Results on Light Hadron Spectroscopy and Prospects at BES3

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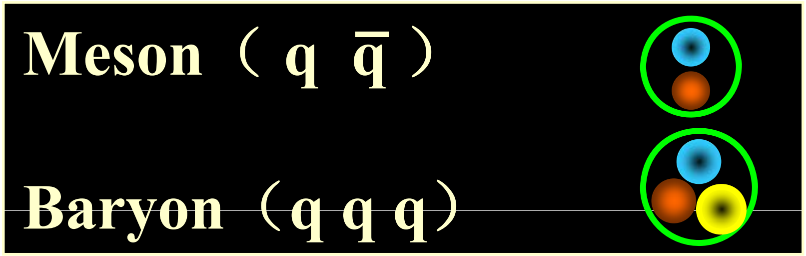
Outline

- Introduction
- Recent light hadron spectroscopy results (selected topics)
- Study of light hadron spectroscopy @ BES3
- Summary

New forms of hadrons

- **Hadrons consist of 2 or 3 quarks:**

  Naive Quark Model:



- **New forms of hadrons:**
  - **Multi-quark states： Number of quarks >= 4**
  - **Hybrids： $qq\bar{g}$， $qqqg$ …**
  - **Glueballs： gg， ggg …**

Multi-quark states, glueballs and hybrids have been searched for experimentally for a very long time, but none is established.

However, during the past years, a lot of surprising experimental evidences showed the existence of hadrons that cannot (easily) be explained in the conventional quark model.

Meson spectroscopy

- **The low mass 0^{++} states have been confusing for many years. There are so many 0^{++}s', such as $f_0(1370)$, $f_0(1500)$, $f_0(1710)$ ….**
- **Two ground-state isoscalar 1^{++} states at 1240 and 1480 MeV in the quark model. But there are 3 1^{++} states in this region -- $f_1(1285)$, $f_1(1420)$, $f_1(1530)$.**
- **whether 0^{++} $f_0(980)$ and $a_0(980)$ are molecular states or not.**
- **extra 2^{++} states**

Baryon spectroscopy

- The understanding of the internal quark-gluon structure of baryons is one of the most important tasks in both particle and nuclear physics.

- The systematic study of various baryon spectroscopy will provide us with critical insights into the nature of QCD in the confinement domain.

- The available experimental information is still poor, especially for the excited baryon states with two strange quarks, e.g., Ξ^*. Some phenomenological QCD-inspired models predict more than 30 such kinds of baryons, however only few are experimentally well settled.

  Totally only about 10% excited baryons are observed.

Study of light hadron spectroscopy

- Search for glueballs, hybrids and multi-quark states
- Systematic study of the light meson spectroscopy
- Study of the excited baryon states

Y(2175)

- **BaBar**
- **BES2**
- **BELLE**

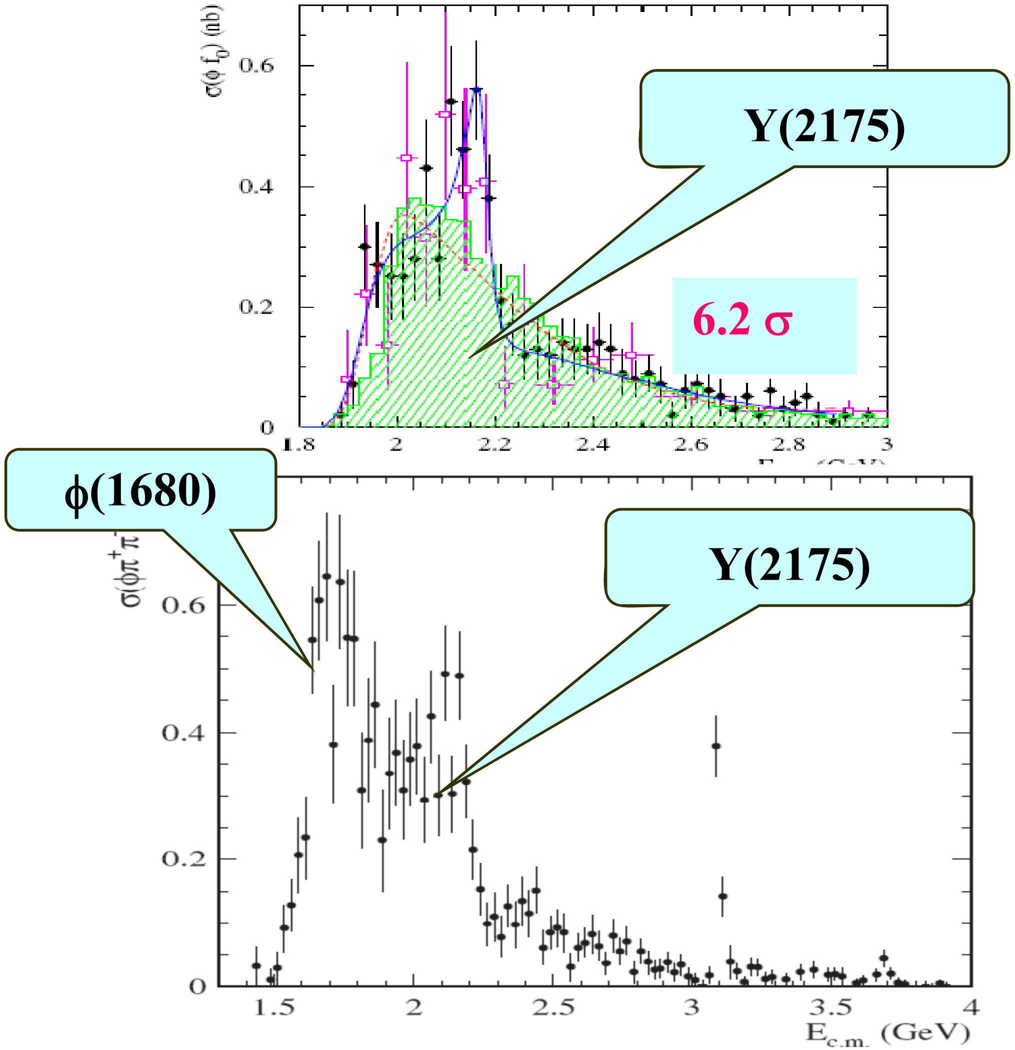
Observation of a new 1^{--} resonance Y(2175) at BaBar

BaBar Collaboration Home Page

- A structure at 2175MeV was observed in
  $e^+e^- \to \gamma_{ISR}\, \phi f_0(980)$,
  $e^+e^- \to \gamma_{ISR}\, K^+K^- f_0(980)$
  initial state radiation processes

$$M = 2175 \pm 10 \pm 15\ \text{MeV}$$

$$\Gamma = 58 \pm 16 \pm 20\ \text{MeV}$$

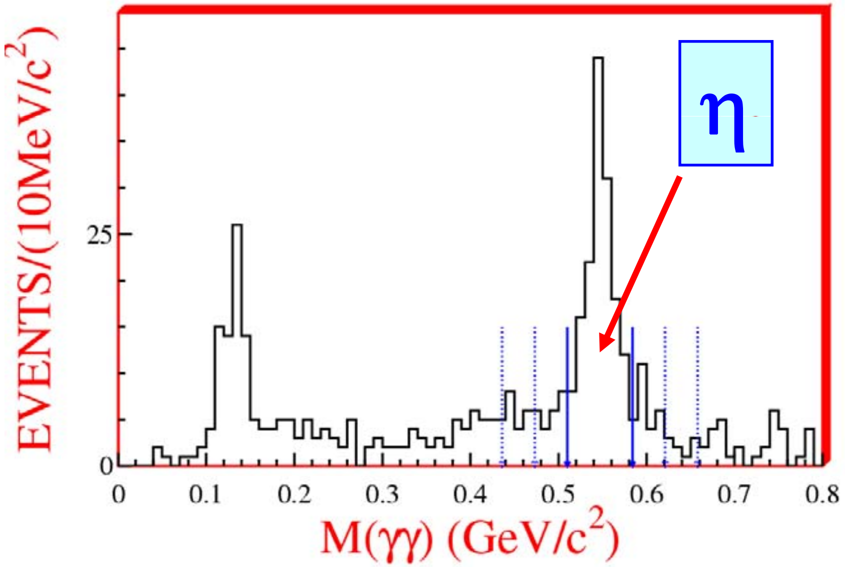


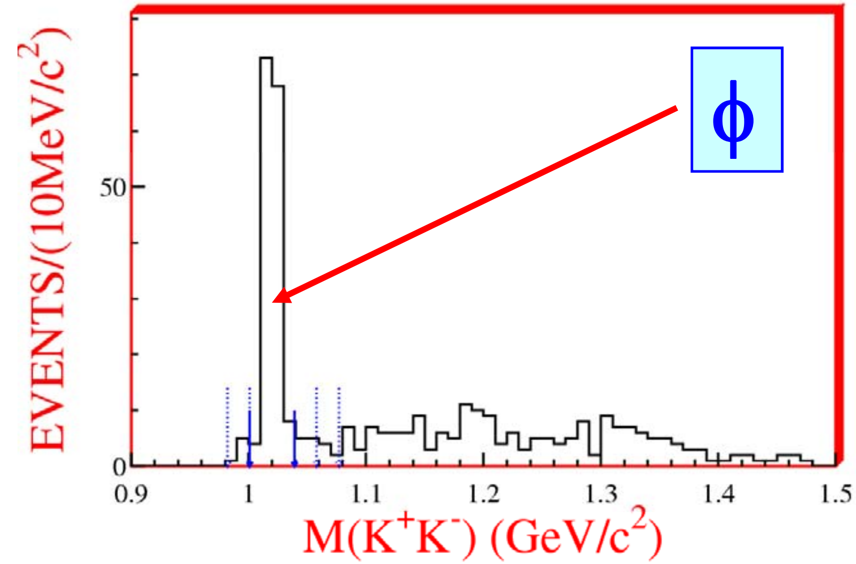
Phys. Rev. D 74 (2006) 091103(R)
Phys. Rev. D 76 (2007) 012008

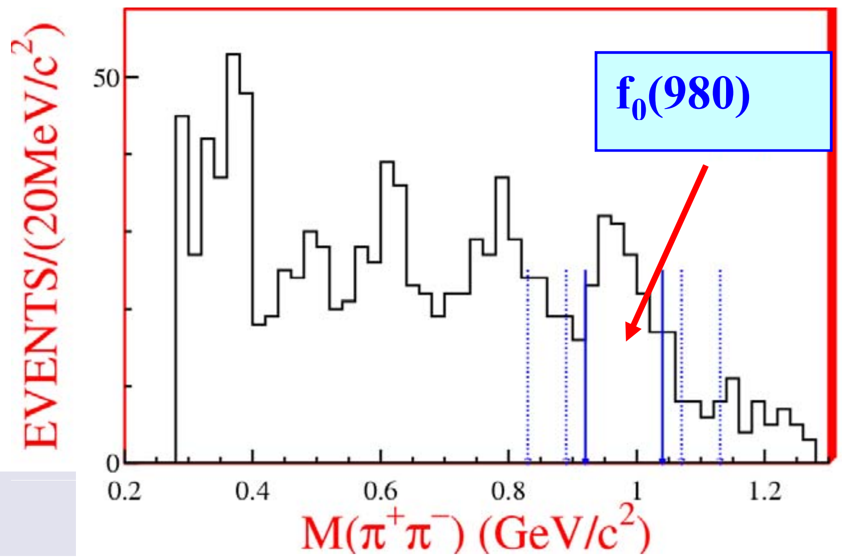
BESII: Y(2175) in $J/\psi \to \eta\phi f_0(980)$

Final states:

$\eta \rightarrow \gamma\gamma$, $\phi \rightarrow K^+K^-$, $f_0(980) \rightarrow \pi^+\pi^-$



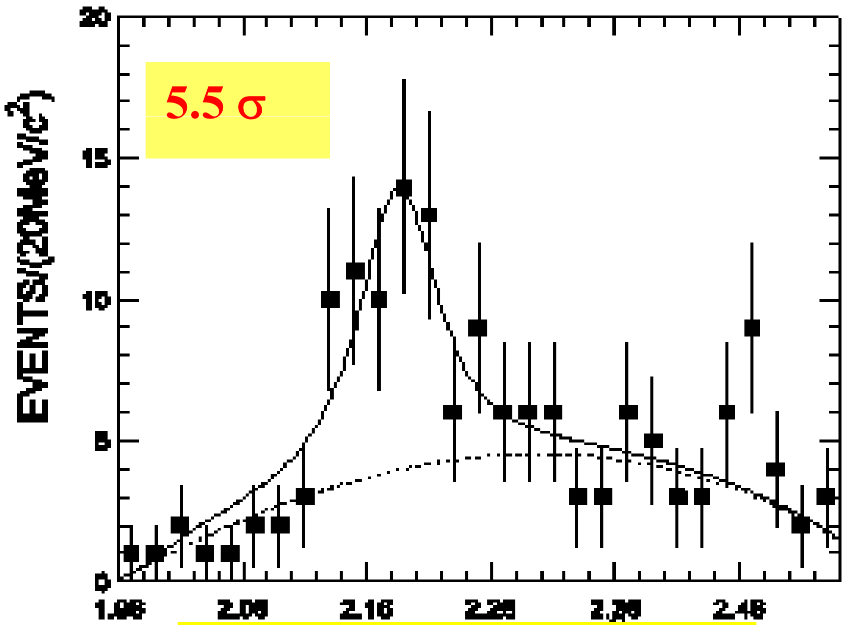




Define η, ϕ, $f_0(980)$ signal and sideband regions.

Phys. Rev. Lett., 100, 102003 (2008)

A peak around 2175 MeV/c^2 is observed in $J/\psi \rightarrow \eta\phi f_0(980)$



M =2.186 ± 0.010 GeV/c^2

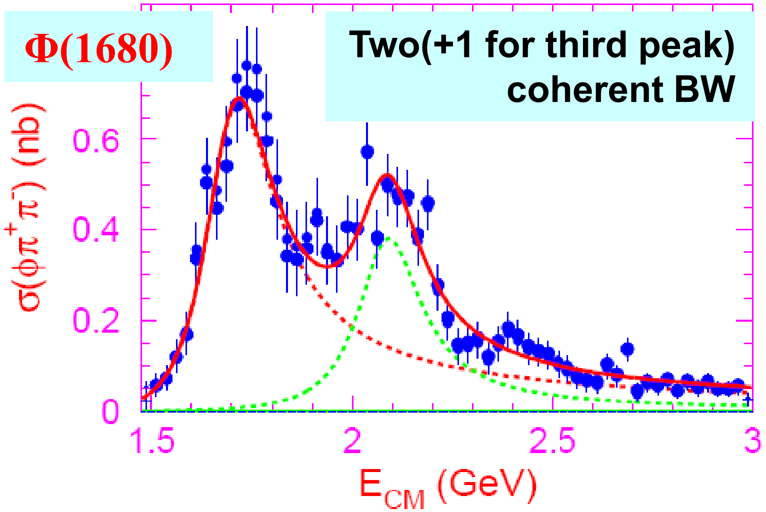
Γ=0.065 ± 0.023 GeV/c^2

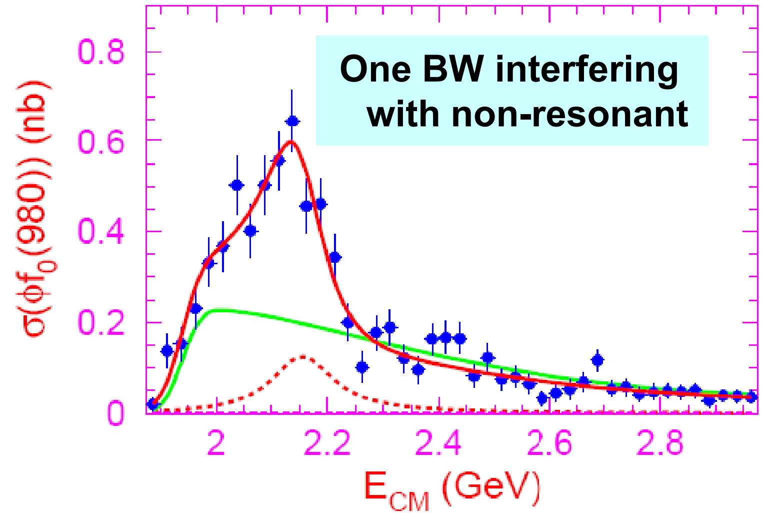
N_{events}= 52±12

$$B(J/\psi \to \eta Y(2175))B(Y(2175) \to \varphi f_0(980))B(f_0(980) \to \pi^+\pi^-) =$$
$$(3.23 \pm 0.75(stat) \pm 0.73(syst)) \times 10^{-4}$$

BELLE: $e^+e^- \rightarrow \gamma_{ISR}\, \phi\, \pi^+\pi^-$

673 fb^{-1}





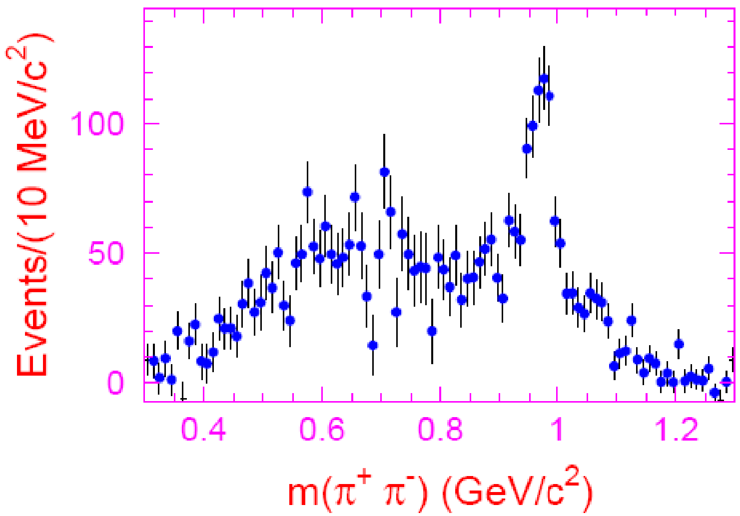
Fit results:

$M(\Phi(1680)) = 1687 \pm 21$ MeV/c^2

$\Gamma(\Phi(1680)) = 212 \pm 29$ MeV/c^2

$M(Y(2175)) = 2133^{+69}_{-115}$ MeV/c^2

$\Gamma(Y(2175)) = 169^{+105}_{-92}$ MeV/c^2



Belle: I. Adachi et al., arXiv:0808.0006

What is Y(2175)?

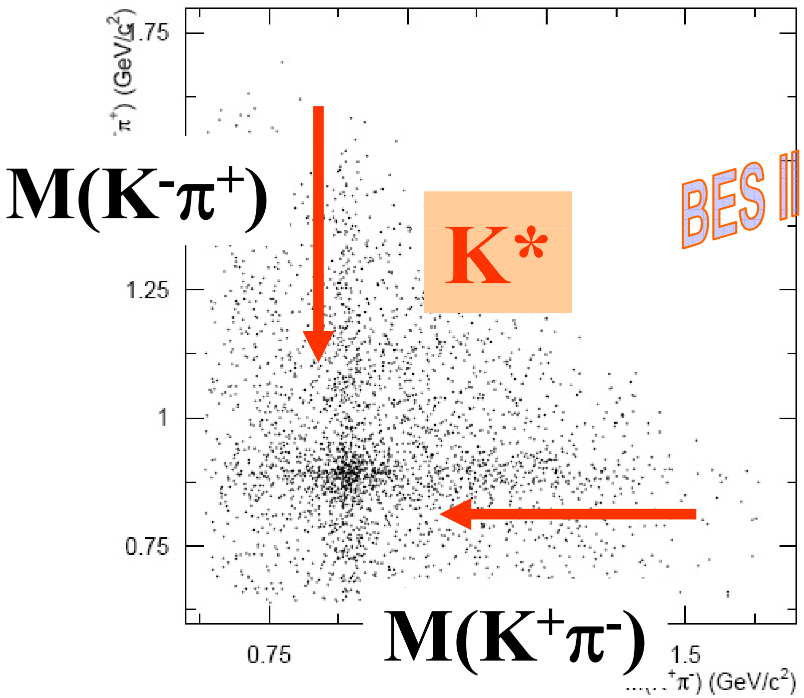
Some theoretical interpretations:

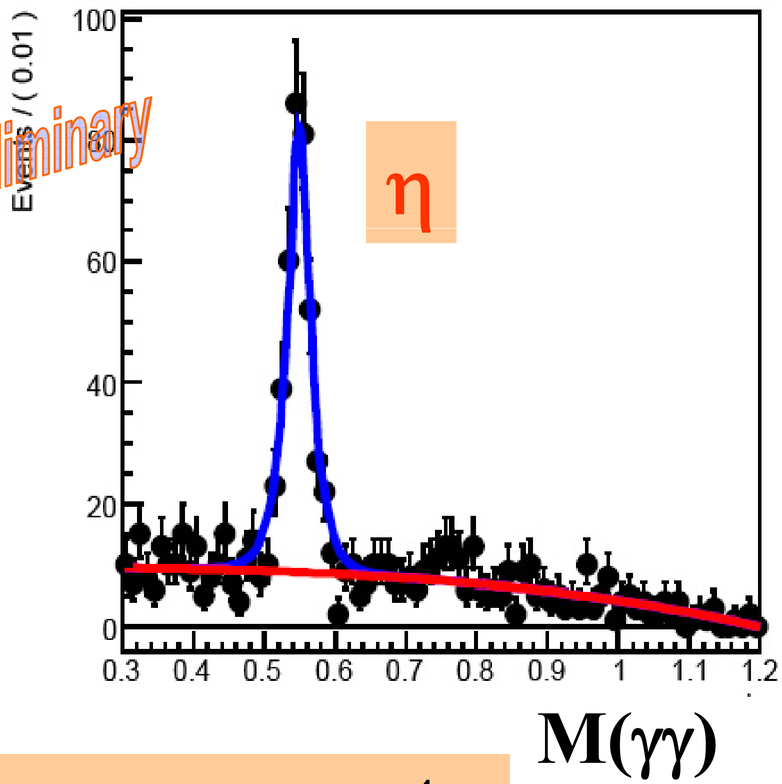
- A conventional $s\bar{s}$ state?
- An $s\bar{s}$ analog of Y(4260) ($s\bar{s}g$)?
- An $s\bar{s}s\bar{s}$ 4-quark state?

More experimental information needed.

To understand the nature of Y(2175), we are now working on $J/\psi \to \eta K^* \bar{K}^*$, $\eta \Lambda \bar{\Lambda}$, $\eta K \bar{K}$, …

BESII: Y(2175) in $J/\psi \to \eta K^{*0} \bar{K}^{*0}$?

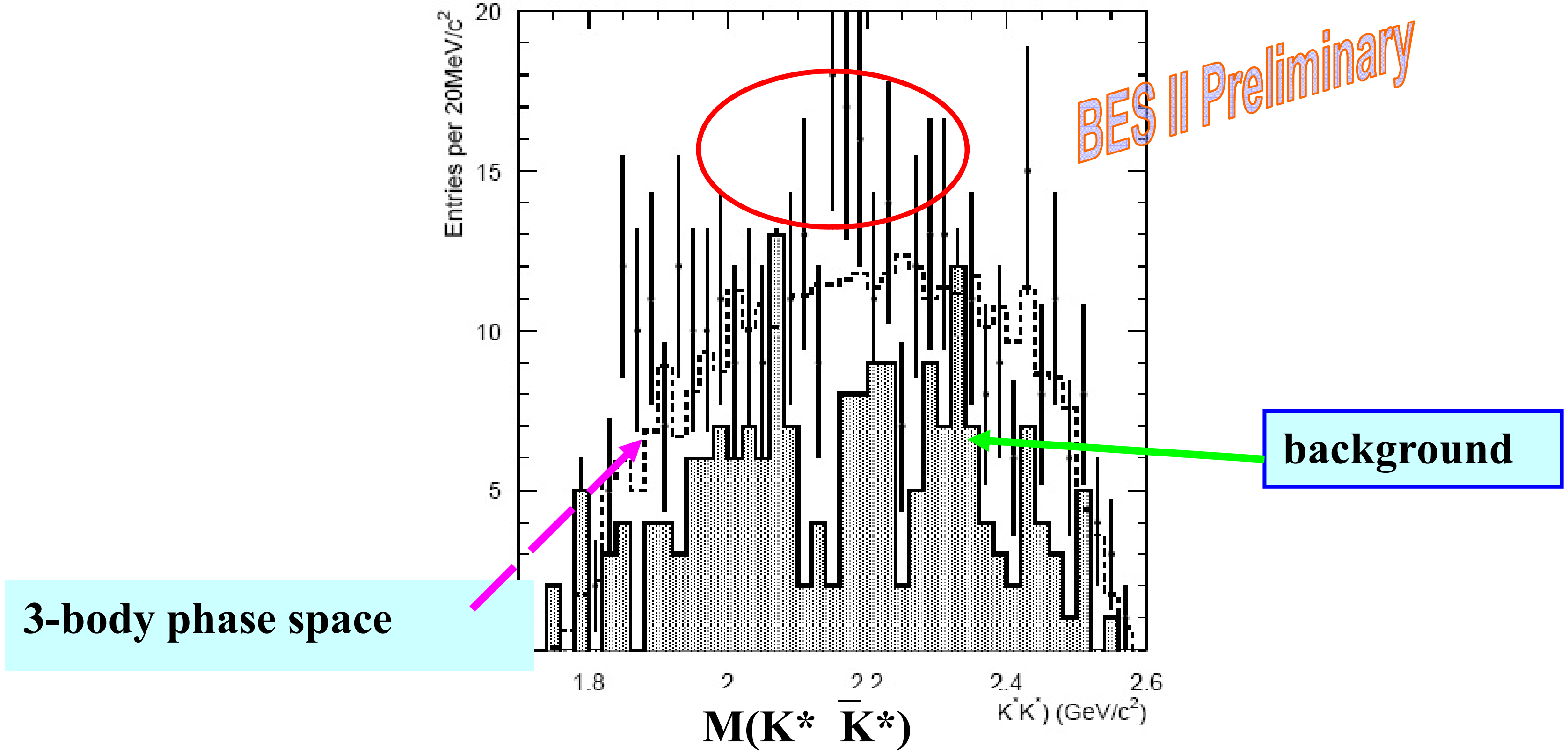




$B(J/\psi \to \eta K^* \bar{K}^*) = (7.7 \pm 0.8 \pm 1.4) \times 10^{-4}$

First measured.

$K^{*0}\ \bar{K}^{*0}$ invariant mass in $J/\psi \to \eta K^{*0}\ \bar{K}^{*0}$



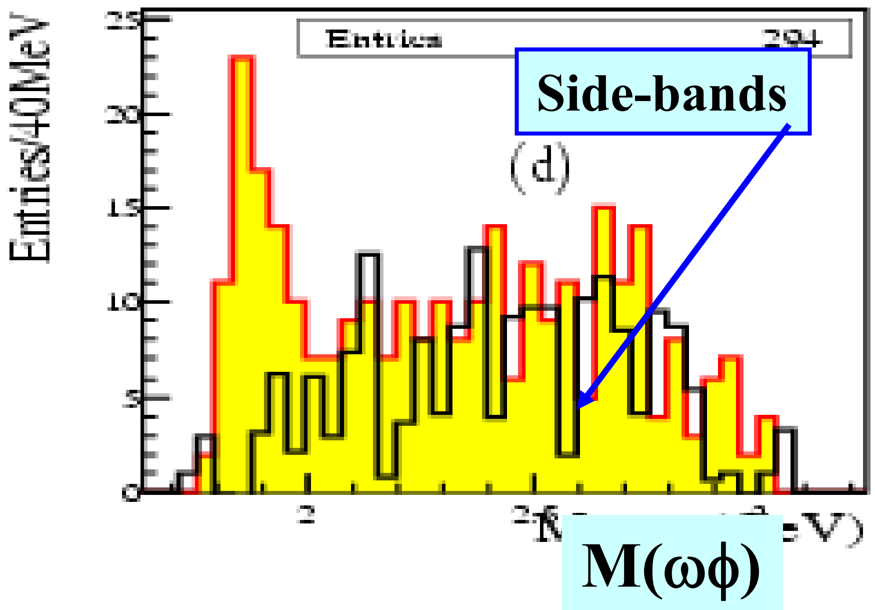
Upper limit @ 90% C.L.

$B(J/\psi \to \eta Y(2175))B(Y(2175) \to K^*\ \bar{K}^*) < 2.52 \times 10^{-4}$

X(1812)

- **BES2**
- **BELLE**

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



PRL 96 (2006) 162002

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

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

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

X(1812) favors 0^{++} over 0^{-+} and 2^{++}

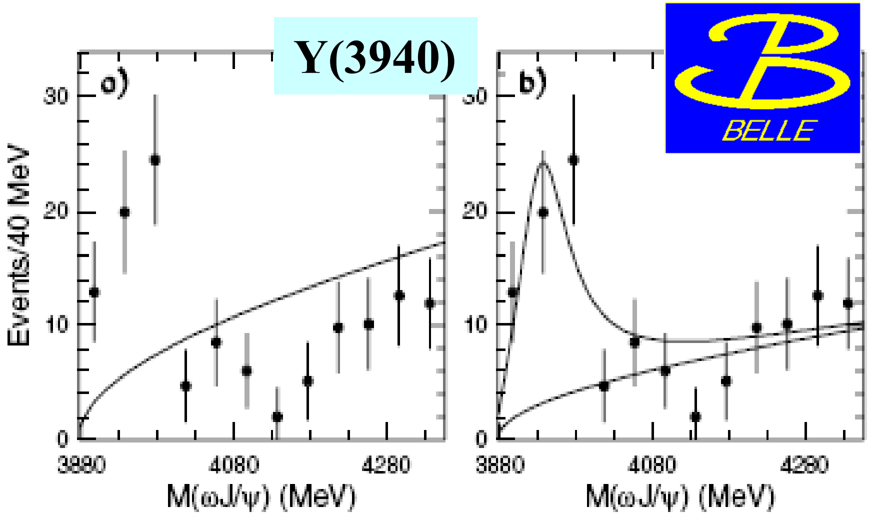
Same 0^{++} observed in γKK or $\phi\pi\pi$ ($f_0(1710)$, or $f_0(1790)$), or is it a glueball, hybrid, tetraquark state, threshold cusp …..?

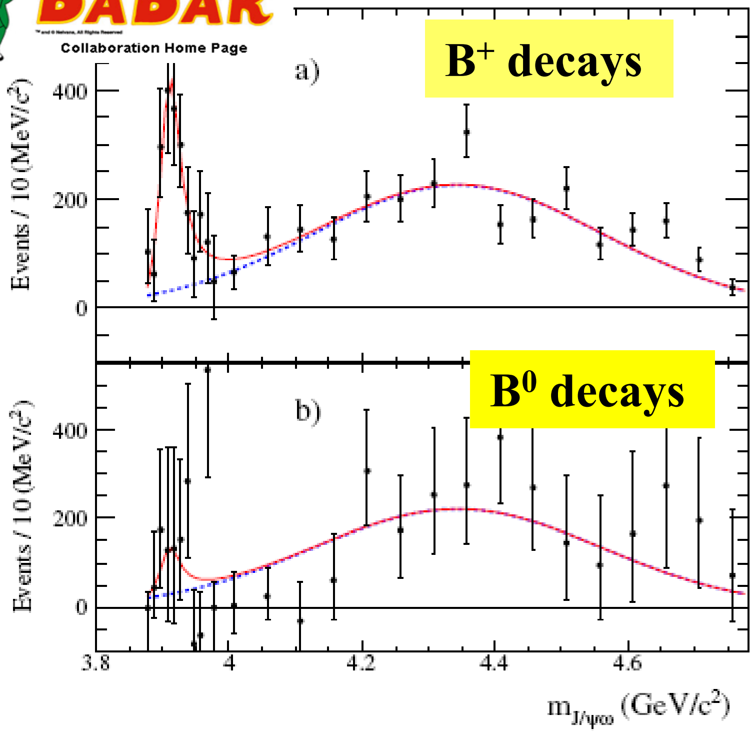
Further look in $\omega\omega$, K^*K^*, $\phi\phi$ …. is desirable !

BELLE: Search for X(1812) in $B^{\pm} \rightarrow K^{\pm}\,\omega\phi$

BELLE observed $\omega J/\psi$ threshold enhancement in $B^{\pm} \rightarrow K^{\pm}\,\omega J/\psi$

PRL 94 (2005) 182002





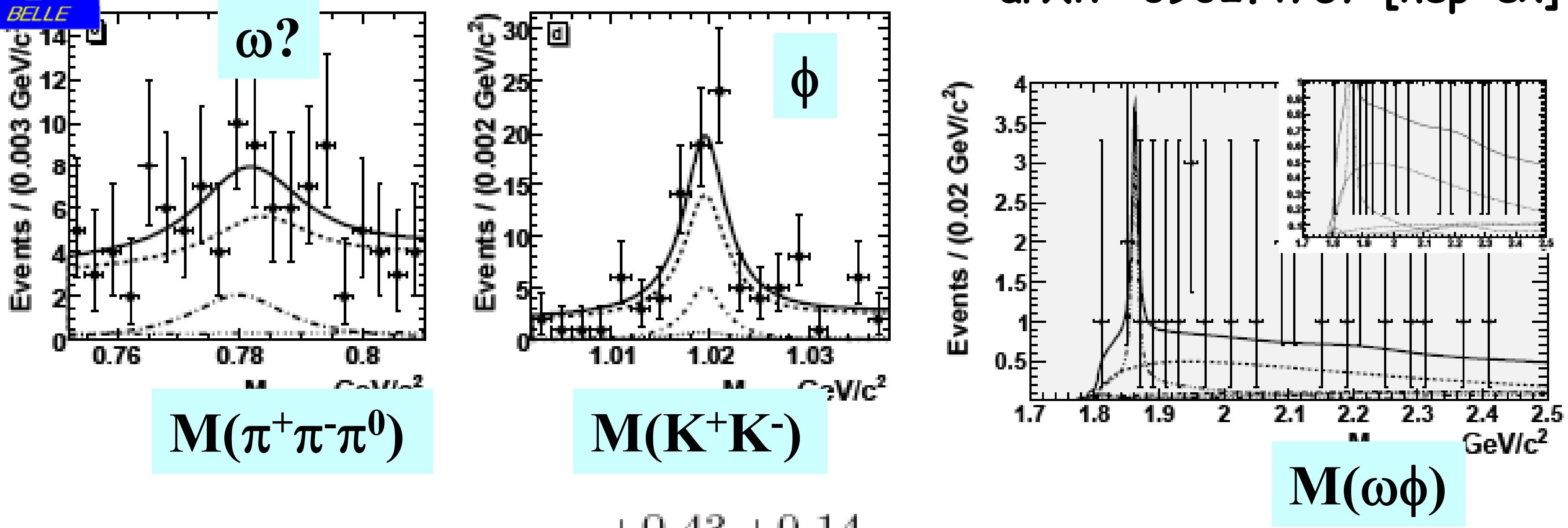
BaBar confirmed $\omega J/\psi$ threshold enhancement in $B^{0,+} \rightarrow K^{0,+}\,\omega J/\psi$

PRL 101 (2005) 082001

BELLE: Search for X(1812) in $B^{\pm} \to K^{\pm}\,\omega\phi$

605 fb^{-1}

arXiv: 0902.4757 [hep-ex]



$$\mathcal{B}(B^{\pm} \to K^{\pm}\omega\phi) = (1.15\,^{+0.43}_{-0.38}\,^{+0.14}_{-0.13}) \times 10^{-6}$$

$$\mathcal{B}(B^{\pm} \to K^{\pm}\omega\phi) < 1.9 \times 10^{-6}$$

- **No significant signal is observed in $\omega\phi$ mass spectrum.**

$$B(B \to K^{\pm} X(1812)) \cdot B(X(1812) \to \omega\phi) < 3.2 \times 10^{-7}\ (90\%\ \text{C.L.})$$

Study of the light scalars

- There have been hot debates on the existence of σ and κ .
- σ, κ, $f_0(980)$ and $a_0(980)$ are possible mutiquark states. They are all near threshold.
- Lattice QCD predicts the 0^{++} scalar glueball mass ~ 1.6 GeV. $f_0(1500)$ and $f_0(1710)$ are good candidates.

(KLOE and BESII experiments)

KLOE: Scalars in ϕ decays

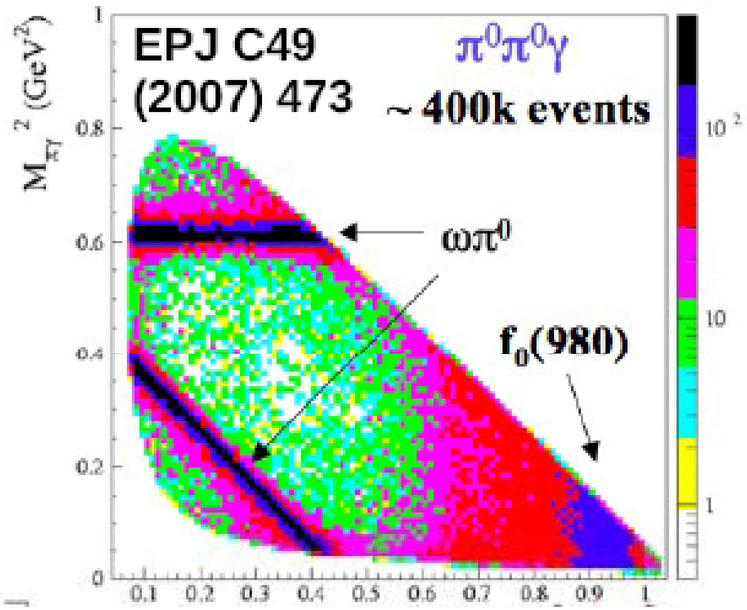
$e^+e^- \to \phi \to (f_0 + \sigma)\gamma \to \pi^0\pi^0\gamma, \pi^+\pi^-\gamma$

Talk by B. D. Micco
at Phi to Psi 2008

$e^+e^- \to \phi \to a_0\gamma \to \eta\pi^0\gamma$

Nucl. Phys. B (Proc. Suppl.) 186 (2009) 290

$e^+e^- \to \phi \to (a_0 + f_0)\gamma \to K^0\overline{K^0}\gamma \to K_sK_s\gamma$

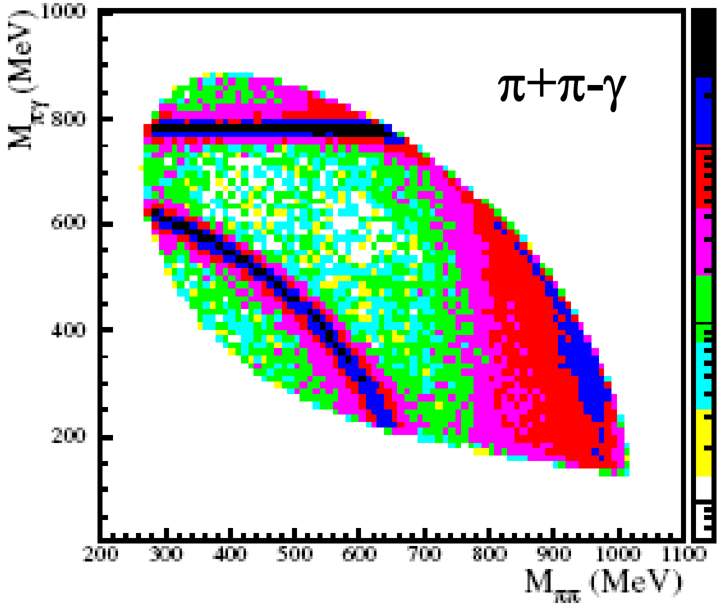


- Dalitz plot fit to $\gamma\pi^0\pi^0$ gives the parameters of f_0

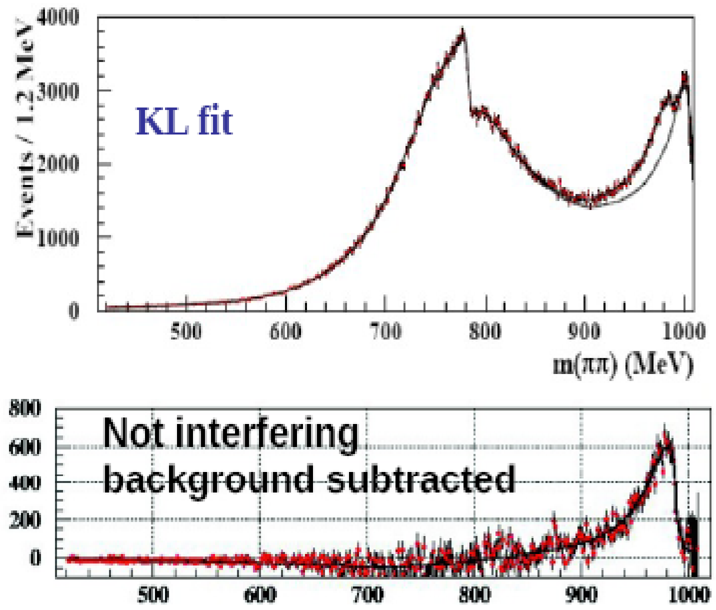
Fit result	
M_{f0} =	984.7 ± 1.9 MeV
g_{f0K+K-} =	3.97 ± 0.43 GeV
$g_{f0\pi+\pi-}$ =	–1. 82 ± 0.19 GeV

- σ is needed in the fit.

KLOE: Scalars in ϕ decays



Nucl. Phys. B (Proc. Suppl.) 186 (2009) 290



Fit result $P(\chi^2) = 2.5\%$

M_{f0} = 983.7 MeV

g_{f0K+K-} = 4.74 GeV

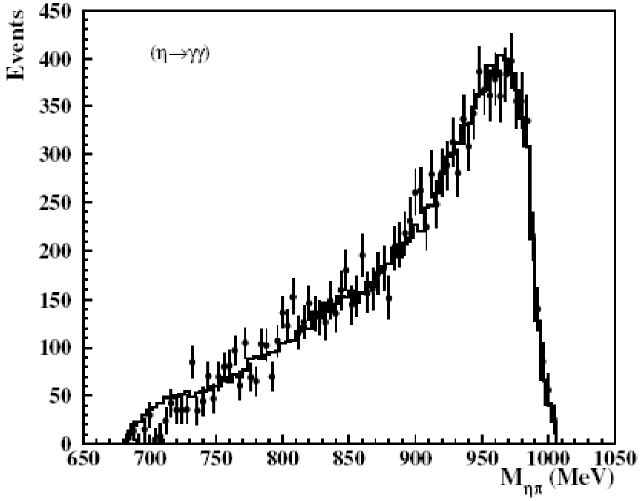
$g_{f0\pi+\pi-}$ = -2.22 GeV

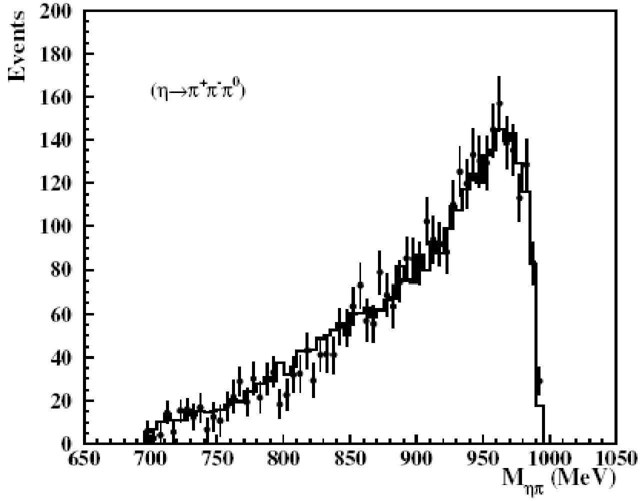
σ is also included in the Dalitz plot fit.

KLOE: Scalars in ϕ decays

$e^+e^- \rightarrow \phi \rightarrow a_0\gamma \rightarrow \eta\pi^0\gamma$

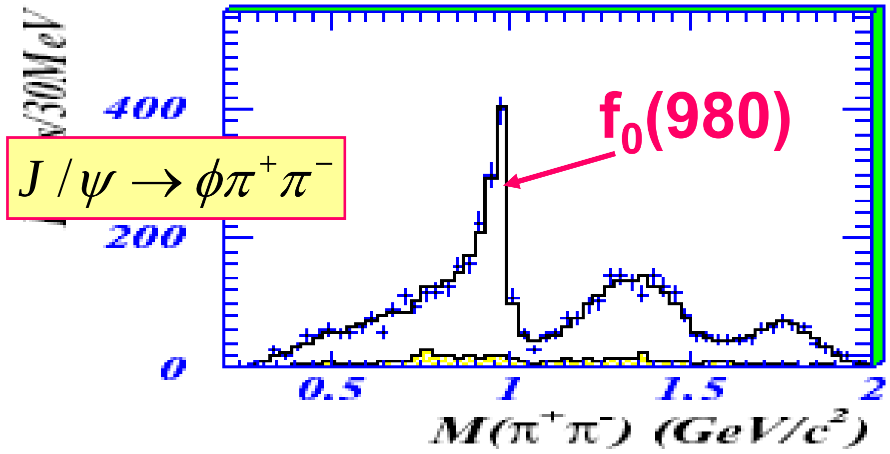
Nucl. Phys. B (Proc. Suppl.) 186 (2009) 290

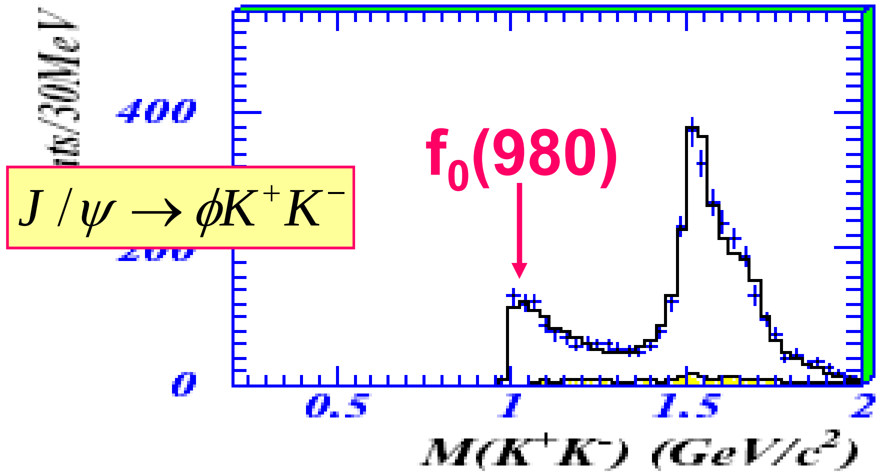




Parameter	K_L fit
m_{a_0} (MeV)	$982.5 \pm 1.3 \pm 2.7$
$g_{a_0K^+K^-}$ (GeV)	$2.15 \pm 0.05 \pm 0.17$
$g_{a_0\eta\pi}$ (GeV)	$2.82 \pm 0.04 \pm 0.12$

BESII: $f_0(980)$





- **Important parameters from PWA fit:**

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

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

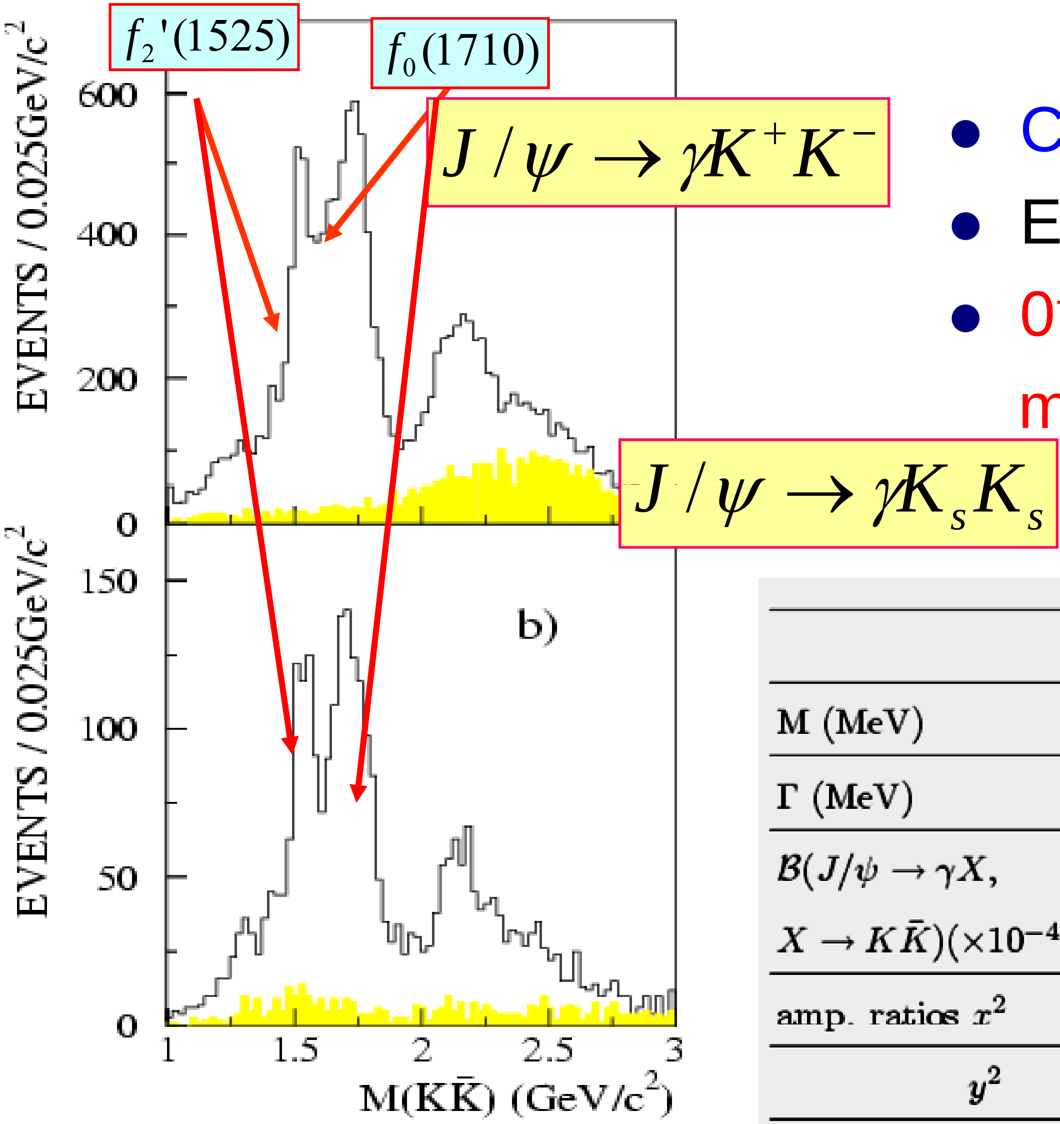
$$\left(\frac{g_{KK}}{g_{\pi\pi}}\right)^2 = 4.21 \pm 0.25 \pm 0.21$$

- **Large coupling with KK indicates big $s\bar{s}$ component in $f_0(980)$**

Phys. Lett. B 607 (2005) 243

$(g_{f0K+K-}/g_{f0\pi+\pi-})^2$		Theoretical predictions		
Exps.		4q	$f_0=s\bar{s}$	$f_0=n\bar{n}$
KLOE (2009)	4.8±1.4	>>1	>>1	1/4
CMD-2 (1999)	3.61±0.62			
SND (2000)	4.6±0.8			
BESII (2005)	4.21±0.33			
$(g_{f0K+K-}/g_{a0K+K-})^2$		Theoretical predictions		
KLOE	3.4±0.8	1	2	1

BESII: $f_0(1500)$ and $f_0(1710)$



- Clear $f_2^{'}(1525)$ signal.
- Evidence of $f_2(1270)$.
- 0^{++} dominant in 1.7GeV mass region

	$f_2'(1525)$	$f_0(1710)$
M (MeV)	$1519 \pm 2^{+15}_{-5}$	$1740 \pm 4^{+10}_{-25}$
Γ (MeV)	$75 \pm 4^{+15}_{-5}$	166^{+5+15}_{-8-10}
$\mathcal{B}(J/\psi \to \gamma X,$ $X \to K\bar{K})(\times 10^{-4})$	$3.42 \pm 0.15^{+0.69+1.55}_{-0.65-0.00}$	$9.62 \pm 0.29^{+2.11+2.81}_{-1.86-0.00}$
amp. ratios x^2	$1.00 \pm 0.28^{+1.06}_{-0.36}$	—
y^2	$0.44 \pm 0.08^{+0.10}_{-0.56}$	—

J/ψ→γππ PWA results

- Lower 0^{++} : 0^{++} is strongly preferred over 2^{++}

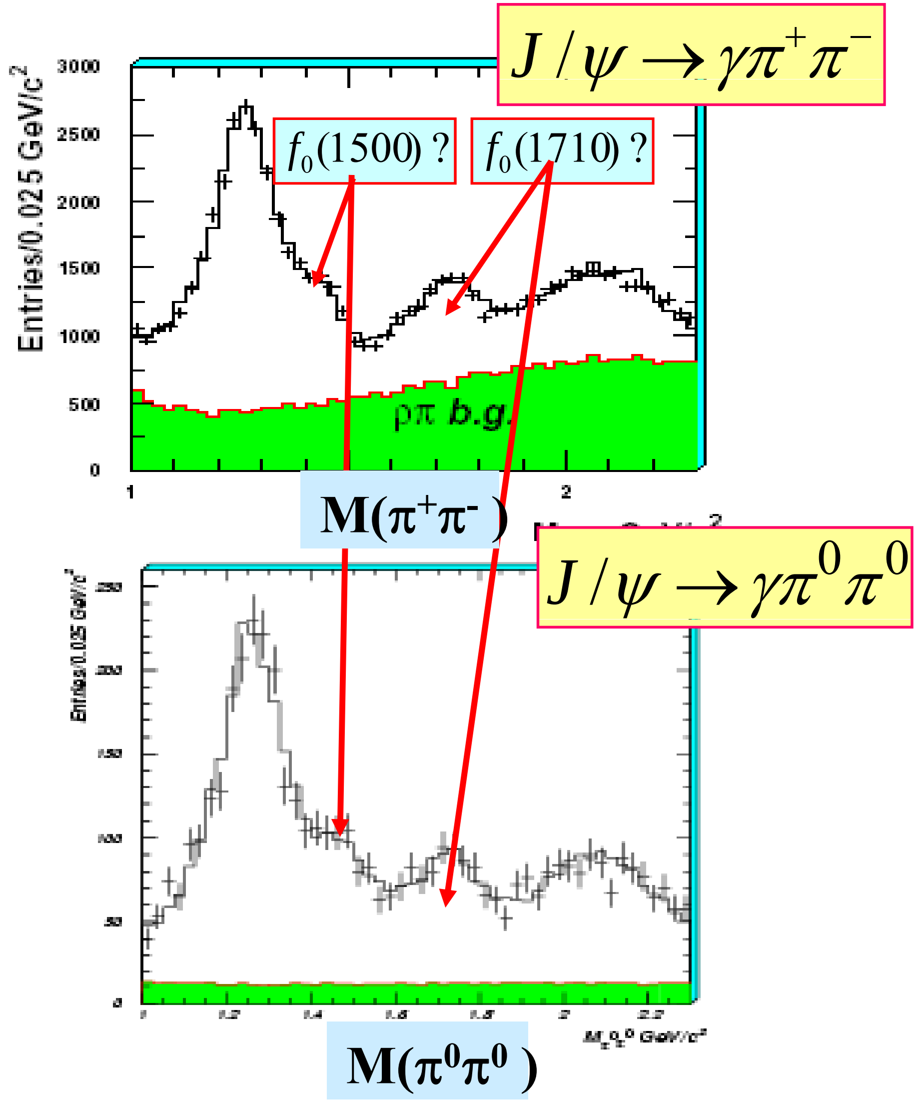
$f_0(1500)$:

$$M = (1466 \pm 6 \pm 16)\ \text{MeV}$$
$$\Gamma = (108^{+14}_{-11} \pm 21)\ \text{MeV}$$

- $f_0(1370)$ cannot be excluded

- Higher 0^{++}: $f_0(1710)$ or $f_0(1790)$ or both?

$$M = (1765^{+4}_{-3} \pm 11)\ \text{MeV}$$
$$\Gamma = (145 \pm 8 \pm 23)\ \text{MeV}$$



About f_0(1500) and f_0(1710)

- It is first clearly observed in J/ψ radiative decays.
- Its production rate in J/ψ radiative decays:

$$BR(J/\psi \to \gamma f_0(1500)) \bullet BR(f_0(1500) \to \pi\pi) \sim 1 \times 10^{-4}$$
$$(BESII)$$

$$BR(f_0(1500) \to \pi\pi) \sim 35\%$$
$$(PDG)$$

$$\Longrightarrow \quad BR(J/\psi \to \gamma f_0(1500)) \sim 3 \times 10^{-4}$$

- **The production rate of $f_0(1500)$ in J/ψ radiative decays is lower than that of $f_0(1710)$:**

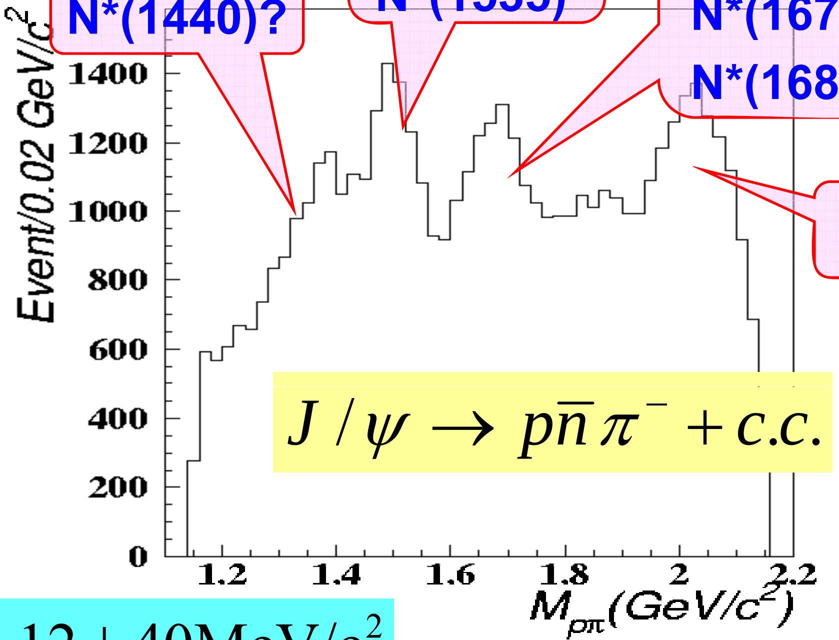
$$BR(J/\psi \rightarrow \gamma f_0(1500)) \sim 3\times10^{-4}$$

$$BR(J/\psi \rightarrow \gamma f_0(1710)) > 9\times10^{-4}$$
$$(PDG)$$

- **It may indicate: $f_0(1710)$ has stronger coupling to gluons than $f_0(1500)$ → which one contains more glueball content?**

BESII: observation of N(2050)

- Quark model predicts N(2050).
- Not observed.



N(2050): 1/2⁺ or 3/2⁺

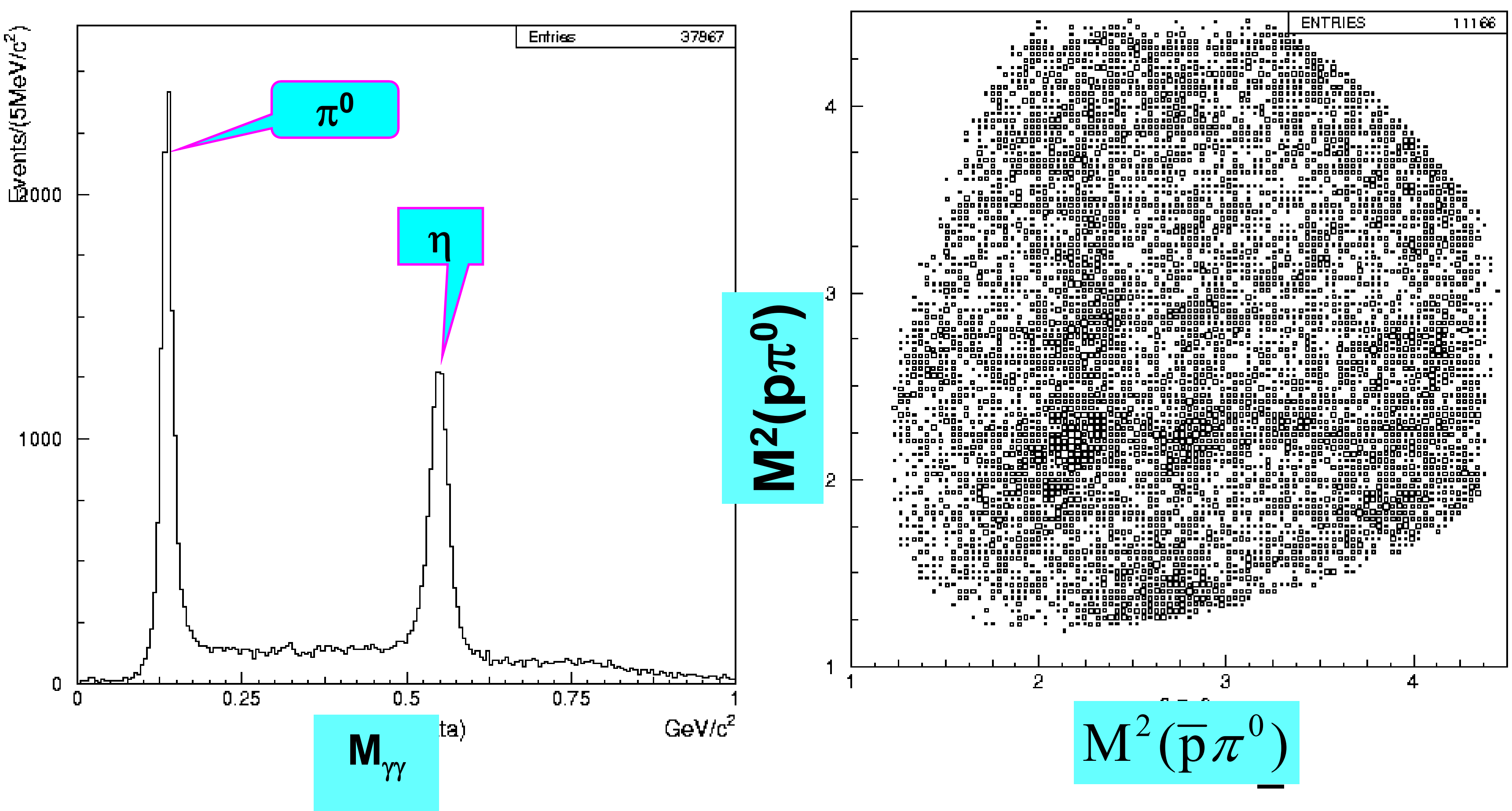
$$M = 2065 \pm 3^{+15}_{-30} \mathrm{MeV/c^2} \quad \Gamma = 175 \pm 12 \pm 40 \mathrm{MeV/c^2}$$

N(1440): （N(1440) peak: never be found before)

$$M = 1358 \pm 6 \pm 16 \,\mathrm{MeV/c^2}, 179 \pm 26 \pm 50 \,\mathrm{MeV/c^2}$$

Phys. Rev. Lett. 97 （2006）062001

BESII: PWA of $J/\psi \to p\bar{p}\pi^0$

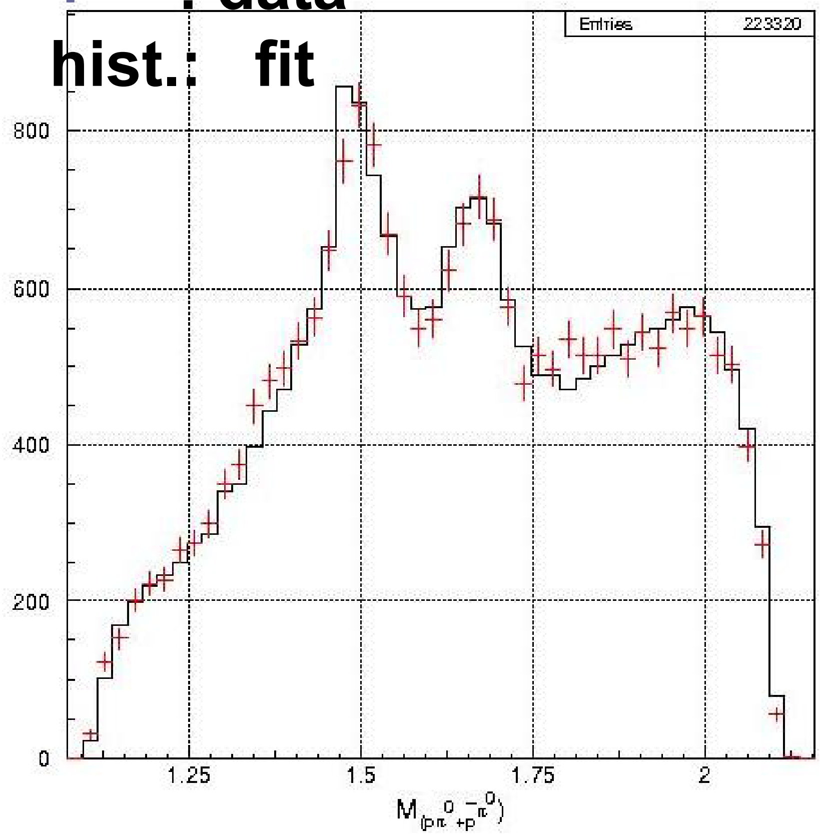


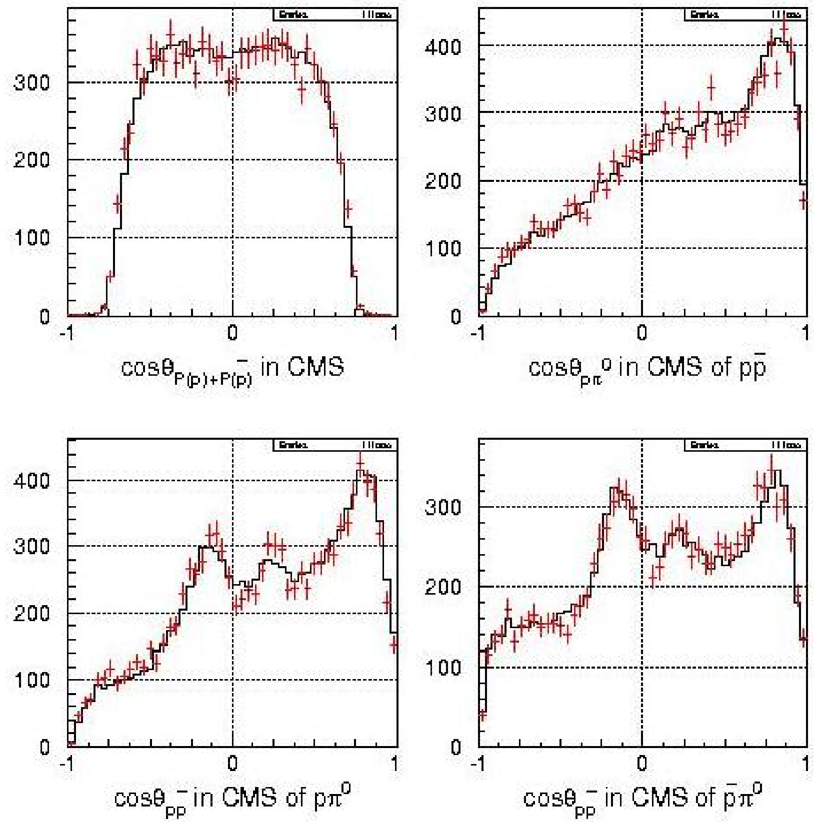
Resonances used in the PWA

Resonance	Mass(MeV)	Width(MeV)	J^P	C.L.
N(940)	940	0	$\frac{1}{2}^+$	off-shell
N(1440)	1440	350	$\frac{1}{2}^+$	****
N(1520)	1520	125	$\frac{3}{2}^-$	****
N(1535)	1535	150	$\frac{1}{2}^-$	****
N(1650)	1650	150	$\frac{1}{2}^-$	****
N(1675)	1675	145	$\frac{5}{2}^-$	****
N(1680)	1680	130	$\frac{5}{2}^+$	****
N(1700)	1700	100	$\frac{3}{2}^-$	***
N(1710)	1710	100	$\frac{1}{2}^+$	***
N(1720)	1720	150	$\frac{3}{2}^+$	****
Nx(1885)	1885	160	$\frac{3}{2}^-$	'Missing' N^*
N(1900)	1900	498	$\frac{3}{2}^+$	**
N(2000)	2000	300	$\frac{5}{2}^+$	**
Nx(2065)	2065	150	$\frac{3}{2}^+$	'Missing' N^*
N(2080)	2080	270	$\frac{3}{2}^-$	**
N(2090)	2090	300	$\frac{1}{2}^-$	*
N(2100)	2100	260	$\frac{1}{2}^+$	*

Comparison of data with fit results

+ : data
hist.: fit





- N(1440), N(1520), N(1535), N(1650), N(1675), N(1680), N(1710) are needed.

- Nx(2065) exists in this channel (stat. sig. >>5σ)
  The spin-parity favors 3/2+

$$M = 2040^{+3}_{-4} \pm 25\ \text{MeV},\ \Gamma = 230 \pm 8 \pm 52\ \text{MeV}$$

N*	M(MeV/c²)	Γ(MeV/c²)	J^P	fraction(%)	Br (×10⁻⁴)
N(1440)	$1455^{+2}_{-7} \pm 43$	$316^{+5}_{-6} \pm 67$	1/2+	9.74~25.93	1.33~3.54
N(1520)	$1513^{+3}_{-4} \pm 13$	$127^{+7}_{-8} \pm 37$	3/2-	2.38~10.92	0.34~1.54
N(1535)	$1537^{+2}_{-6} \pm 12$	$135^{+8}_{-8} \pm 39$	1/2-	6.83~15.58	0.92~2.10
N(1650)	$1650^{+3}_{-6} \pm 26$	$145^{+5}_{-10} \pm 31$	1/2-	6.89~27.94	0.91~3.71
N(1710)	$1715^{+2}_{-2} \pm 29$	$95^{+2}_{-1} \pm 44$	1/2+	4.17~30.10	0.54~3.86
N(2065)	$2040^{+3}_{-4} \pm 25$	$230^{+8}_{-8} \pm 52$	3/2+	23.0~41.8	0.91~3.11

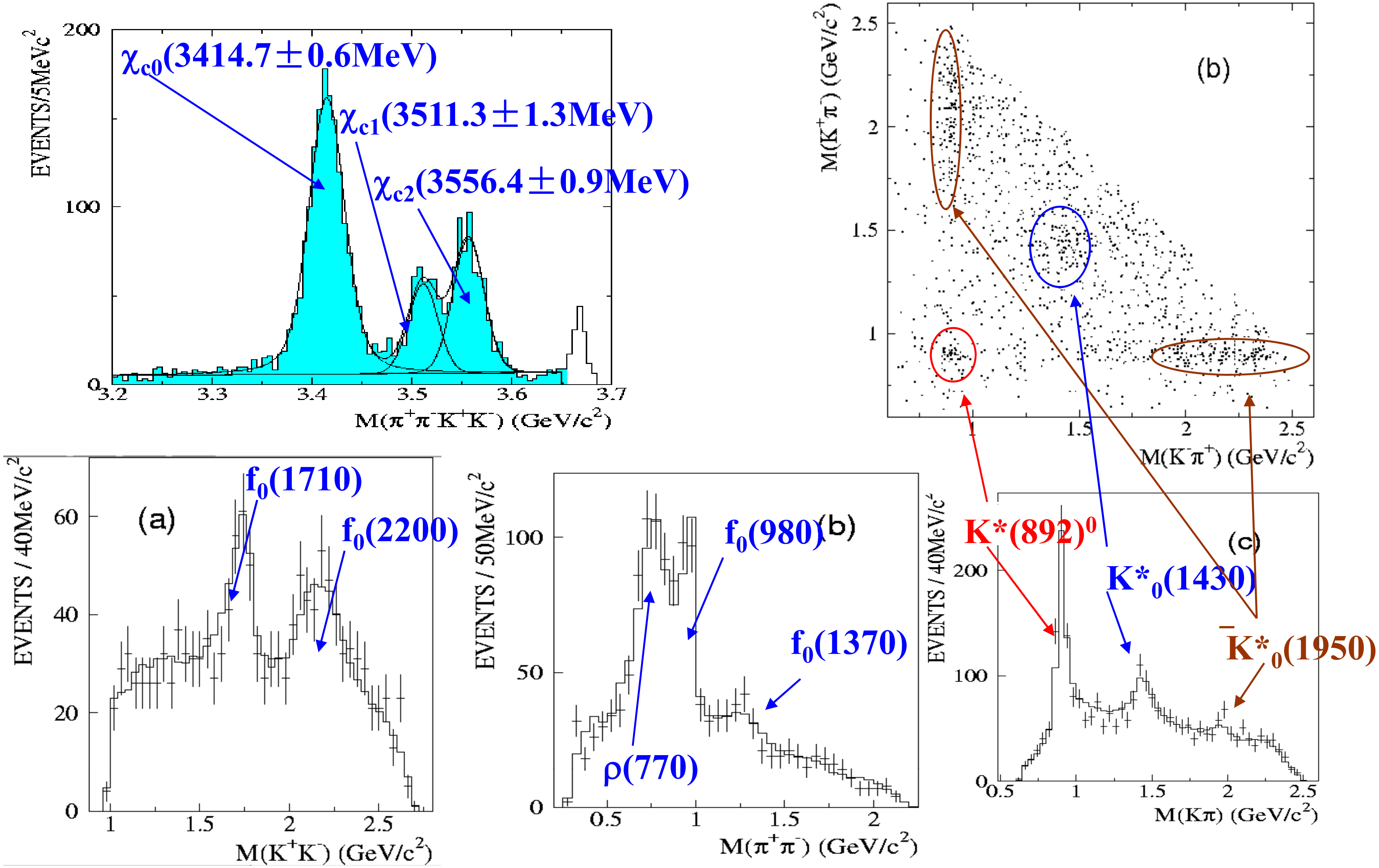
Study of the light hadron spectroscopy from χ_{cJ} decays

- The decays of χ_{cJ} (esp. χ_{c0} and χ_{c2}), provide a direct window on glueball dynamics in 0^{++} and 2^{++} channels, as the χ_{cJ} hadronic decays may proceed via $c\bar{c} \rightarrow g\,g \rightarrow (q\,\bar{q})(q\,\bar{q})$

- Amplitude analysis of χ_{cJ} decay is an excellent tool to investigate the intermediate resonant decay modes

BESII: PWA of $\chi_{c0} \to \pi^+\pi^-K^+K^-$

PRD 72, 092002 (2005)



BESII: PWA of $\chi_{c0} \to \pi^+\pi^-K^+K^-$

PRD 72, 092002 (2005)

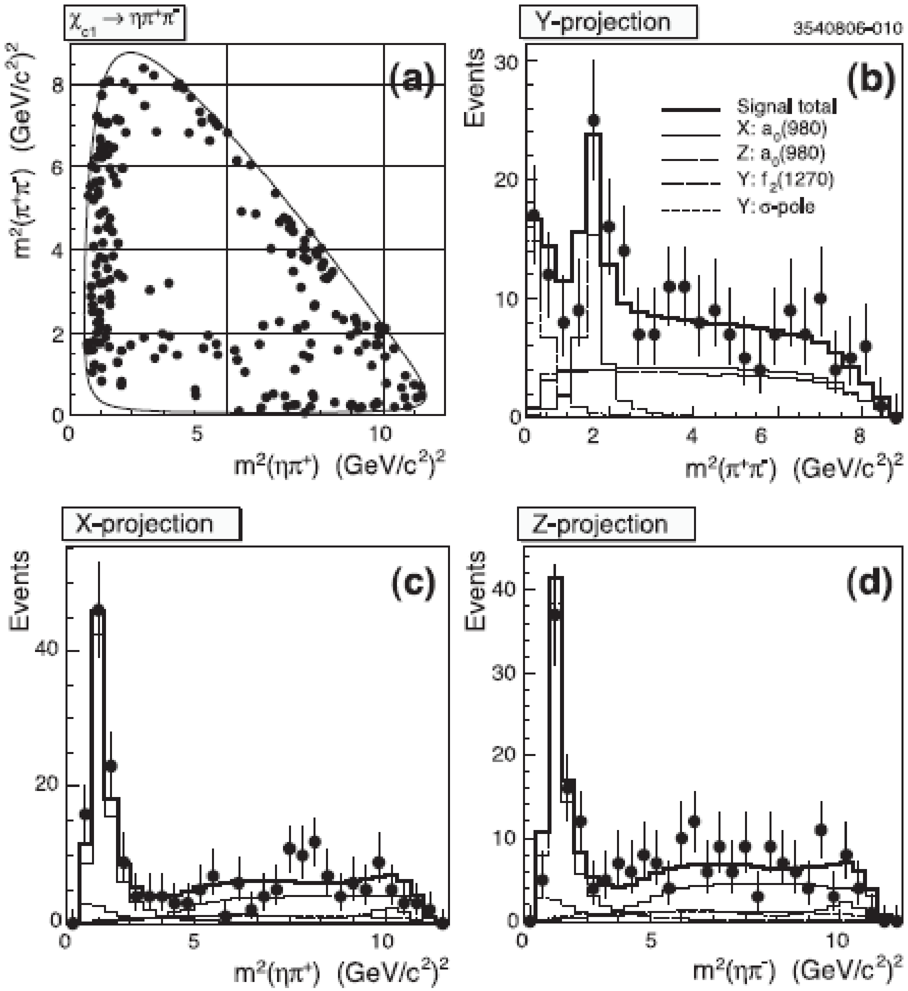
	N^{obs}	ϵ (%)	Sys. error (%)	$\mathcal{B}(\chi_{c0} \to X \to \pi^+\pi^-K^+K^-)$ ($\times 10^{-4}$)	s.s.
$f_0(980)f_0(980)$	27.9 ± 6.7	6.25 ± 0.01	$^{+55.7}_{-45.3}$	$3.46 \pm 0.83^{+1.93}_{-1.57}$	5.3σ
$f_0(980)f_0(2200)$	77.1 ± 10.6	7.09 ± 0.01	$^{+19.6}_{-27.2}$	$8.42 \pm 1.16^{+1.65}_{-2.29}$	7.1σ
$f_0(1370)f_0(1710)$	60.6 ± 12.4	6.59 ± 0.01	$^{+46.1}_{-23.6}$	$7.12 \pm 1.46^{+3.28}_{-1.68}$	6.5σ
$K^*(892)^0\bar{K}^*(892)^0$	64.5 ± 9.9	6.18 ± 0.01	$^{+28.3}_{-24.6}$	$8.09 \pm 1.24^{+2.29}_{-1.99}$	7.1σ
$K_0^*(1430)\bar{K}_0^*(1430)$	82.9 ± 12.5	6.15 ± 0.01	$^{+29.2}_{-18.2}$	$10.44 \pm 1.57^{+3.05}_{-1.90}$	7.2σ
$K_0^*(1430)\bar{K}_2^*(1430) + c.c.$	62.0 ± 10.7	5.66 ± 0.01	$^{+15.6}_{-23.4}$	$8.49 \pm 1.47^{+1.32}_{-1.99}$	8.7σ
$K_1(1270)^\pm K^\mp \to K^\pm \rho K^\mp$	68.3 ± 11.0	5.68 ± 0.01	$^{+19.4}_{-17.6}$	$9.32 \pm 1.50^{+1.81}_{-1.64}$	8.6σ
$K_1(1400)^\pm K^\mp \to K^{*0}\pi^\pm K^\mp$	19.7 ± 6.9	4.94 ± 0.01	$^{+219}_{-24.5}$	< 11.9 (90% C.L.)	2.7σ

χ_{cJ} decays provide good place for the study of the light mesons.

CLEO (3M ψ'): Dalitz plot analyses of $\chi_{c1} \rightarrow \pi^0 K^+ K^-$, $\eta\pi^+\pi^-$ and $\pi^+ K^- K_s^0$

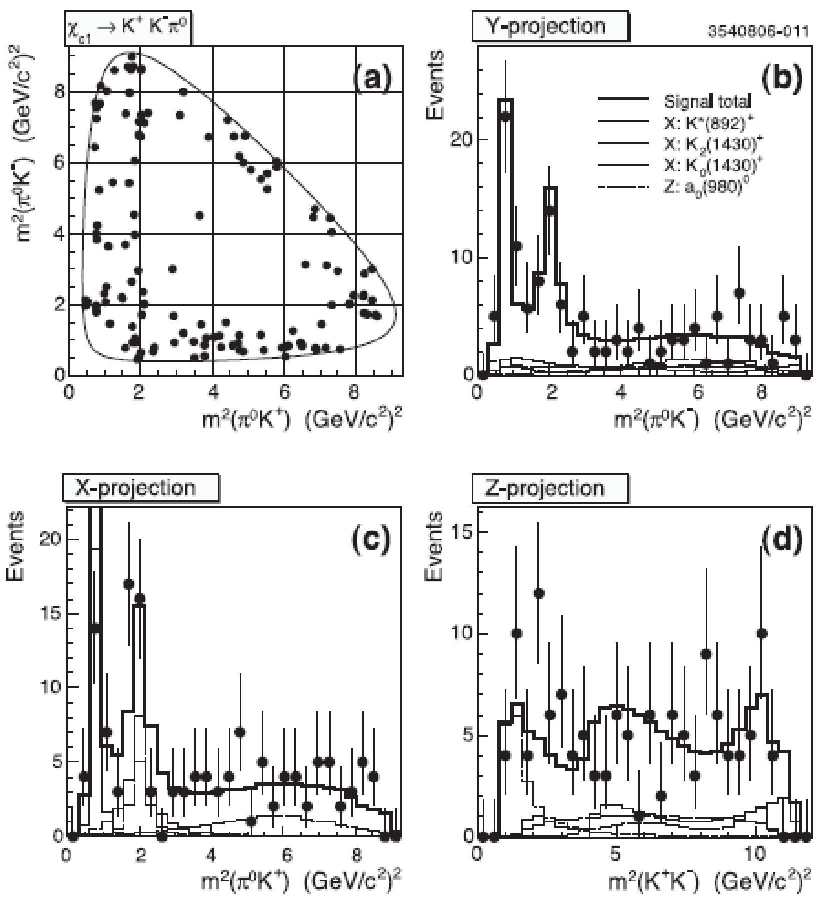
$\chi_{c1} \rightarrow \eta\pi^+\pi^-$

PRD 72, 032002 (2007)

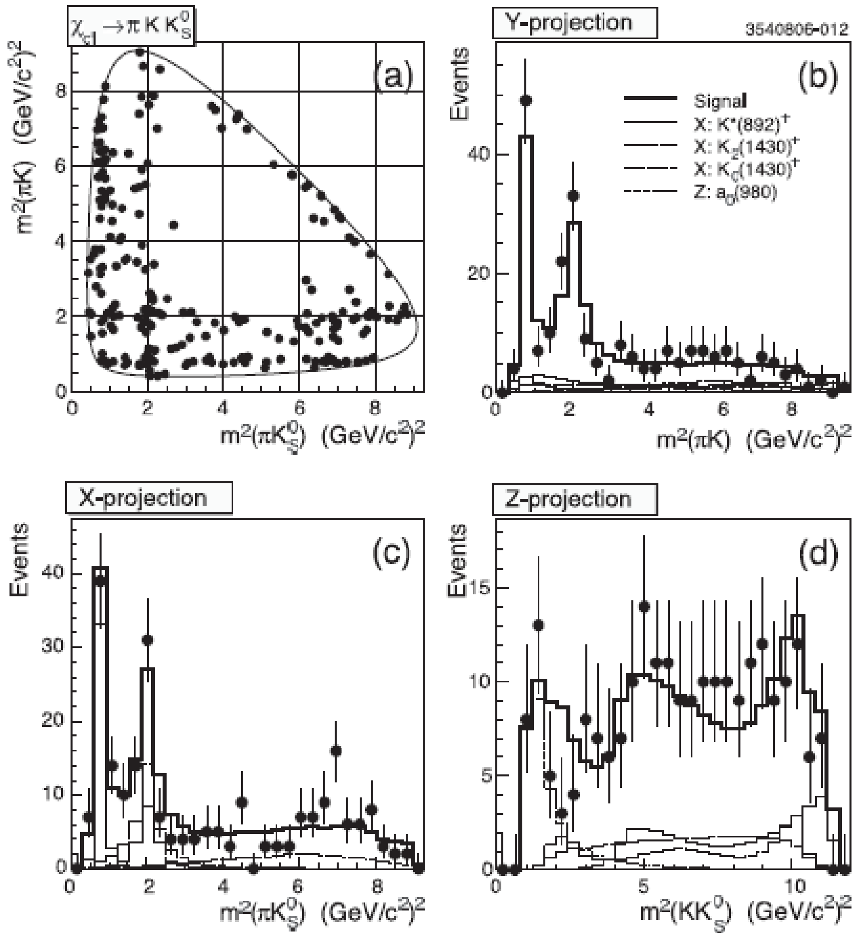


PRD 72, 032002 (2007)

$\chi_{c1} \rightarrow \pi^0 K^+ K^-$



$\chi_{c1} \rightarrow \pi^+ K^- K_s^0$



Combined fit to these two modes to take the advantage of the isospin symmetry.

Study of the light hadron spectroscopy from charm meson decays

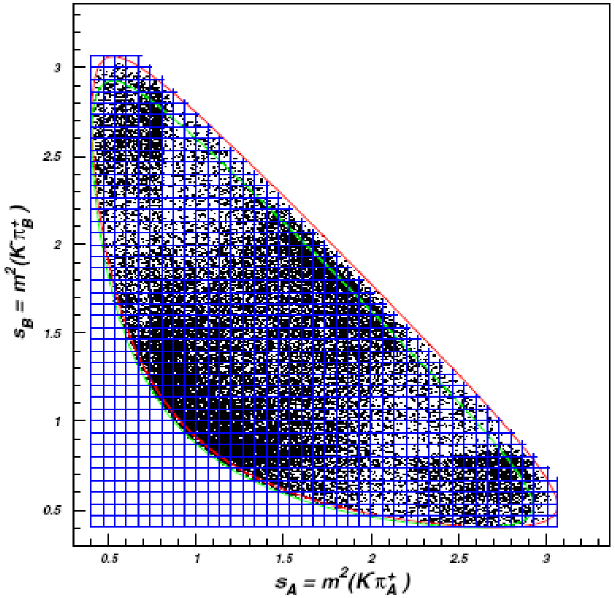
- Dalitz plot analysis of charm meson decays can be served as a platform for the study of the light hadron spectroscopy.

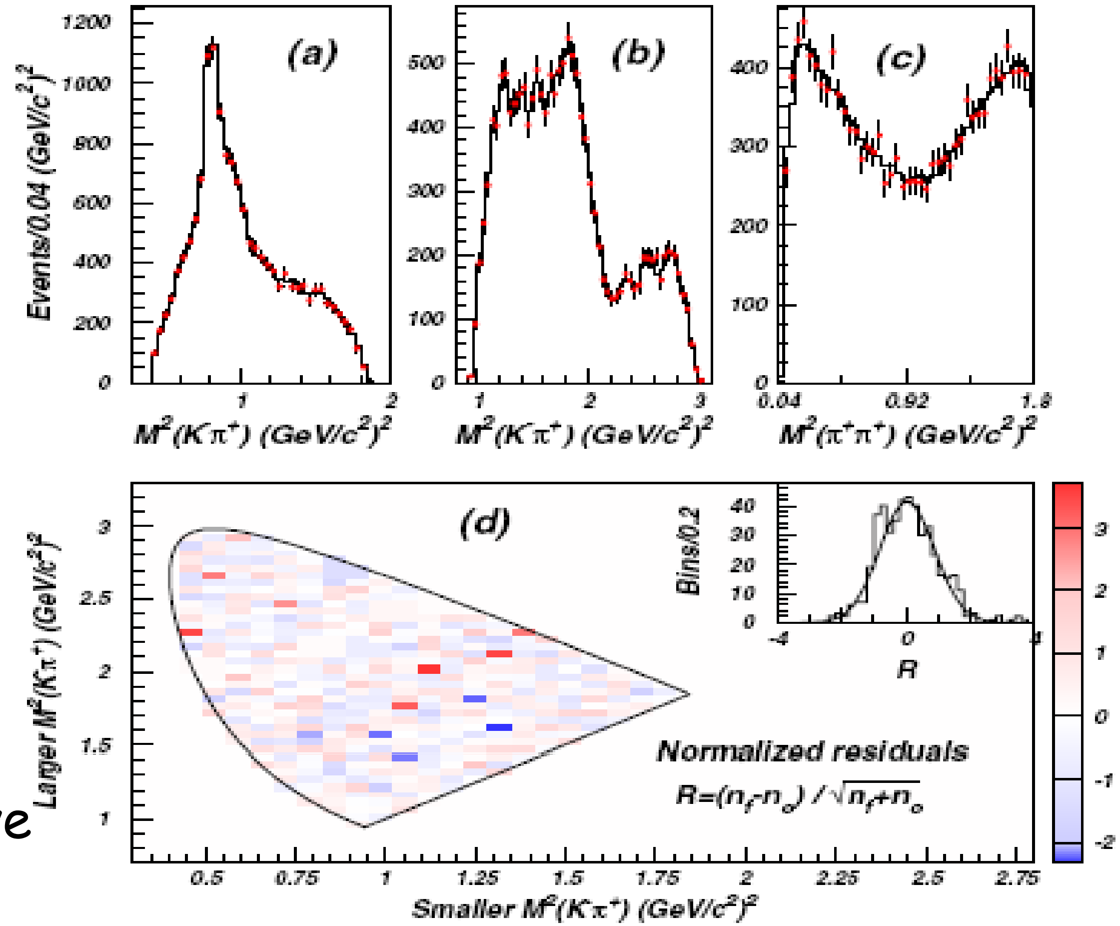
- e+ e- collisions accumulated at $\sqrt{s}$ = 3.77, 4.17 GeV,… provide clean charm meson samples.

- E791 at FNAL, B decays, …

E791 : PWA analysis of $D^+ \to K^- \pi^+ \pi^+$

PRD 73, 032004 (2006)



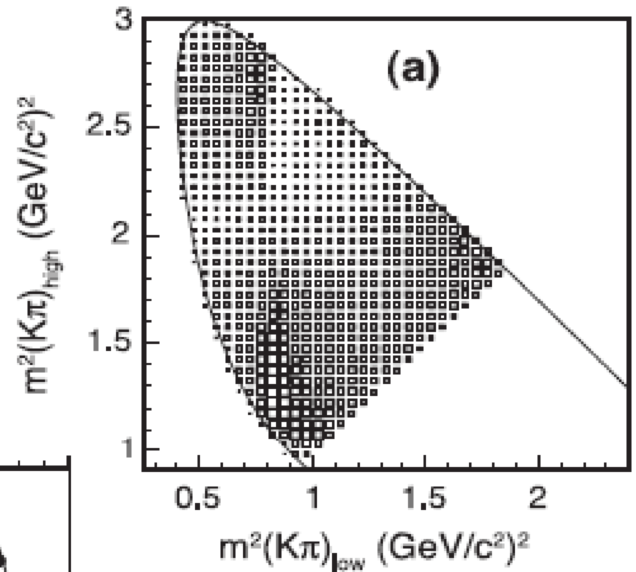


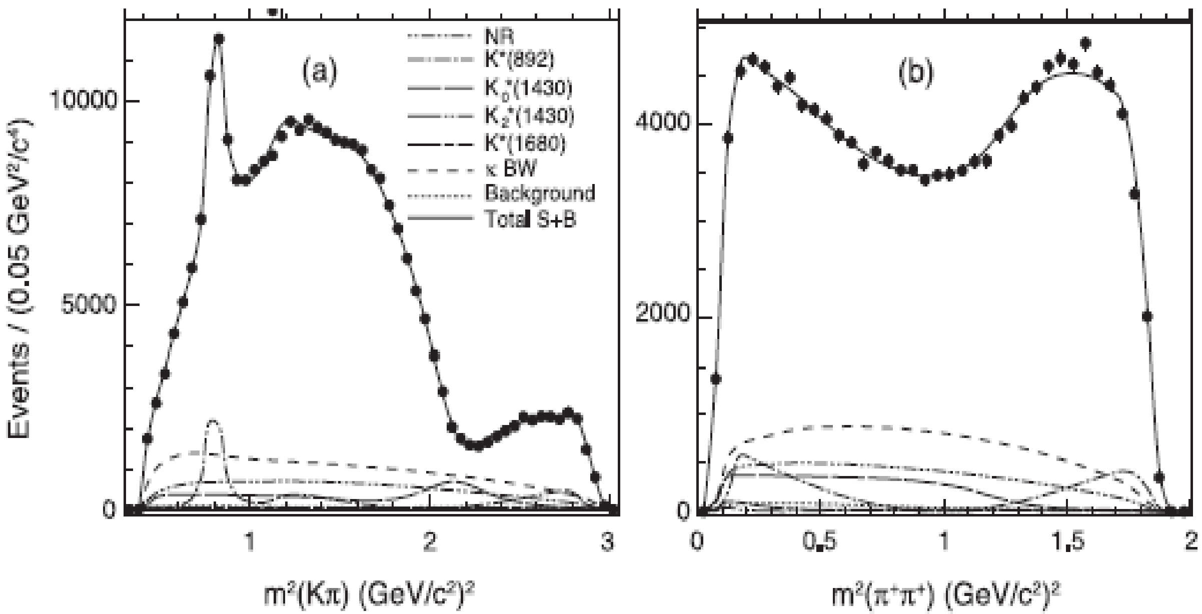
- model independent PWA
- doesn't assume any form of energy dependant of S-wave
- no significant difference with isobar model

CLEO : Dalitz plot analysis of $D^+ \rightarrow K^-\pi^+\pi^+$

PRD 78, 052001 (2008)

572 pb^{-1} $\psi(3770) \rightarrow$ 1.6M D^+D^- pairs





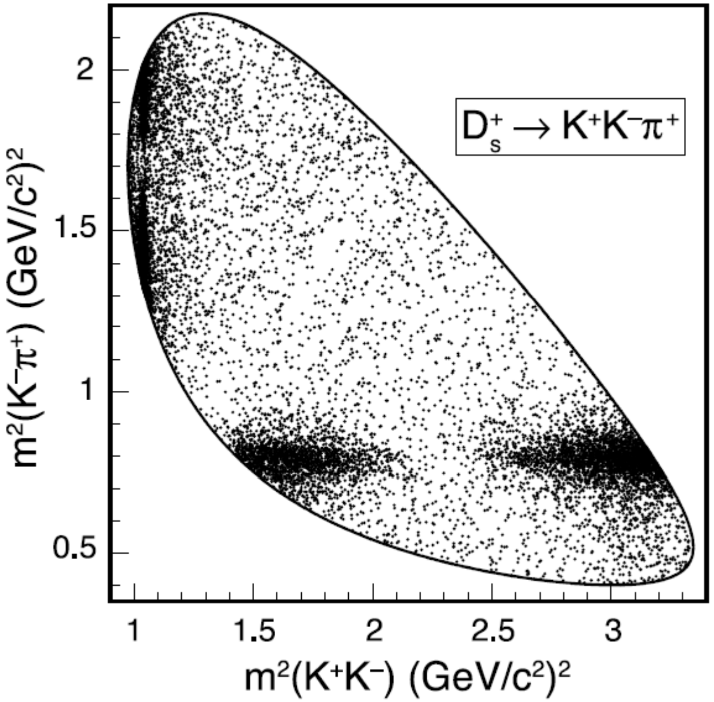
Comparison of the results between E791 and CLEO

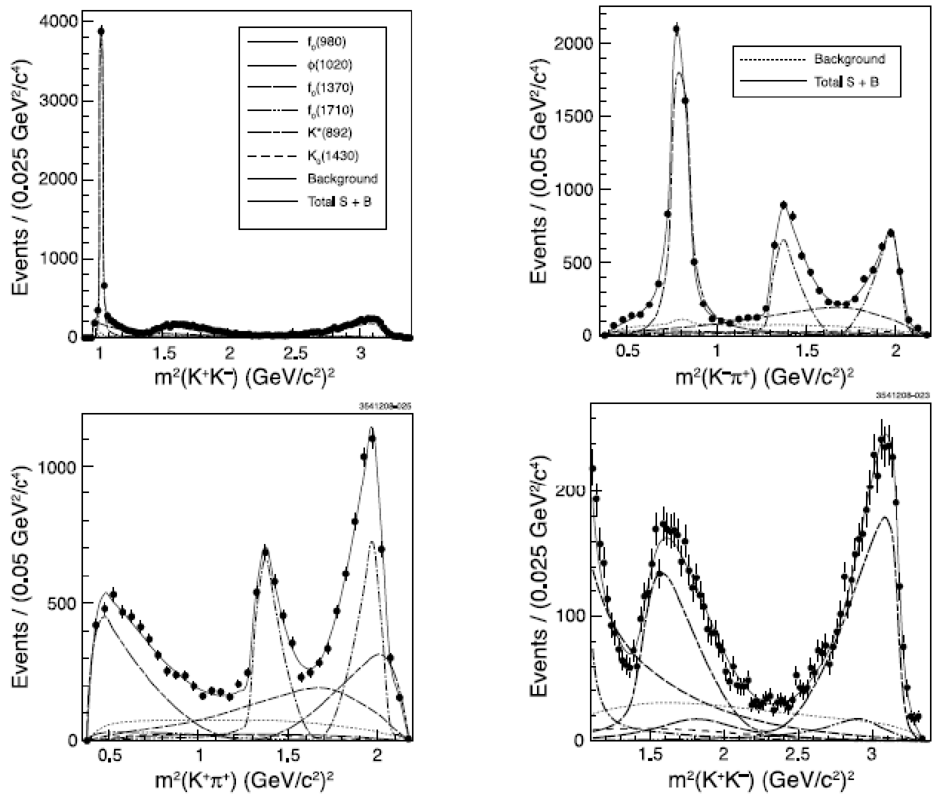
Parameter (MeV/c^2)	E791 [PDG 2000]	CLEO-c Model C (if float)	CLEO-c Model I2 (if float)	PDG 2006 [1]
$m_{K^*(892)}$	$896.1[\pm 0.27]$	$896(894.8 \pm 0.5)$	$895.7 \pm 0.2 \pm 0.3$	896.00 ± 0.25
$\Gamma_{K^*(892)}$	$50.7[\pm 0.6]$	$50.3(45.5 \pm 0.4)$	$45.3 \pm 0.5 \pm 0.6$	50.3 ± 0.6
$m_{K^*(1430)}$	$1459 \pm 7 \pm 12$	$1463.0 \pm 0.7 \pm 2.4$	$1466.6 \pm 0.7 \pm 3.4$	1414 ± 6
$\Gamma_{K^*(1430)}$	$175 \pm 12 \pm 12$	$163.8 \pm 2.7 \pm 3.1$	$174.2 \pm 1.9 \pm 3.2$	290 ± 21
$m_{K_2^*(1430)}$	$1432.4[\pm 1.3]$	$1432.4(1436 \pm 11)$	$1432.4(1427 \pm 7)$	1432.4 ± 1.3
$\Gamma_{K_2^*(1430)}$	$109[\pm 5]$	$109(132 \pm 21)$	$109(120 \pm 13)$	109 ± 5
$m_{K^*(1680)}$	$1717[\pm 27]$	$1717(1782 \pm 41)$	$1717(1679 \pm 59)$	1717 ± 27
$\Gamma_{K^*(1680)}$	$322[\pm 110]$	$322(565 \pm 131)$	$322(446 \pm 119)$	322 ± 110
$m_{K^*(1410)}$	$1414[\pm 15]$	1414	1414	1414 ± 15
$\Gamma_{K^*(1410)}$	$232[\pm 21]$	232	232	232 ± 21
m_κ	$797 \pm 19 \pm 43$	$809 \pm 1 \pm 13$	Complex pole,	$K_0^*(800)$ is not
Γ_κ	$410 \pm 43 \pm 87$	$470 \pm 9 \pm 15$	see Table VI	established

CLEO : Dalitz plot analysis of $Ds^+ \to K^+K^-\pi^+$

arXiv: 0903. 1301

586 pb^{-1} data at $\sqrt{s}$ =4.17 GeV → 0.57 M Ds Ds* pairs





CLEO : Dalitz plot analysis of $D_s^+ \to K^+K^-\pi^+$

arXiv: 0903. 1301

Resonance	Parameter (MeV/c^2)	Central Fit	Floated	PDG [8]
$K^*(892)$	m	895.8±0.5	895.8±0.5	896.00±0.25
	Γ	44.2±1.0	44.2±1.0	50.3±0.6
$K_0^*(1430)$	m	1414	1422±23	1414±6
	Γ	290	239±48	290±21
$f_0(980)$	m	965	933±21	980±10
	$g_{\pi\pi}$	406	393±36	Γ=40 to 100
	g_{KK}	800	557±88	
$\phi(1020)$	m	1019.460	1019.64±0.05	1019.460±0.019
	Γ	4.26	4.780±0.14	4.26±0.05
$f_0(1370)$	m	1350	1315±34	1200 to 1500
	Γ	265	276±39	200 to 500
$f_0(1710)$	m	1718	1749±12	1718±6
	Γ	137	175±29	137±8

Prospects of light hadron spectroscopy at BESIII

Beijing Electron Positron Collider (BEPC) at IHEP

BESI: 1989-1998

BESII: 1999-2004

$L \sim 5 \times 10^{30} /cm^2 \cdot s$ at J/ψ

$E_{beam} \sim 1 - 2.5$ GeV

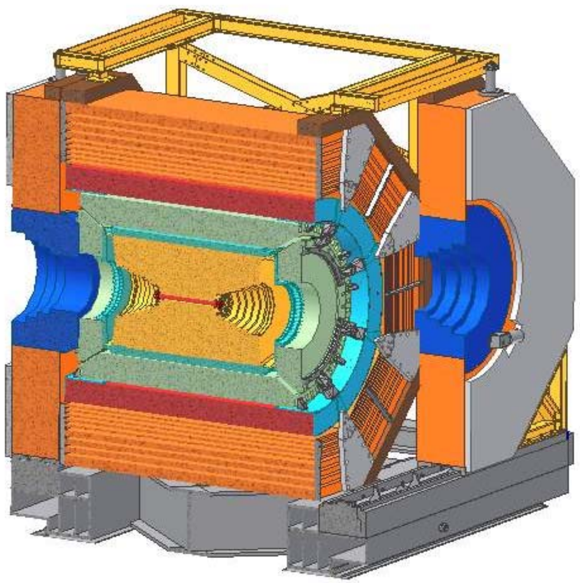
BESIII: 2008-

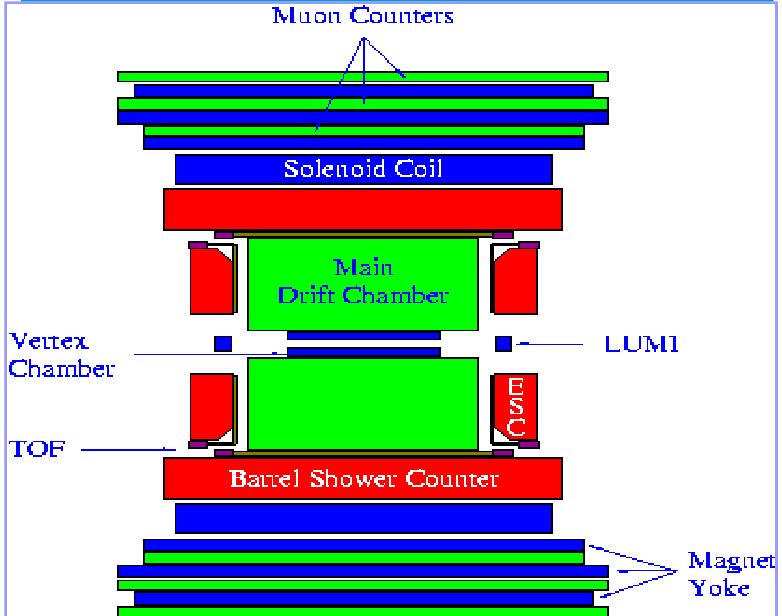
Physics run started in March, 2009. 100M $\psi(2S)$ collected

BEPCII: L reached $3 \times 10^{32}/cm^2 \cdot s$ at $\psi(3770)$

designed L: $10^{33}/cm^2 \cdot s$

BESIII @ BEPC	BESII @ BEPCII





Side view of the BES detector

	BESIII	BESII
MDC	$\sigma_{p_t}/p_t = 0.32\% p_t, dE/dx < 6\%$	$\sigma_p/p = 1.78\%\sqrt{1+p^2}, dE/dx = 8\%$
TOF	90 ps (for bhabha)	180 ps (for bhabha)
EMC	$\sigma_E/E = 2.3\%/\sqrt{E}$	$\sigma_E/E = 22\%/\sqrt{E}$
MUC	9 for barrel, 8 for end-cap	3 layers for barrel
Magnet	1.0 T	**0.4 T**

BESIII/BEPCII running

- BEPCII
  - L_{peak} ~ 2.8×10^{32} cm^{-2} s^{-1} at 3.686 GeV
  - $L_{J/\psi\ peak}$ ~ 1.4×10^{32} cm^{-2} s^{-1} at J/ψ (50%)
  - $L_{average}$ ~ 0.7×10^{32} cm^{-2} s^{-1} at J/ψ (50%)

- J/ψ production cross section ~ 2500-3000 nb

  $\psi(2S)$ production cross section ~ 600 nb

  Average J/ψ events rate ~ 150-200 Hz

  Average $\psi(2S)$ events rate ~ 70 Hz

  Running time: ~ 50000 s/day (86400 s/day)

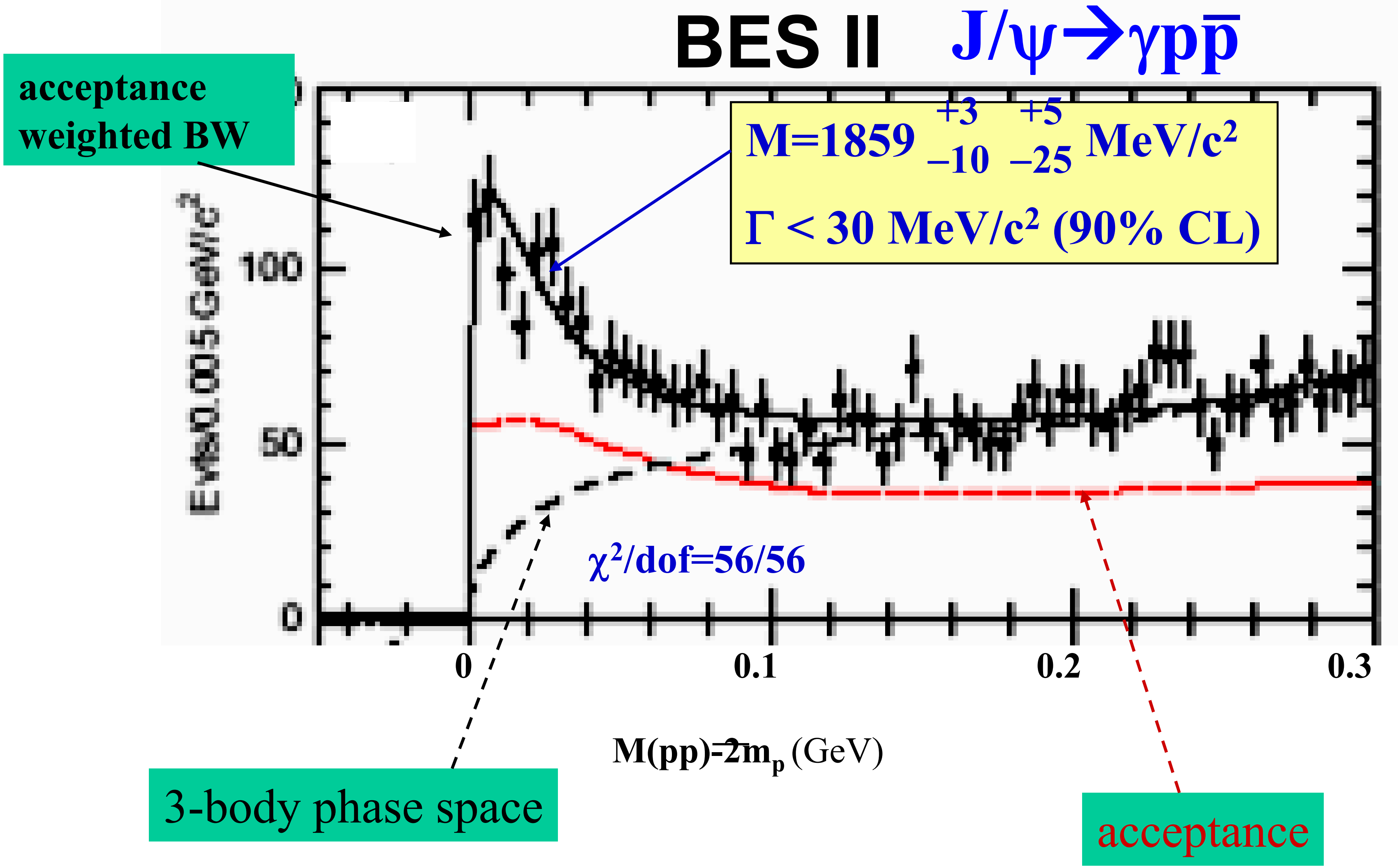
- Number of J/ψ events: ~ 7.5 -10 M /day
- Number of $\psi(2S)$ events: ~ 3.5 M /day

BESII J/ψ: 58 M

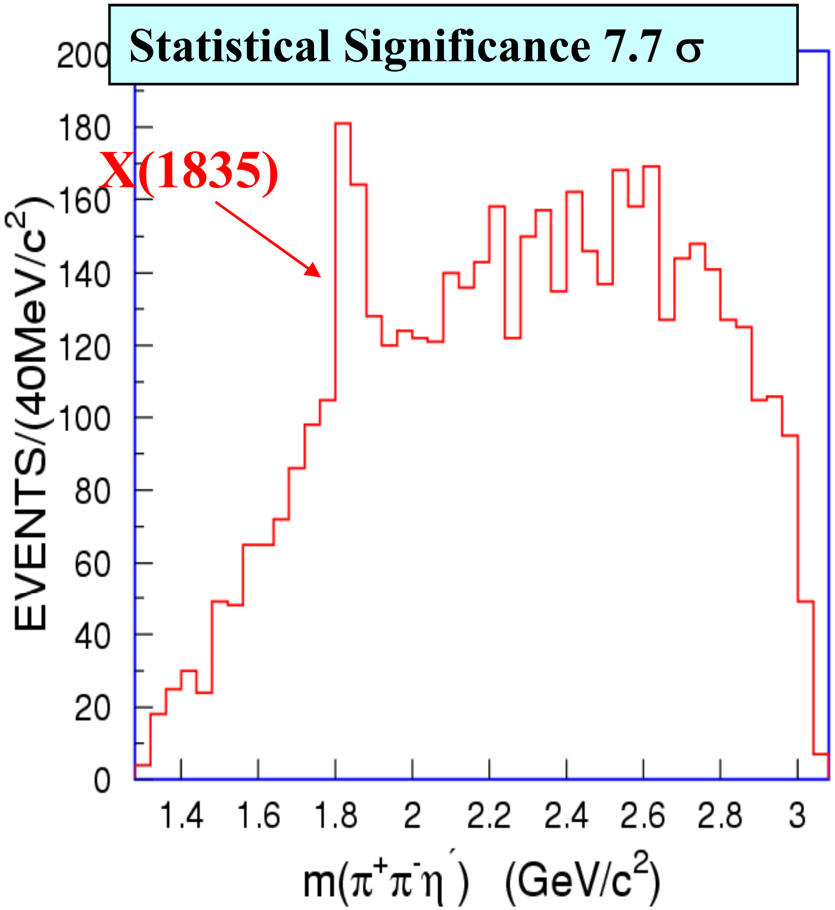
BESII $\psi(2S)$: 14 M, BESIII: 100M

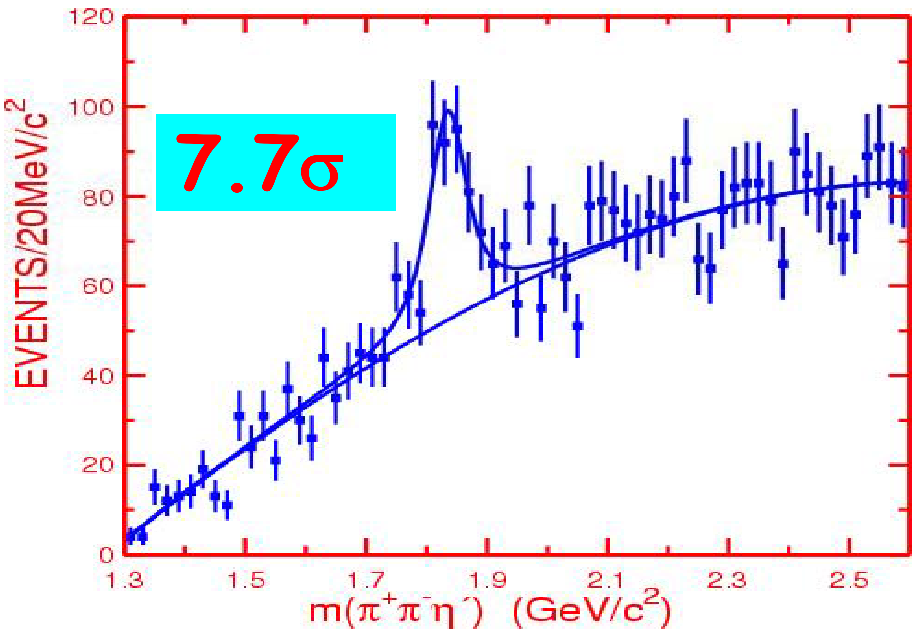
CLEO-c $\psi(2S)$: 28 M

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



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





$N_{obs} = 264 \pm 54$

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

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

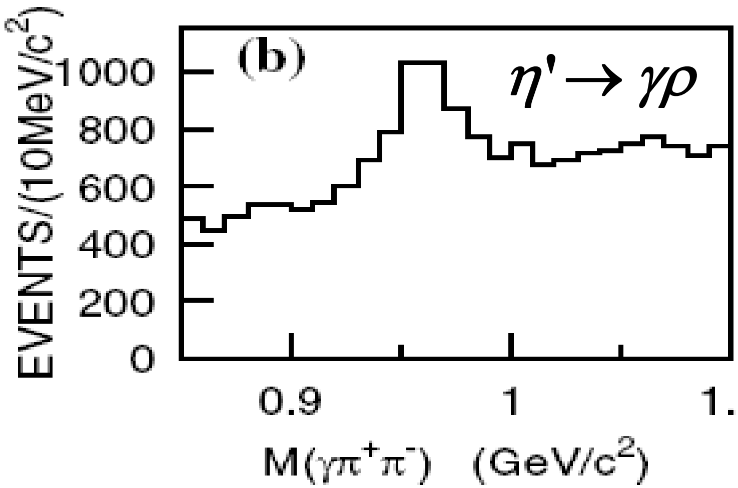
$$B(J/\psi \to \gamma X)B(X \to \pi^+\pi^-\eta') = (2.2 \pm 0.4 \pm 0.4) \times 10^{-4}$$

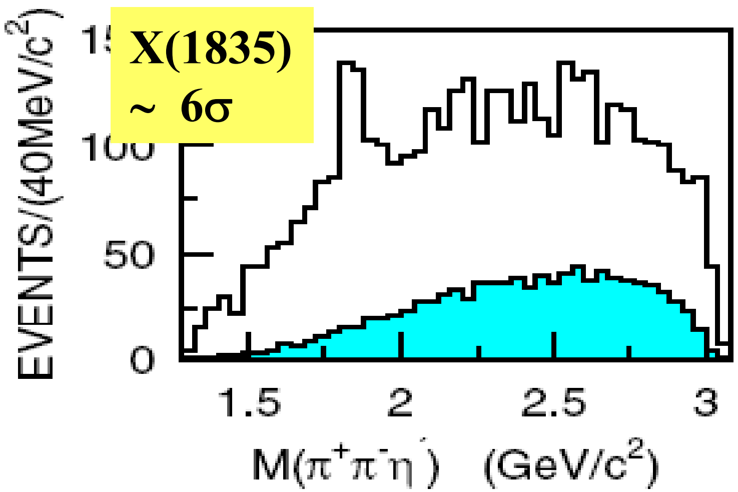
PRL 95 (2005) 262001

MC simulation: Confirm X(1835) at BESIII

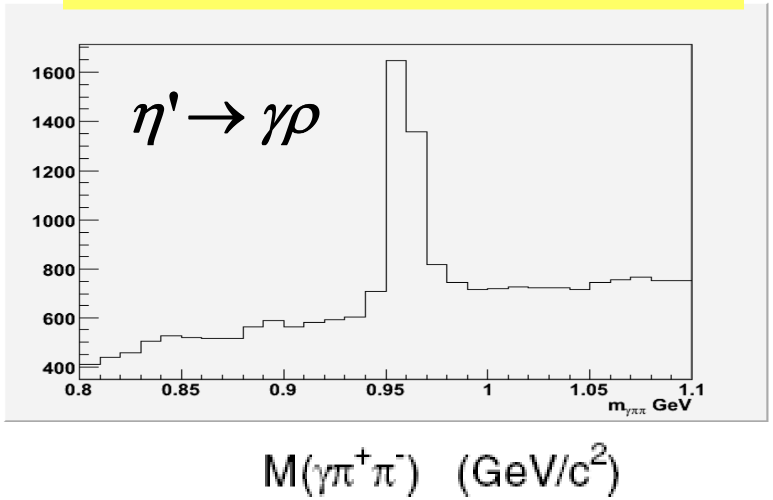
$$J/\psi \to \gamma\eta'\pi^+\pi^-,\ \eta' \to \gamma\rho,\ \rho \to \pi^+\pi^-$$

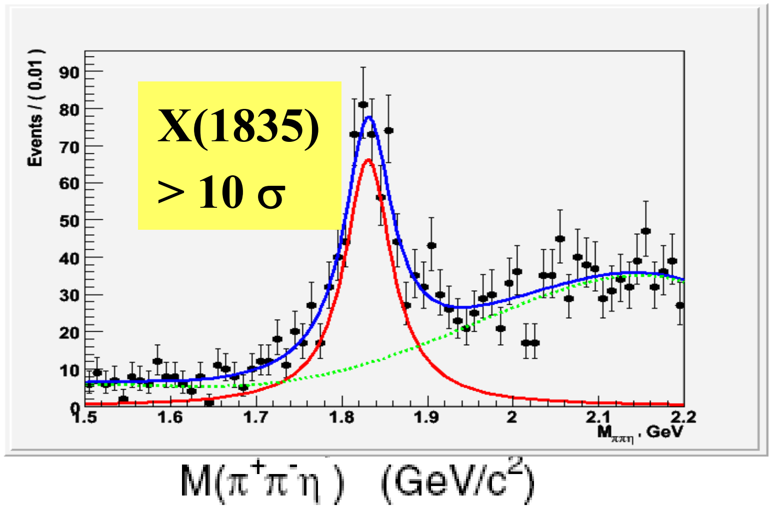
BESII data ~ 58M J/ψ





BESIII MC ~ 58M J/ψ

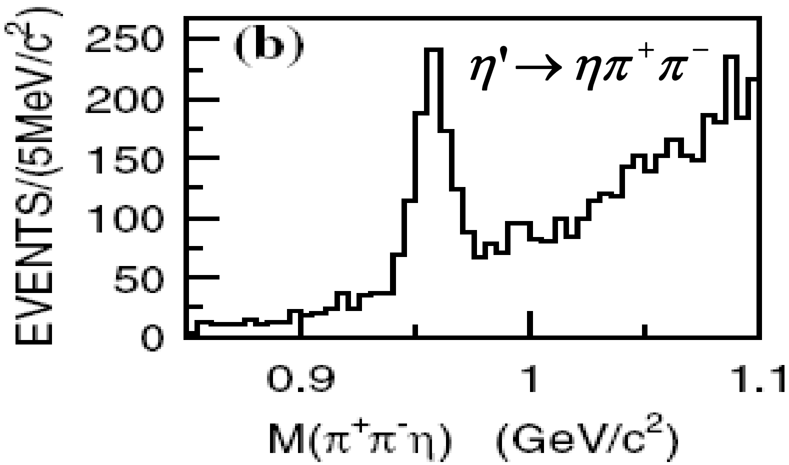


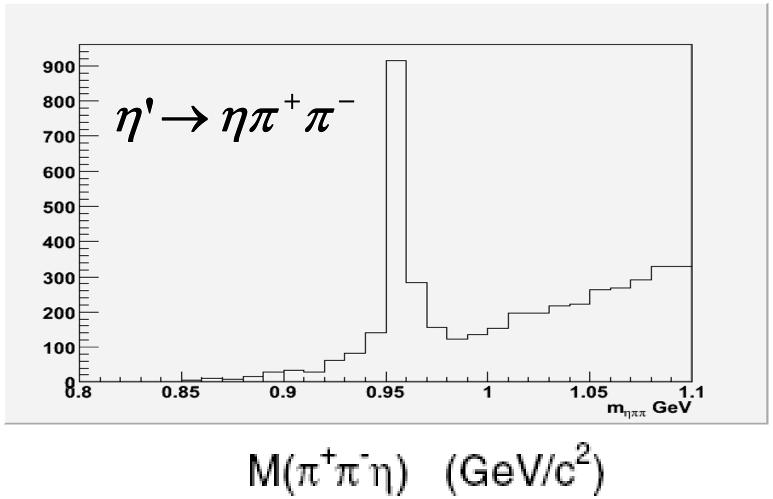


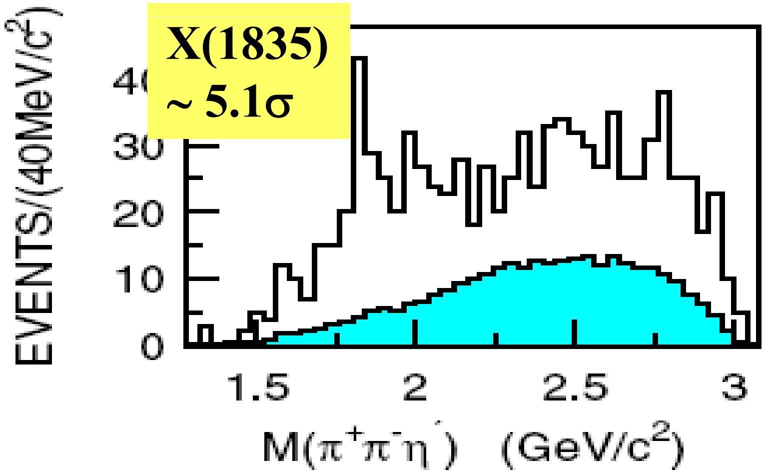
$$J/\psi \to \gamma\eta'\pi^+\pi^-,\ \eta' \to \eta\pi^+\pi^-,\ \eta \to \gamma\gamma$$

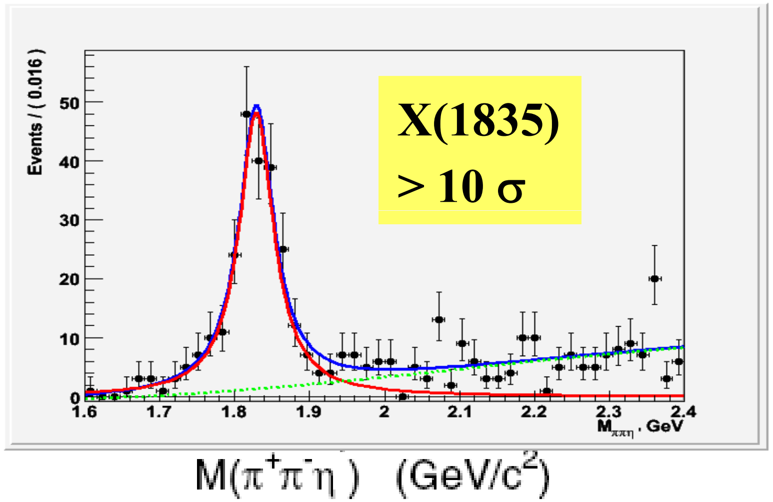
BESII data ~ 58M J/ψ

BESIII MC ~ 58M J/ψ





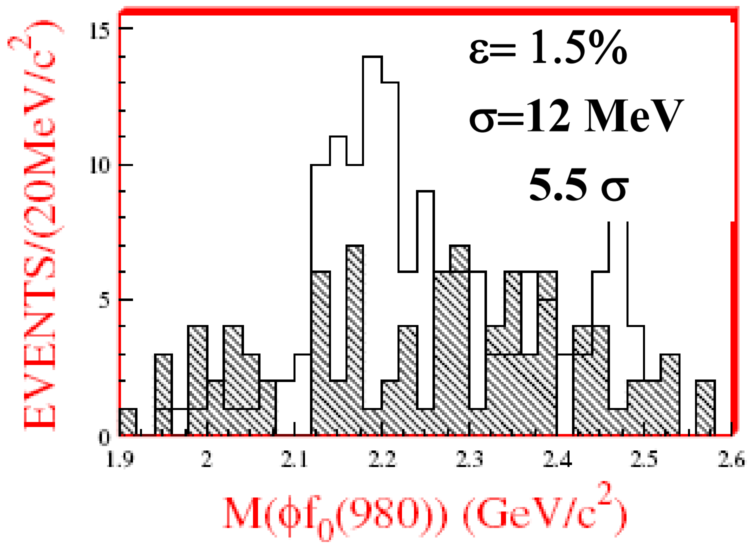


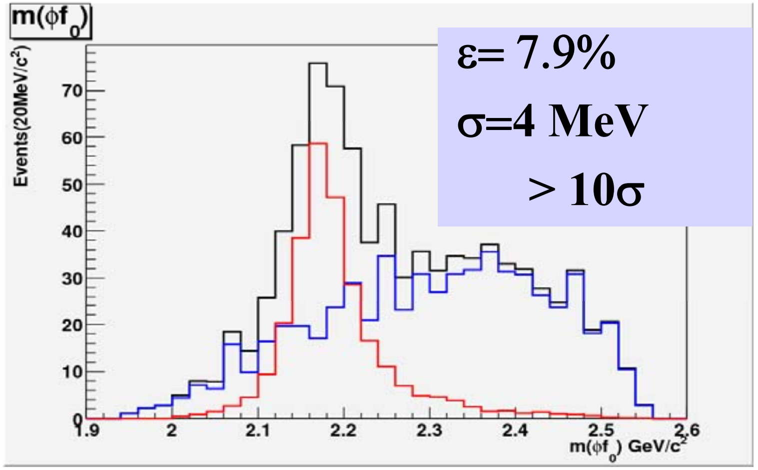


The Y(2175) in $J/\psi \to \eta\phi f_0(980)$ at BESIII

BOSS 6.3.4

BESII data ~ 58M J/ψ	BESIII MC ~ 58M J/ψ





Mass(GeV)		Width(GeV)		Br(*10-4)	
Input	output	Input	output	Input	output
2.175	2.177± 0.004	0.061	0.060± 0.010	3.23	2.99± 0.38

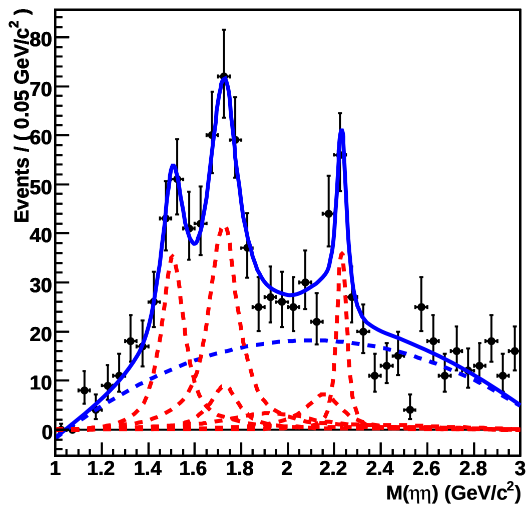
MC Simulation of $J/\psi \to \gamma\eta\eta$, $\gamma\eta\eta'$

$J/\psi \to \gamma\eta\eta$, $\eta \to \gamma\gamma$ (BOSS 6.3.4)

Assume:

$Br(J/\psi \to \gamma f_J(2220))Br(f_J(2220) \to \eta\eta) \sim 1*10^{-5}$

$J/\psi \to \gamma X, X \to \eta\eta$	Br ($*10^{-5}$)	Efficiency (%)	N_{obs} (norm. to $1.8*10^8$ J/ψ)
$X=f_0(1500)$	1.84	23.5	188
$X=f_0(1710)$	2.88	24.4	195
$X=f_0(2100)$	~1.0	24.2	67.5
$X=f_2(1910)$	~1.0	24.2	67.4
$X=f_2(2150)$	~1.0	24.2	67.6
$X=f_J(2220)$	~1.0	24.4	68.0



For $f_J(2220)$:

$\varepsilon = 24.4\%$

$\sigma = 18$ MeV

Significance: 4.8 σ

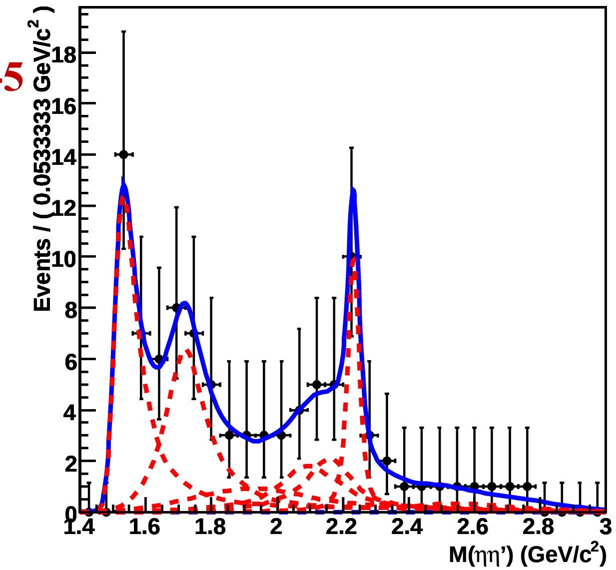
(BOSS 6.3.4)

$J/\psi \to \gamma\eta\eta'$, $\eta \to \gamma\gamma$, $\eta' \to \eta\pi\pi$

Assume:

$Br(J/\psi \to \gamma f_J(2220))Br(f_J(2220) \to \eta\eta') \sim 1*10^{-5}$

$J/\psi \to \gamma X$, $X \to \eta\eta'$	Br ($*10^{-5}$)	Efficiency (%)	N_{obs} (norm. to $1.8*10^8$ J/ψ)
$X=f_0(1500)$	1.8	6.73	15.0
$X=f_0(1710)$	2.8	7.15	24.8
$X=f_0(2100)$	~1.0	7.90	9.78
$X=f_2(1910)$	~1.0	7.92	9.80
$X=f_2(2150)$	~1.0	8.31	10.3
$X=f_J(2220)$	~1.0	8.62	10.7



For $f_J(2220)$

$\varepsilon = 8.6\%$

$\sigma = 12$ MeV

Significance: 2.6 σ

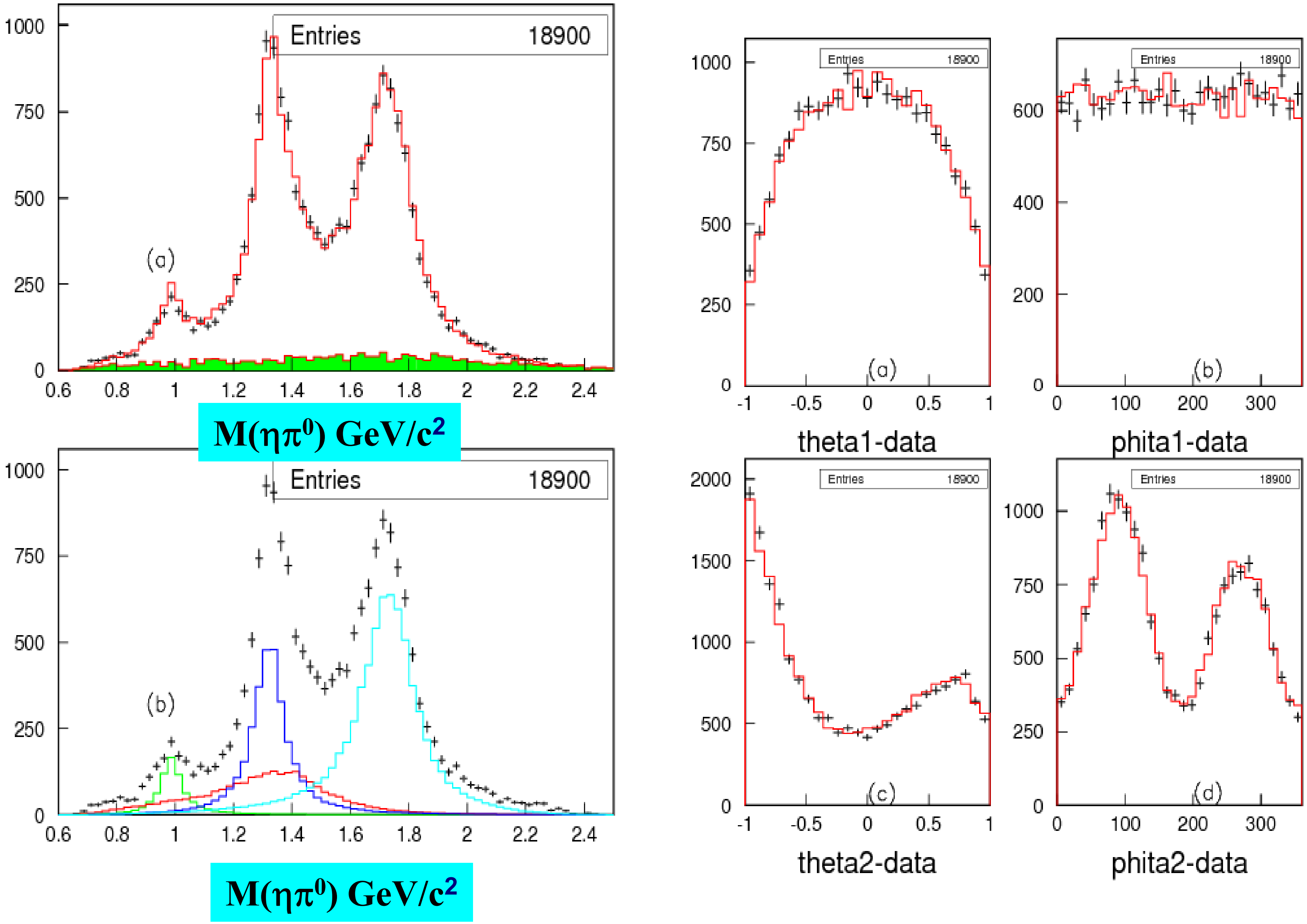
Search for 1^{-+} in $J/\psi \to \rho^0 \eta \pi^0$

- assuming 2.5 × BESII J/ψ events
- $J/\psi \to \rho a_0(980)$, $\rho a_2(1320)$, $\rho\pi(1390)$, $\rho a_2(1700)$ are included.

  the spin-parity of each component as well as the interference between them are considered.

- background included (estimated from sideband, about 10%)
- a full PWA is performed.

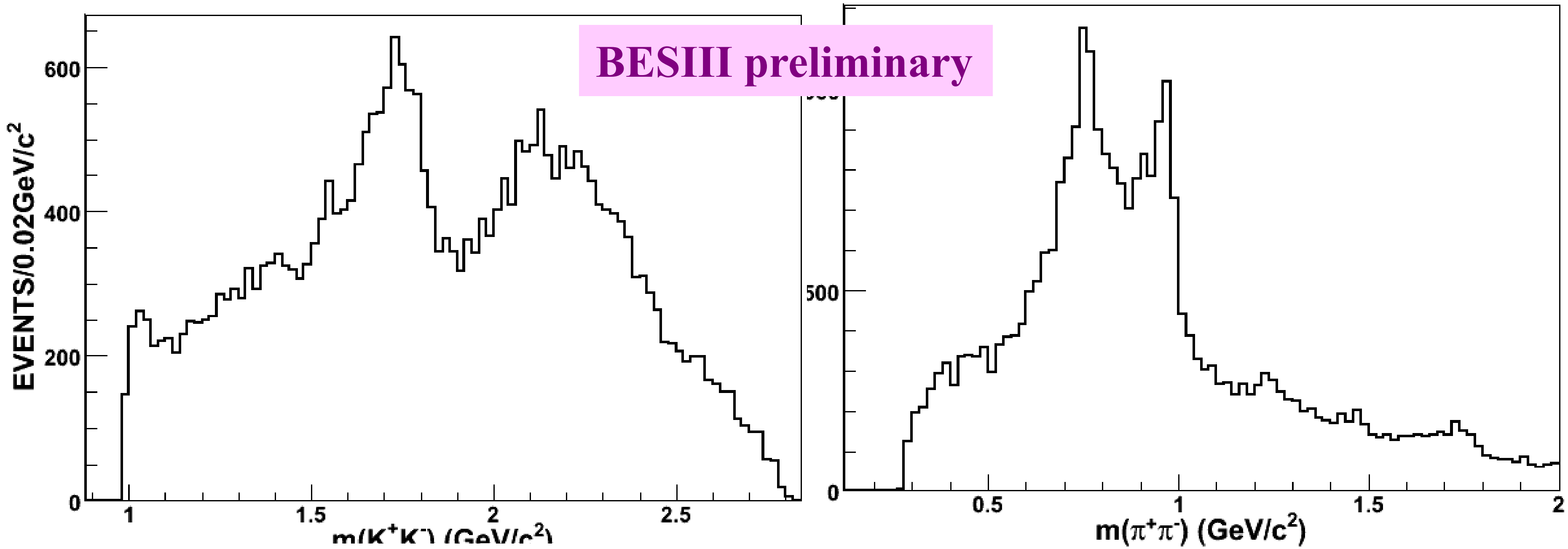
Comparison of generated data and PWA projections

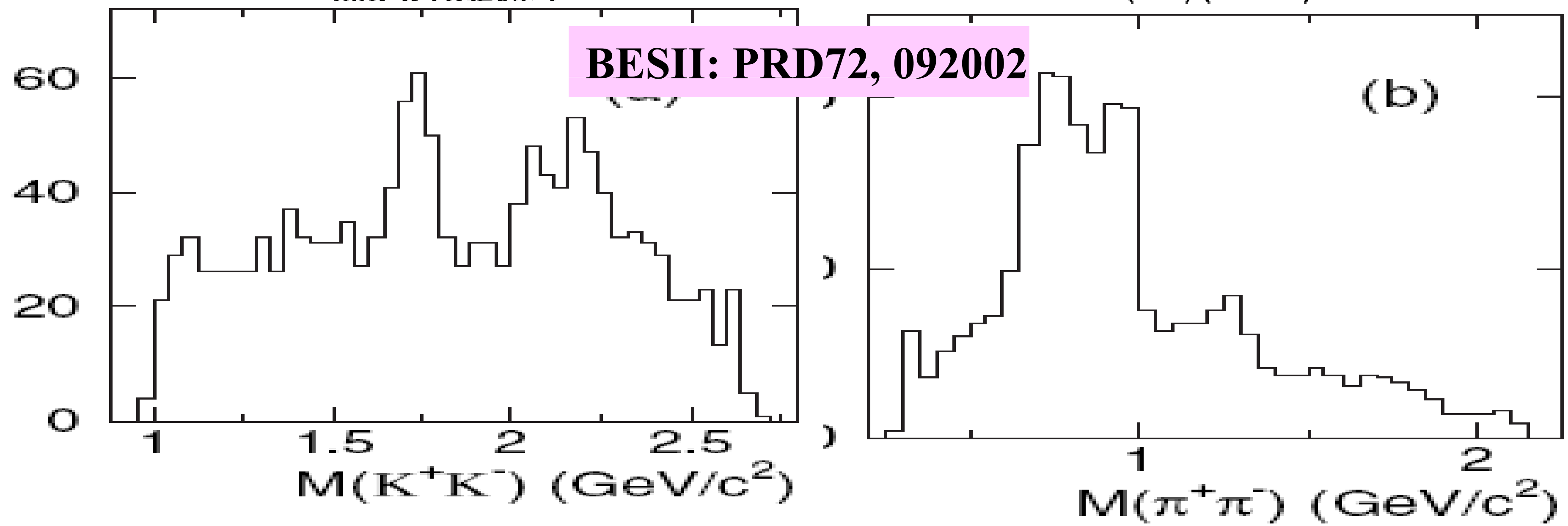


Input/output check

	Mass(MeV/c^2)		Width(MeV/c^2)		Fraction(%)	
	input	output	input	output	input	output
a_2(1320)	1318	1320±2	107	112± 4	20.84	19.49± 0.80
π_1(1400)	1376	1380 ±8	360	376±16	14.57	14.66± 1.30

Structures in $\chi_{c0} \to \pi^+\pi^-K^+K^-$ at BESIII





Summary

- Recent light hadron spectroscopy results from BELLE, BABAR, CLEO, KLOE and BESII are presented.
- 100M $\psi(2S)$ data are accumulated at BESIII. Will take J/ψ data soon.
- Expecting new and exciting results from new data.

Thank you!

comparison of inputs/outputs for X(1835)

Input: mass = 1.833 GeV

Γ= 0.066 GeV (for $\gamma\rho$ mode)

0.060 GeV (for $\eta\pi^+\pi^-$ mode)

Br=2.09 $\times 10^{-4}$

	Reso.(MeV)		Eff. (%)		M(GeV)	Γ(GeV)	Br($\times 10^{-4}$)
	BESII	BESIII	BESII	BESIII	output	output	output
$\eta'\to\gamma\rho$	13.0	4.2	4.9	19.0	1.831±0.002	0.067±0.009	2.0±0.3
$\eta'\to\eta\pi^+\pi^-$	12.0	3.8	3.7	12.8	1.829±0.003	0.056±0.008	1.9±0.2

Study of the inclusive photon spectrum

- Glueballs can be largely produced in J/ψ radiative decays. The inclusive photon spectrum provides a good lab. to search for glueballs and other new states.

- Measure the absolute branching ratios of the radiative decays.

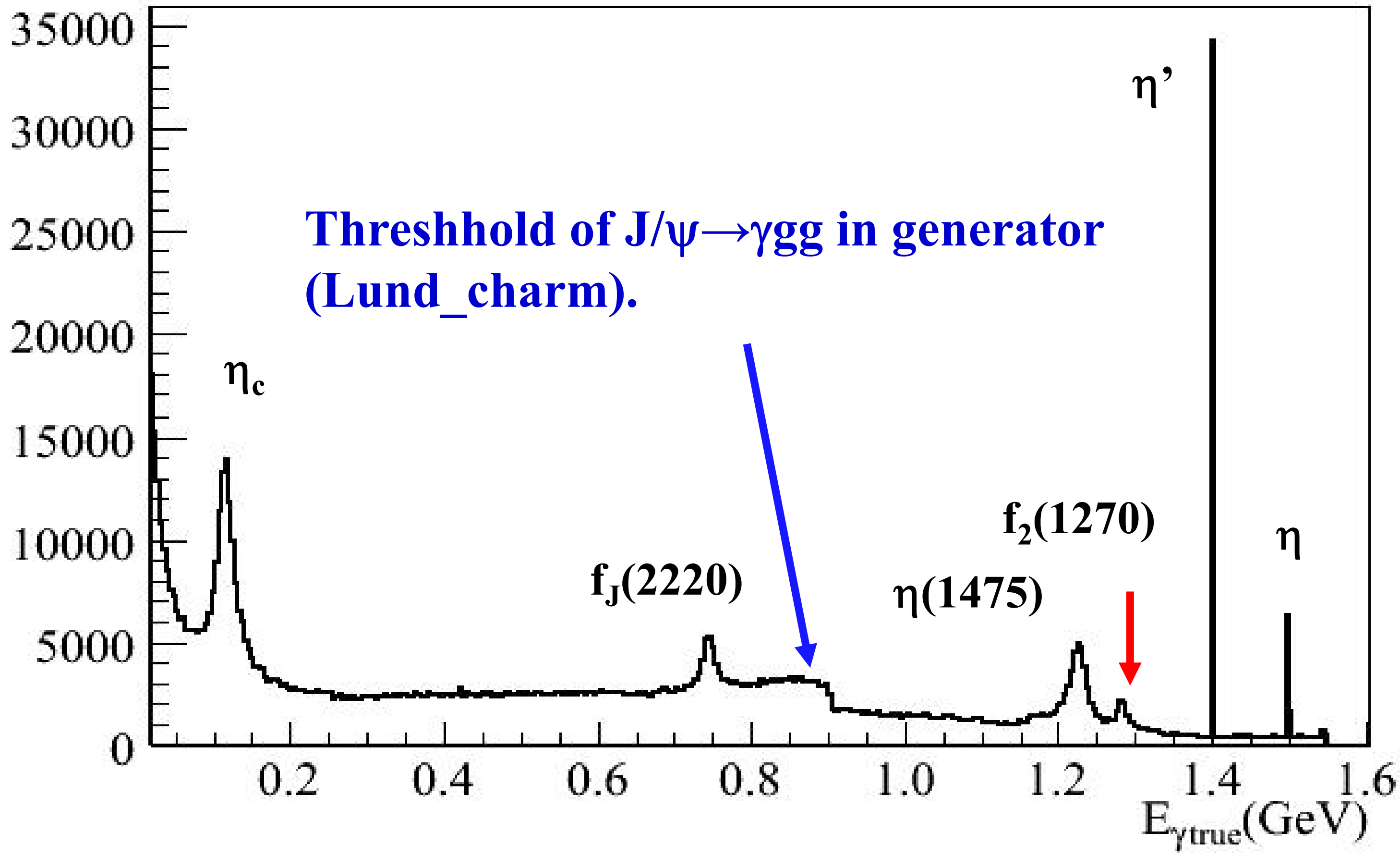
- Only EMC information is used. Already have a better agreement between data and MC.

- Large statistics compared with the exclusive decays. Can be carried out at the very beginning of BESIII's data taking.

The γ energy spectrum in $J/\psi \to \gamma X$ (MCTruth)

15M J/ψ → anything MC sample

Mix $J/\psi \to \gamma f_J(2220)$ ($Br=2.5*10^{-3}$) into the inclusive sample



Decay modes of $f_J(2220)$

$J/\psi \rightarrow \gamma\, f_J(2220)$ on PDG:

$\gamma f_J(2220)$	$> 2.50 \times 10^{-3}$	CL=99.9%	745
$\gamma f_J(2220) \rightarrow \gamma\pi\pi$	$(8 \pm 4) \times 10^{-5}$		–
$\gamma f_J(2220) \rightarrow \gamma K\overline{K}$	$(8.1 \pm 3.0) \times 10^{-5}$		–
$\gamma f_J(2220) \rightarrow \gamma p\overline{p}$	$(1.5 \pm 0.8) \times 10^{-5}$		–

- The known decay modes of $f_J(2220)$ ~ 4%-10%
- For different $f_J(2220)$ decay modes, the effs are different.
- Study the sensitivity of $f_J(2220)$ under 2 assumptions

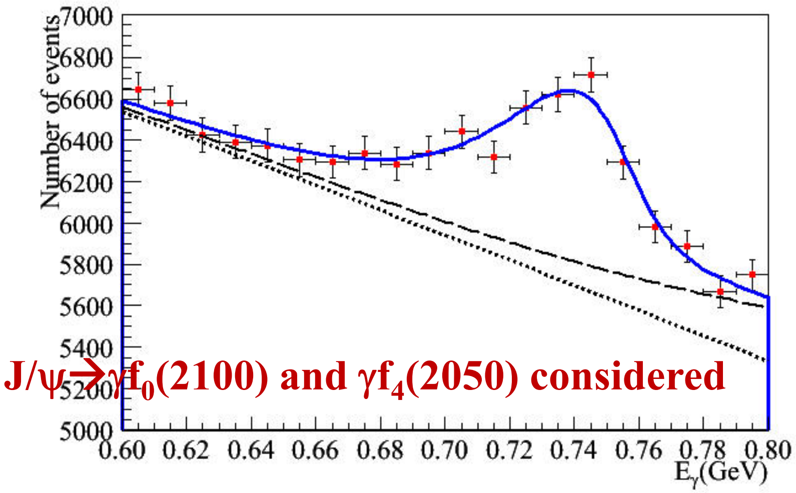
Two assumptions for $f_J(2220)$ decays

- 10% known modes + 70% ($\eta\eta+\eta\eta'+\eta'\eta'$) +20% 4 prong
- 4% known modes + 96% ($\eta\eta+\eta\eta'+\eta'\eta'$)

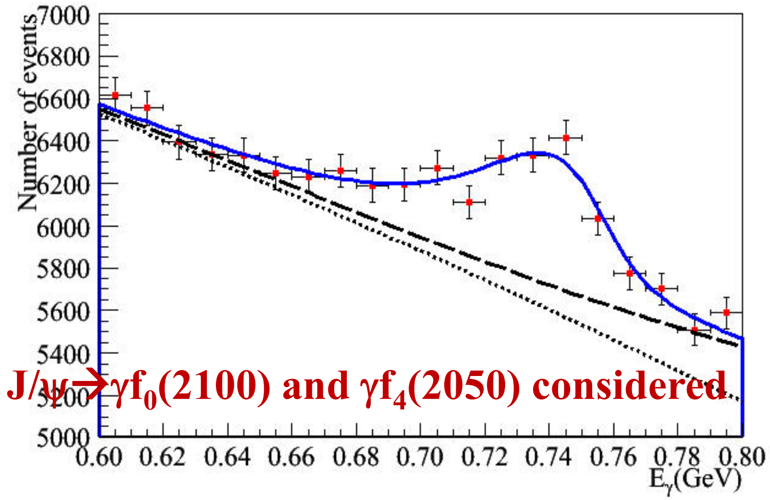
Channel	Efficiency	Assumption 1 eff. = 15.2%	Assumption 2 eff. = 11.1%
$K_S^0 K_S^0$	18.12%	10%	4%
K^+K^-	37.0%		
$p\bar{p}$	17.06%		
$\pi^+\pi^-$	35.66%		
$\eta\eta$	15.2%	70%	96%
$\eta\eta'$	9.2%		
$\eta'\eta'$	6.6%		
$\pi^+\pi^-\pi^+\pi^-$	26.7%	20%	0%
$K^+K^-\pi^+\pi^-$	20.5%		

Inclusive photon spectrum under two assumptions

assumption 1



assumption 2



	input	Assumption 1	Assumption 2
$N(f_J)$		5627 ± 595	4185 ± 554
$Br(J/\psi \to \gamma f_J(2220))$ ($\times$ 10 -3)	2.5	2.46 ± 0.26	2.51 ± 0.26
E_γ(MeV)	745	744.3 ± 1.8	745.6 ± 2.2
$M(f_J)$(MeV)	2230	2231.9 ± 2.5	2230.2 ± 3.1
Significance		10.0σ	7.7σ