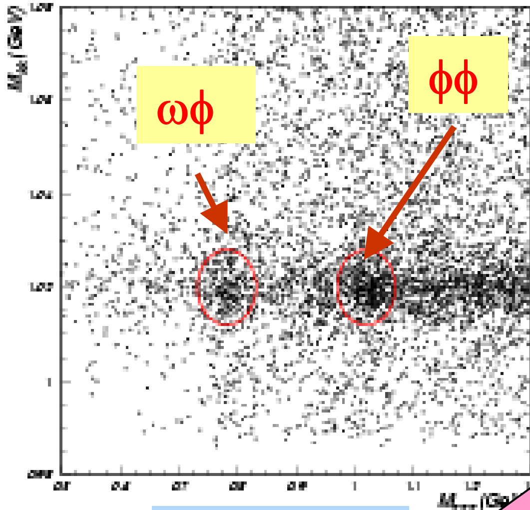


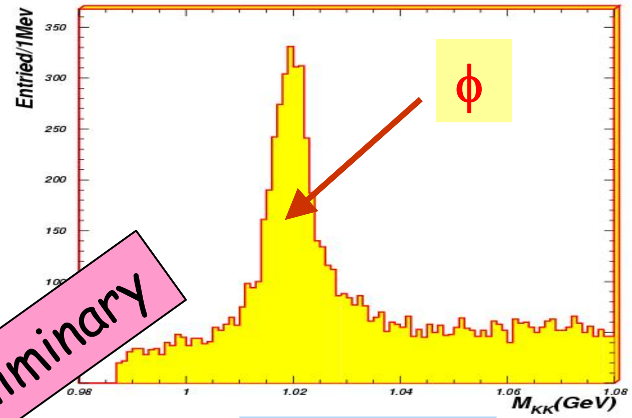
In good agreement with X(1835)

Observation of ωϕ threshold enhancement in $J/\psi \rightarrow \gamma\omega\phi$

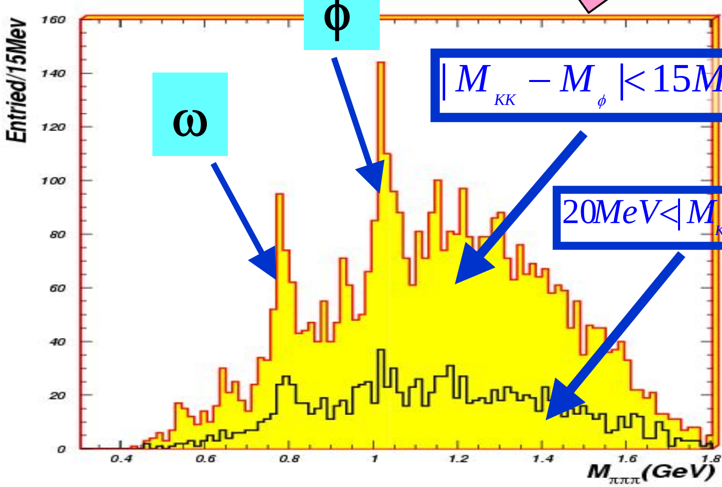
$$(\omega \rightarrow \pi^{+}\pi^{-}\pi^{0}, \phi \rightarrow K^{+}K^{-})$$

Clear ϕ and ω signals

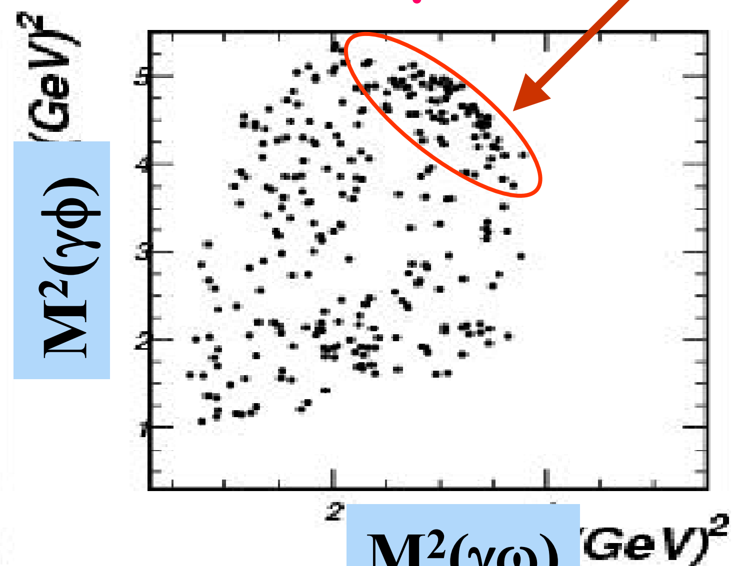




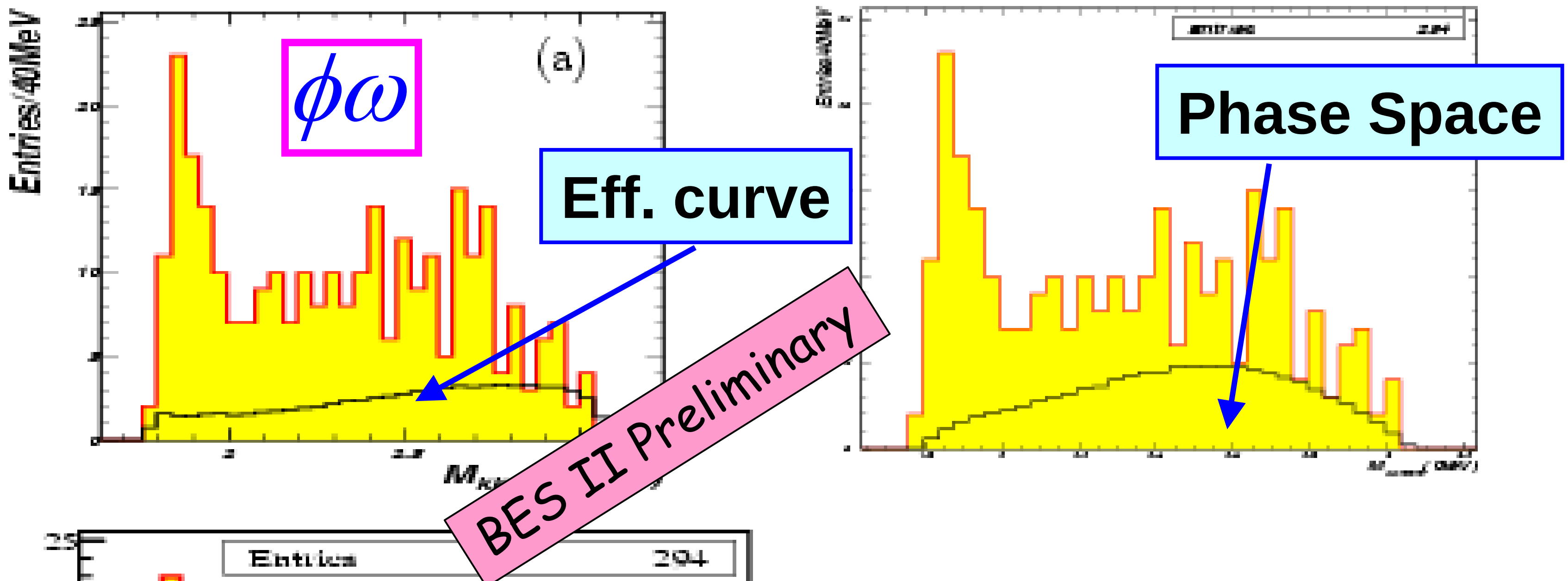
BES II Preliminary

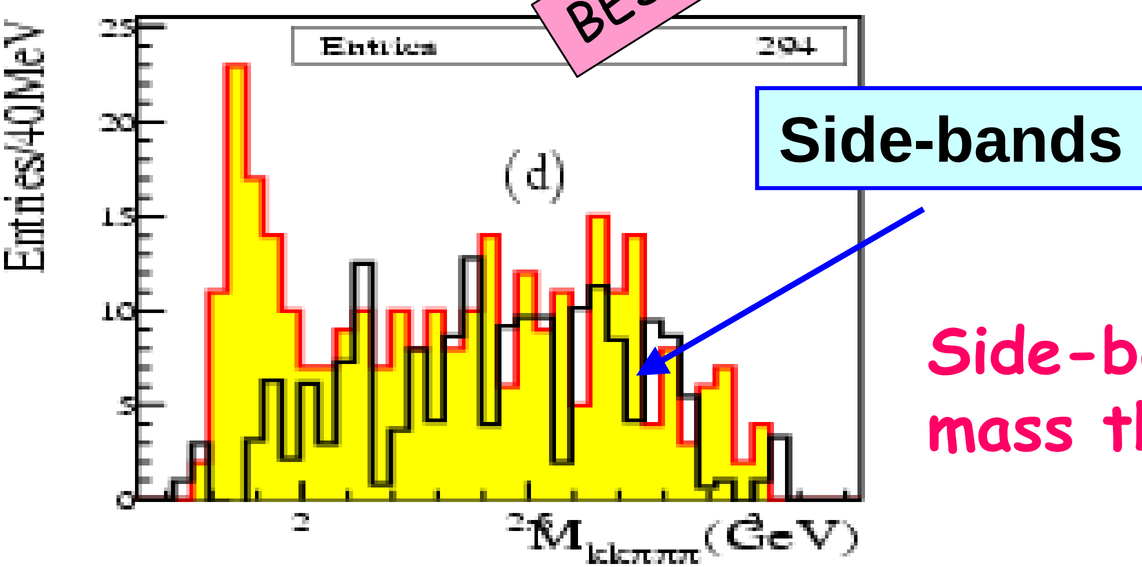


Dalitz plot



A clear threshold enhancement is observed





Side-bands do not have mass threshold enhancement!

BES II Preliminary

Partial Wave Analysis is performed.

0^{++} is favored over 0^{-+} and 2^{++}

$$M = 1812^{+19}_{-26} \pm 18\,\mathrm{MeV/c^2}$$

$$\Gamma = 105 \pm 20 \pm 28\,\mathrm{MeV/c^2}$$

$$Br(J/\psi \to \gamma X)\cdot Br(X \to \omega\phi) = (2.61 \pm 0.27 \pm 0.65)\times 10^{-4}$$

Submitted to Phys. Rev. Lett., hep-ex/0602031

- The DOZI decay of $J/\psi \to \gamma\omega\phi$ is observed and measured with 58M J/ψ data.
- An enhancement in $\omega\phi$ is found near the threshold.
- PWA shows: the structure favors 0^{++}

.

$$M = 1812^{+19}_{-26} \pm 18\ \mathrm{MeV/c^2}$$

$$\Gamma = 105 \pm 20 \pm 28\ \mathrm{MeV/c^2}$$

- Is it the same 0^{++} observed in $K\bar{K}$ mass, or a glueball, or a hybrid?

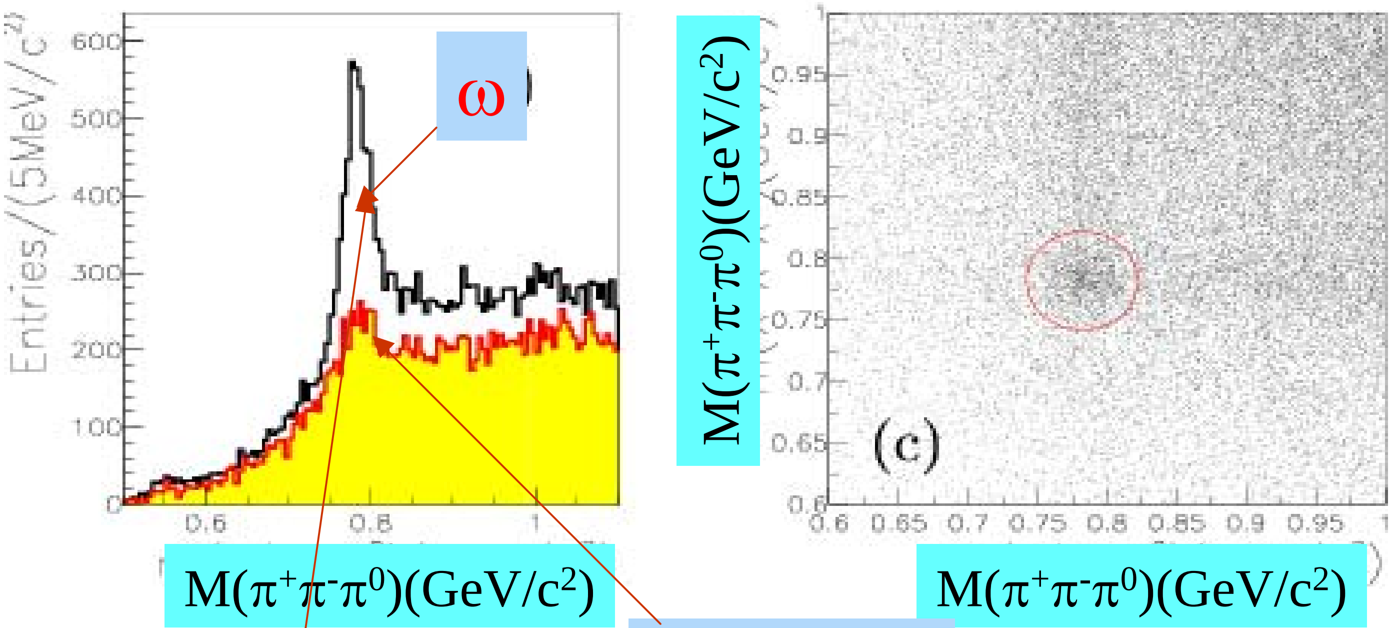
Further look in $\omega\omega$, $K^*\bar{K}^*$, $\phi\phi$ …. are desirable !

hep-ph/0602172, hep-ph/0602190

$$J/\psi \to \gamma\omega\omega$$

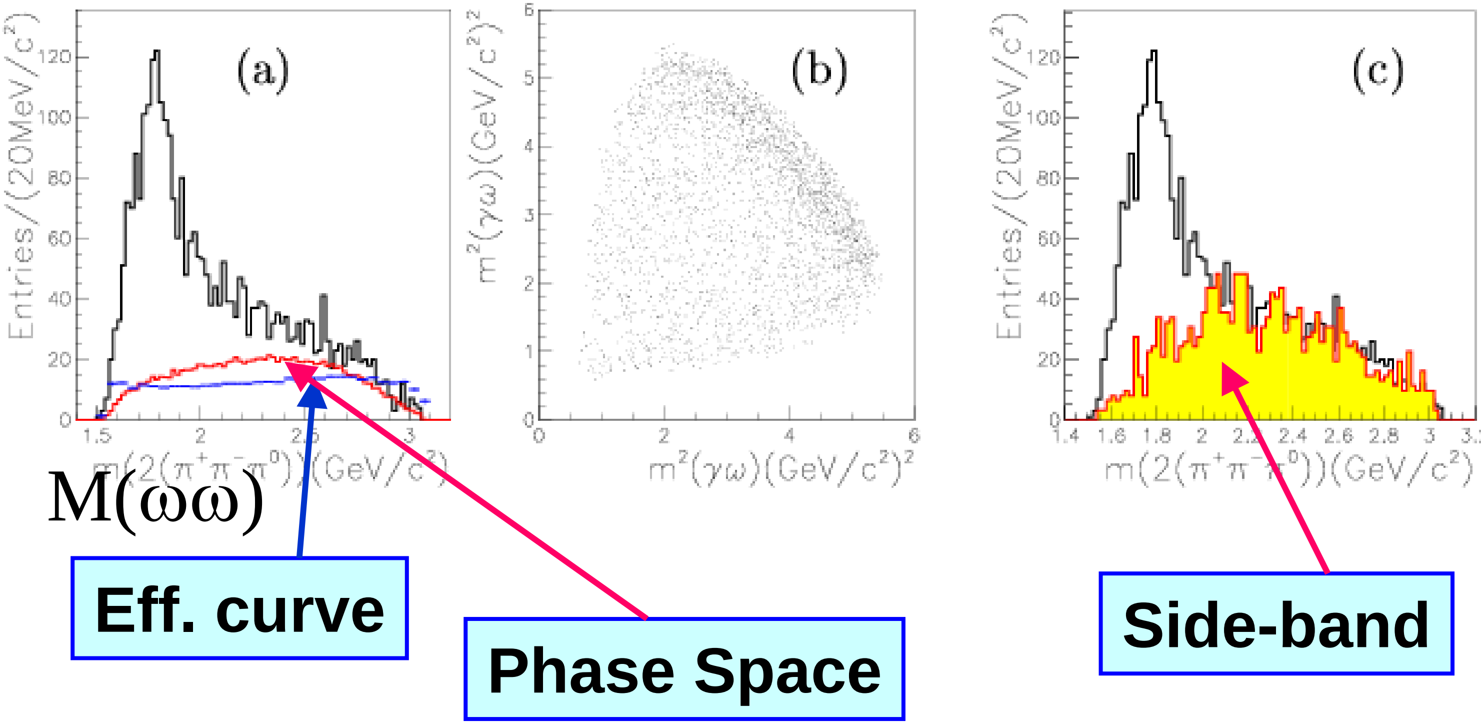
$$\omega \to \pi^{+}\pi^{-}\pi^{0}$$

BES II Preliminary



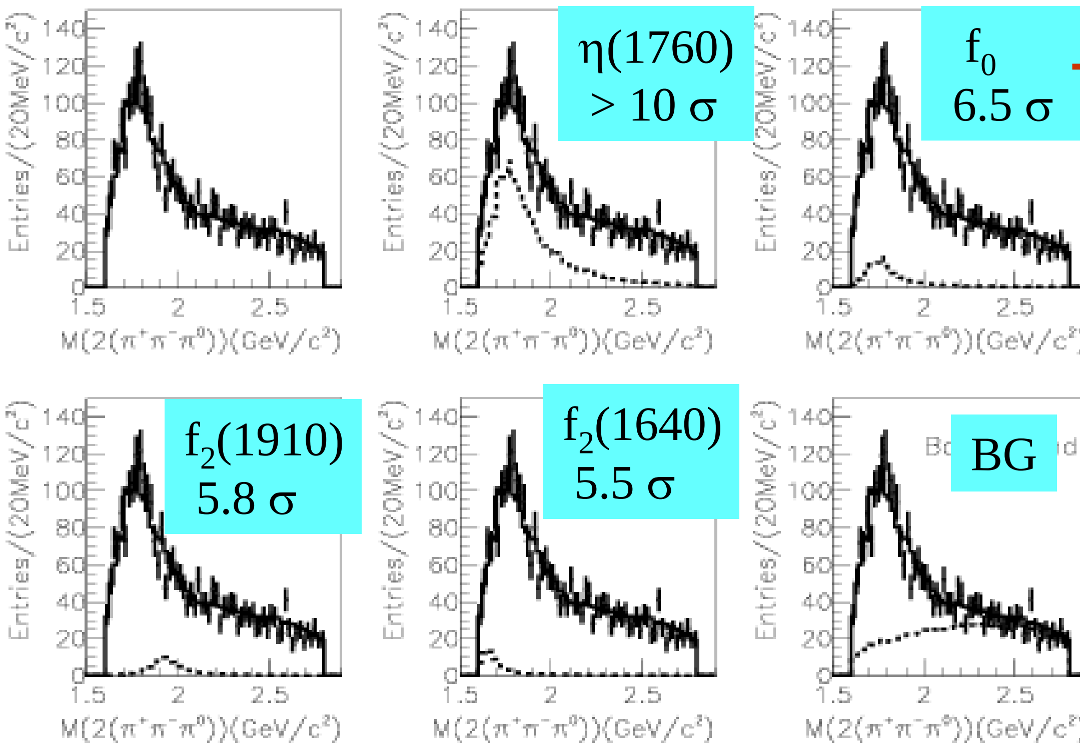
ω signal after best candidate selection (best ω masses)

BES II Preliminary



PWA Fit results

BES II Preliminary



$f_0(1710)$
$f_0(1790)$
$f_0(1810)$

Using observed mass and width for $f_0(1810)$ in $J/\psi \rightarrow \gamma\, \omega\phi$

- **dominated by η(1760)**
- **a 0^{++} is needed (6.5 σ)**

Will be submitted to PRD.

light scalars:

σ, κ, f_0(980), f_0(1370), f_0(1500), f_0(1710), f_0(1790)

Why light scalar mesons are interesting?

- There have been hot debates on the existence of **σ** and **κ** .

- Lattice QCD predicts the 0^{++} scalar glueball mass ~ 1.6 GeV. $f_0(1500)$ and $f_0(1710)$ are good candidates.

0^{++}

- study σ in $J/\psi \to \omega\pi^+\pi^-$

  study κ in $J/\psi \to K^* K\pi$ and $KK\pi\pi$

- study $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $f_0(1710)$ and $f_0(1790)$ in

$$J/\psi \to \{\gamma, \omega, \phi\} + \{\pi\pi, KK\}$$

The σ pole in $J/\psi \to \omega\pi^+\pi^-$ at BESII

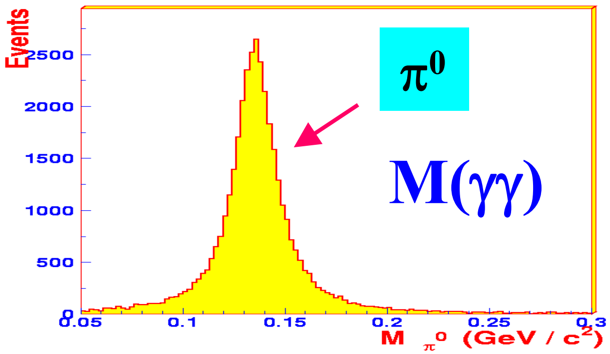


Figure 1: π^0 signal

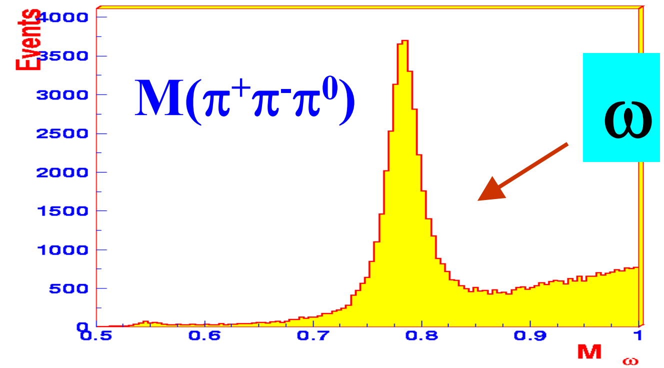


Figure 2: ω signal

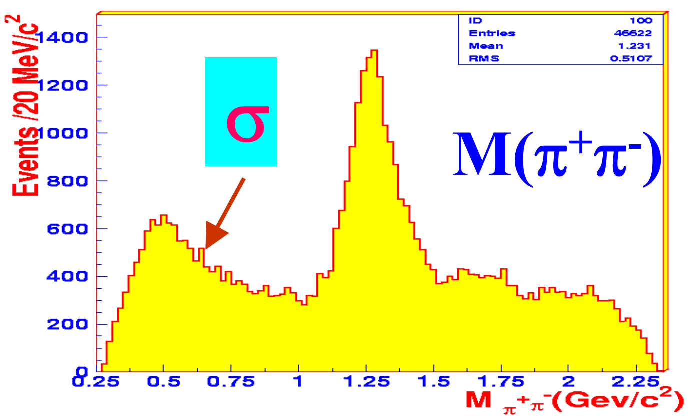
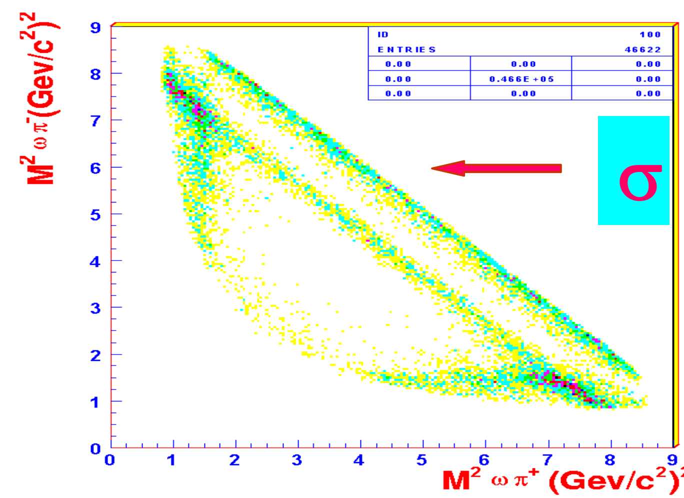


Figure 3: The invariant mass spectrum of $\pi^+\pi^-$



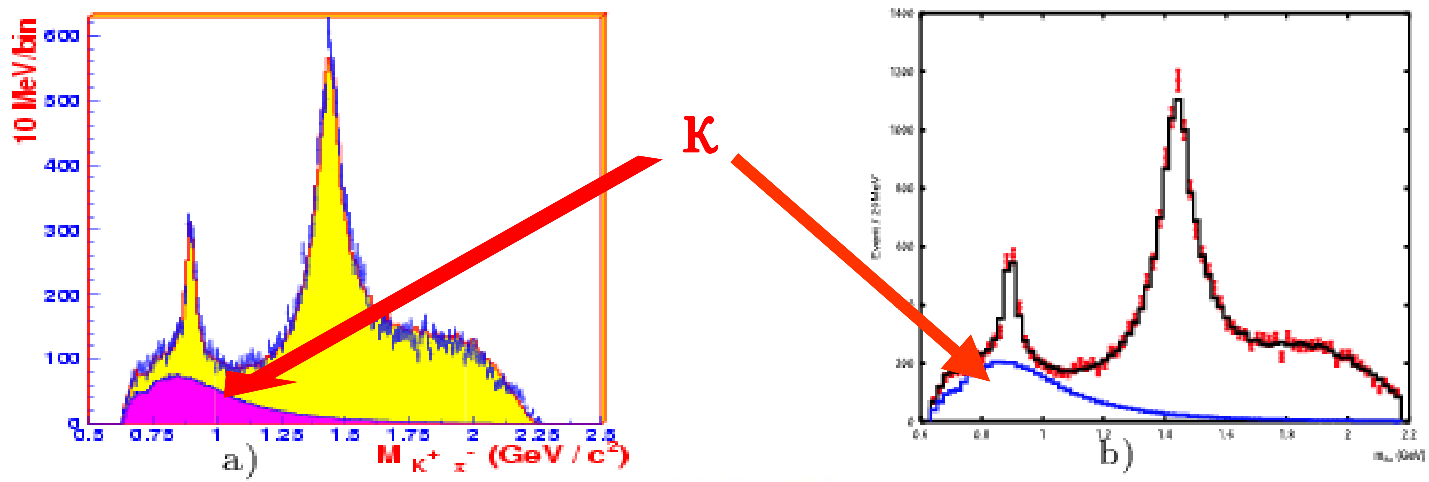
Averaged pole position: $(541 \pm 39) - i(252 \pm 42)$ **MeV**

Phys. Lett. B 598 (2004) 149

κ in $J/\psi \to \bar{K}^*(892)^0 K^+ \pi^-$

Method A (Covariant Helicity Amplitude)

Method B (Variant Mass and Width)

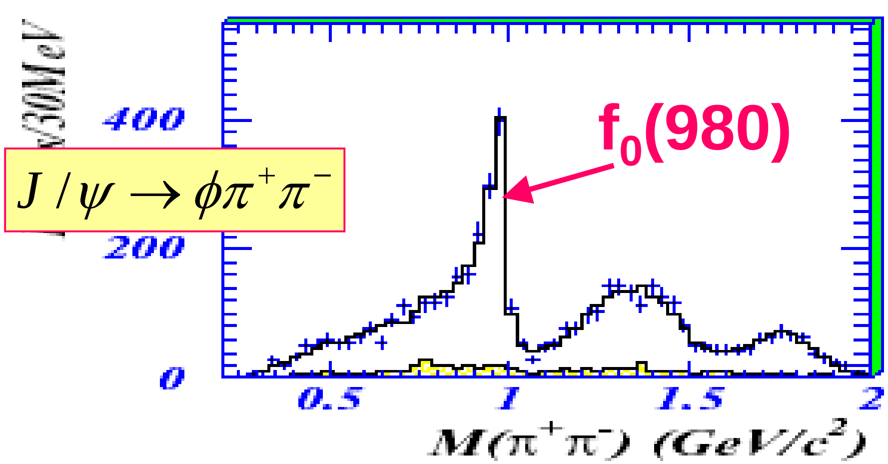


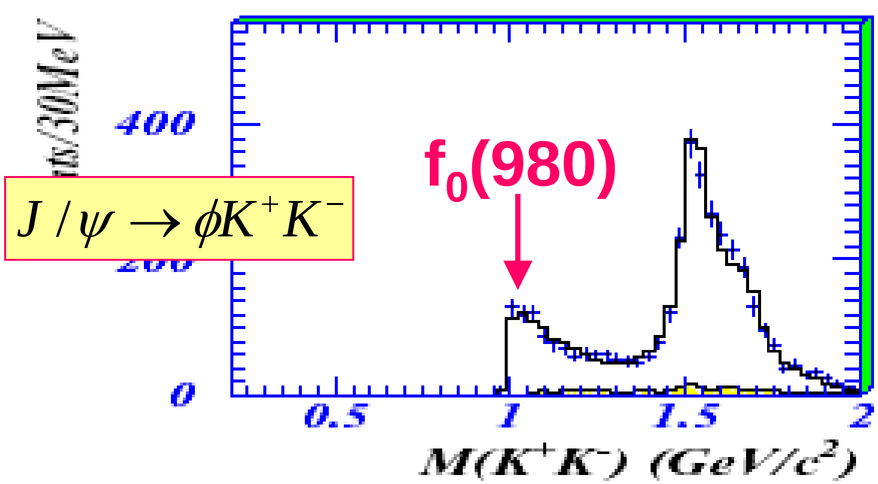
- **Decay channels used in the fit:**
  - ⊙ $J/\psi \to K^*(892)K_0^*(1430)$, $K^*\kappa$, $K^*K_2^*(1430)$, $K^*K_2^*(1922)$;
  - ⊙ $J/\psi \to K_1(1400)K$, $K_1(1270)K$.
- **Two produce similar results: κ is needed.** The average values for κ pole position is:

$$(841 \pm 30^{+81}_{-73}) - i(309 \pm 45^{+48}_{-72})\ \mathrm{MeV/c^2}$$

Phys. Lett. B 633 (2006) 681

$f_0(980)$





- Important parameters from PWA fit:

$$M = 965 \pm 8 \pm 6 \ MeV$$

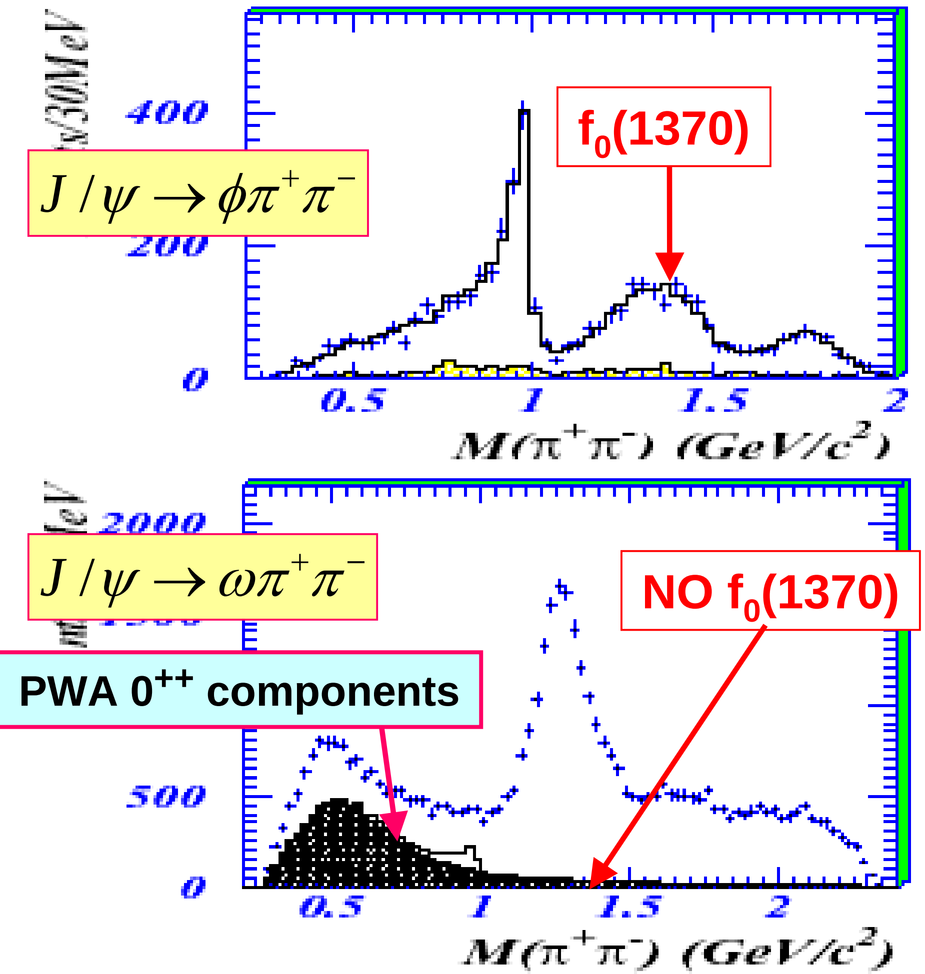
$$g_{\pi\pi} = 165 \pm 10 \pm 15 \ MeV$$

$$\frac{g_{KK}}{g_{\pi\pi}} = 4.21 \pm 0.25 \pm 0.21$$

- **Large coupling with $K\bar{K}$**

Phys. Lett. B 607 (2005) 243

$f_0(1370)$



- There has been debate whether **$f_0(1370)$** exists or not.

- **$f_0(1370)$** clearly seen in $J/\psi \to \phi\pi\pi$, but not seen in $J/\psi \to \omega\pi\pi$.

$$M = 1350 \pm 50\ MeV$$

$$\Gamma = 265 \pm 40\ MeV$$

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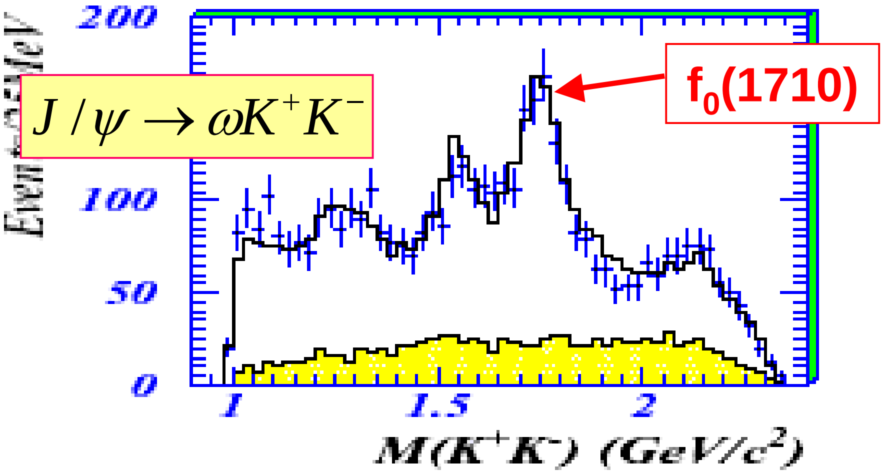
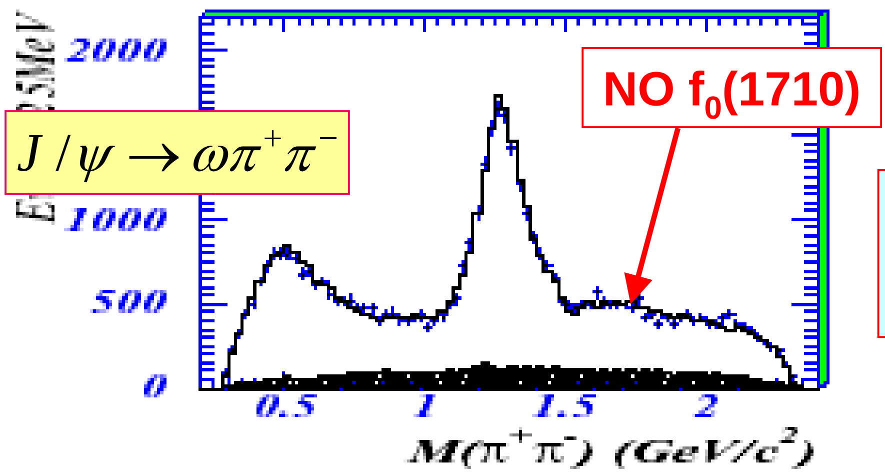
$f_0(1710)$





- **Clear $f_0(1710)$** peak in $J/\psi \rightarrow \omega KK$.

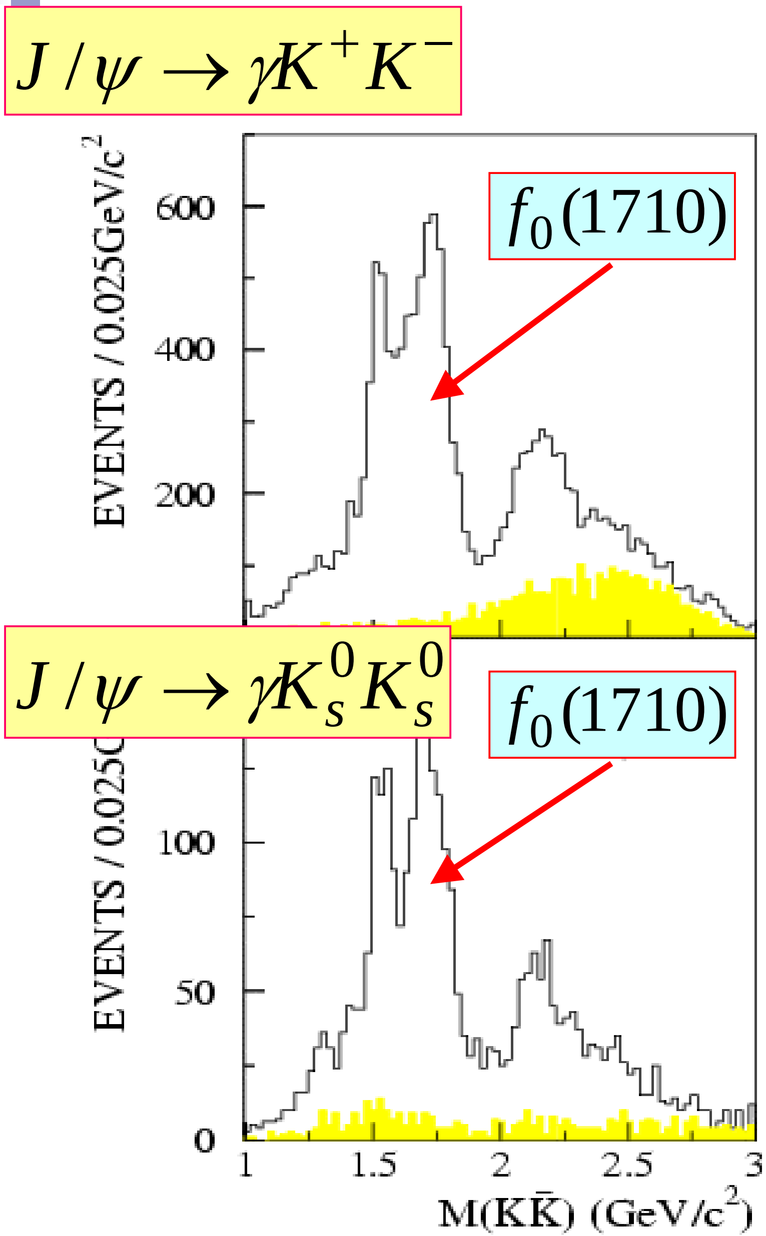
$$M = 1740 \pm 30 \;\; MeV$$
$$\Gamma = 125 \pm 20 \;\; MeV$$

- **No $f_0(1710)$** observed in $J/\psi \rightarrow \omega\pi\pi$!

$$\frac{BR(f_0(1710) \rightarrow \pi\pi)}{BR(f_0(1710) \rightarrow K\bar{K})} < 0.13 \quad @95\%CL$$

Phys. Lett. B 603 (2004) 138

$f_0(1710)$



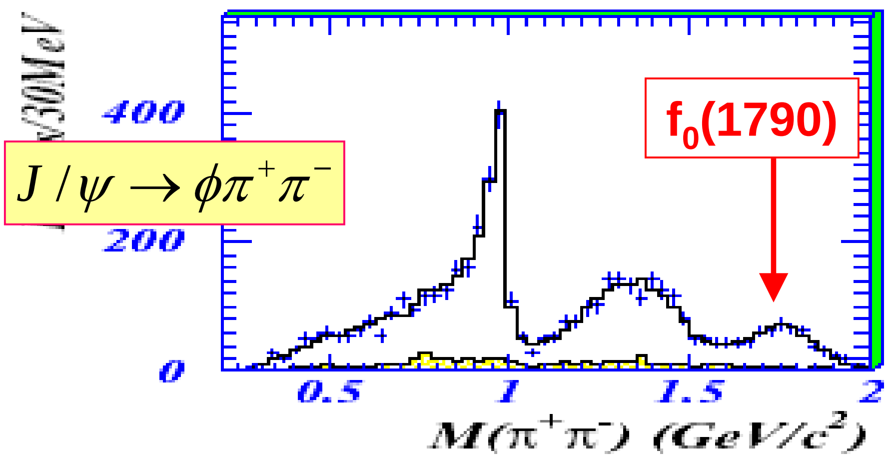
PWA analysis shows one scalar in 1.7 GeV region

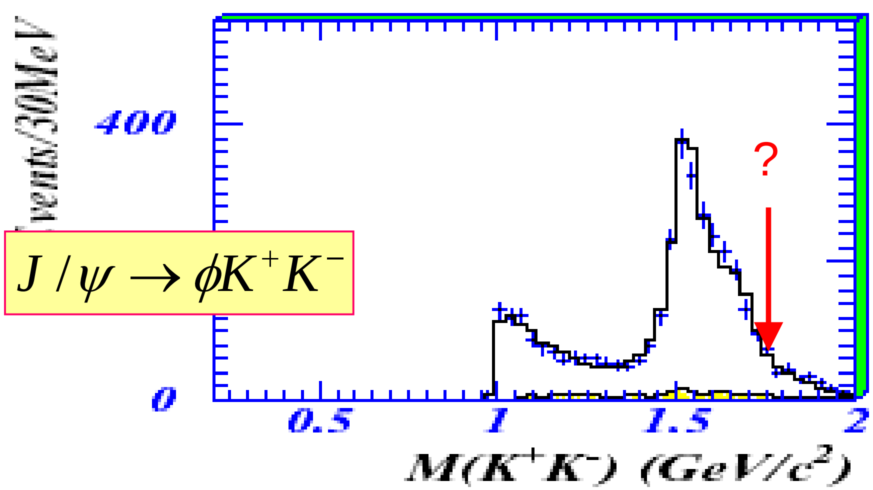
$$M = 1740 \pm 4^{+10}_{-25} \ \ \text{MeV}$$

$$\Gamma = 166^{+5+15}_{-8-10} \ \ \text{MeV}$$

Phys. Rev. D 68 (2003) 052003

New $f_0(1790)$??





- A clear peak around 1790 MeV is observed in $J/\psi \to \phi\pi\pi$.

$$M = 1790^{+40}_{-30} \quad MeV$$

$$\Gamma = 270^{+60}_{-30} \quad MeV$$

- No evident peak in $J/\psi \to \phi KK$. If $f_0(1790)$ were the same as $f_0(1710)$, we would have:

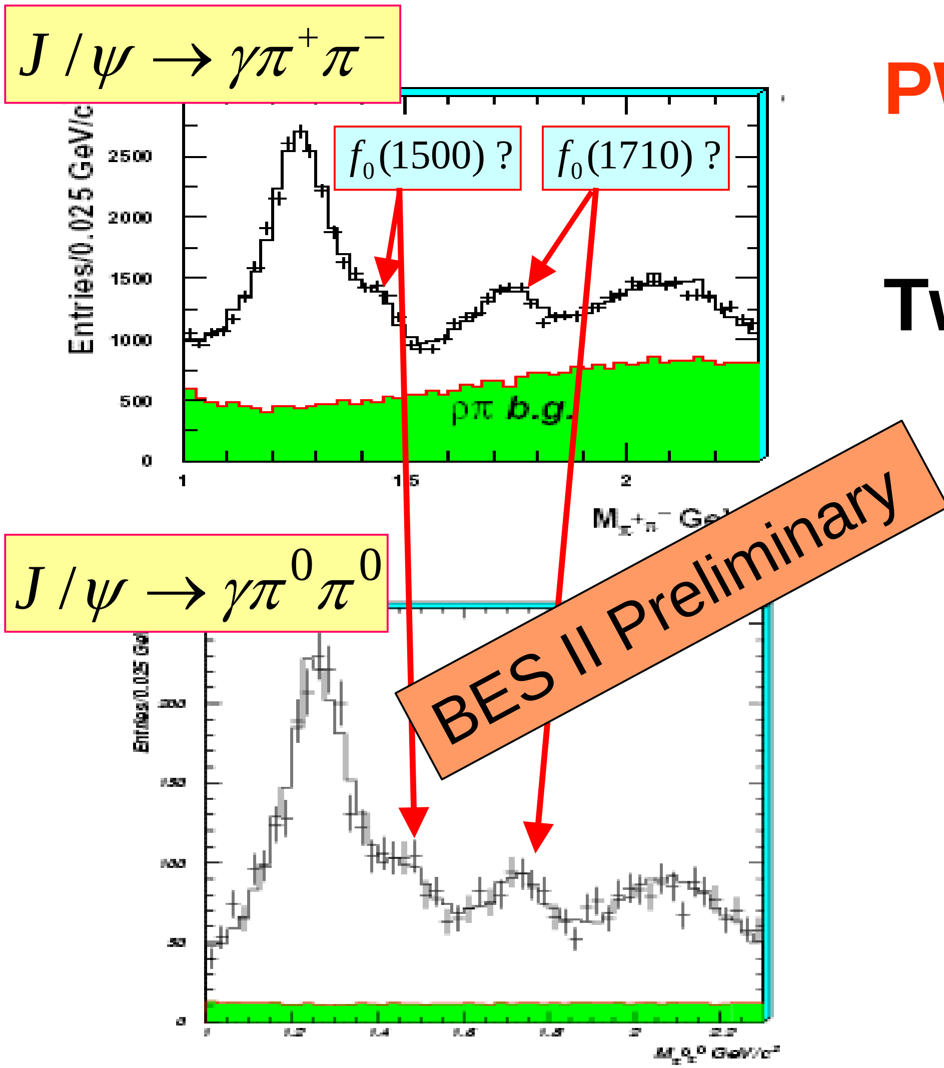
$$\frac{BR(f_0(1790) \to \pi\pi)}{BR(f_0(1710) \to K\bar{K})} \sim 1.5$$

Inconsistent with what we observed in $J/\psi \to \omega\pi\pi$, ωKK

$$\frac{BR(f_0(1710) \to \pi\pi)}{BR(f_0(1710) \to K\bar{K})} < 0.13 \quad @95\%CL$$

→ $f_0(1790)$ is a new scalar ??

f_0(1500) and f_0(1710) / f_0(1790)?



PWA results:

Two scalars in J/ψ → γππ:

- **One is around 1470 MeV, may be f_0(1500)?**
- **The other is around 1765 MeV, is it f_0(1790) or f_0(1710) or a mixture of f_0(1710) and f_0(1790)?**

BES II Preliminary

$J/\psi \rightarrow \gamma\pi^+\pi^-$

$J/\psi \to \gamma X,\ X \to \pi^+\pi^-$			
	Mass (MeV)	Γ (MeV)	$\mathcal{B}$ ($\times 10^{-4}$)
$f_2(1270)$	$1262^{+1}_{-2} \pm 7$	$175^{+6}_{-4} \pm 9$	$9.14 \pm 0.07 \pm 1.01$
$f_0(1500)$	$1466 \pm 6 \pm 20$	$108^{+14}_{-11} \pm 21$	$0.67 \pm 0.02 \pm 0.28$
$f_0(1710)$	$1765^{+4}_{-3} \pm 12$	$145 \pm 8 \pm 69$	$2.64 \pm 0.04 \pm 0.71$

$J/\psi \rightarrow \gamma\pi^0\pi^0$

$J/\psi \to \gamma X,\ X \to \pi^0\pi^0$			
	Mass (MeV)	Γ (MeV)	$\mathcal{B}$ ($\times 10^{-4}$)
$f_2(1270)$	same as charged channel		$4.00 \pm 0.09 \pm 0.58$
$f_0(1500)$	same as charged channel		$0.34 \pm 0.03 \pm 0.15$
$f_0(1710)$	same as charged channel		$1.33 \pm 0.05 \pm 0.88$

Summary

- the observation of X(1835) at BES
- the observation of $\omega\phi$ threshold enhancement $f_0(1810)$ in $J/\psi \to \gamma\omega\phi$
- $\eta(1760)$ dominant in $J/\psi \to \gamma\omega\omega$, existence of f_0
- σ and κ, $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $f_0(1710)$, … are studied