Recent Results from BESII

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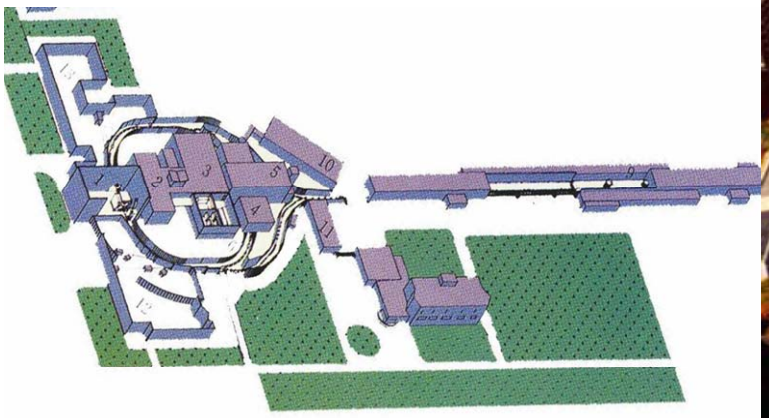
Beijing Electron Positron Collider (BEPC) at IHEP

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

at J/ψ

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

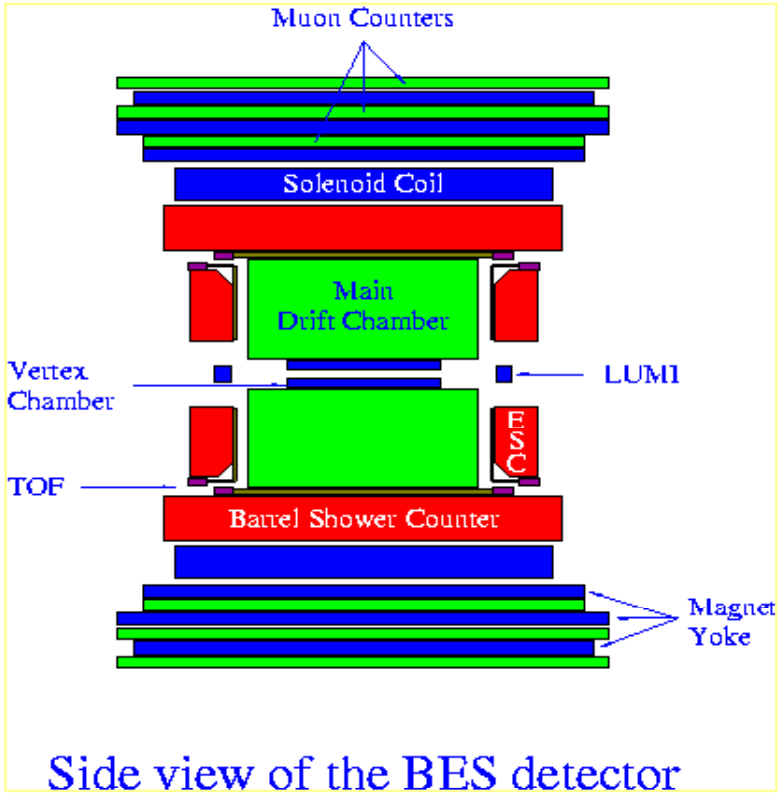


BESI: run from 1989-1998

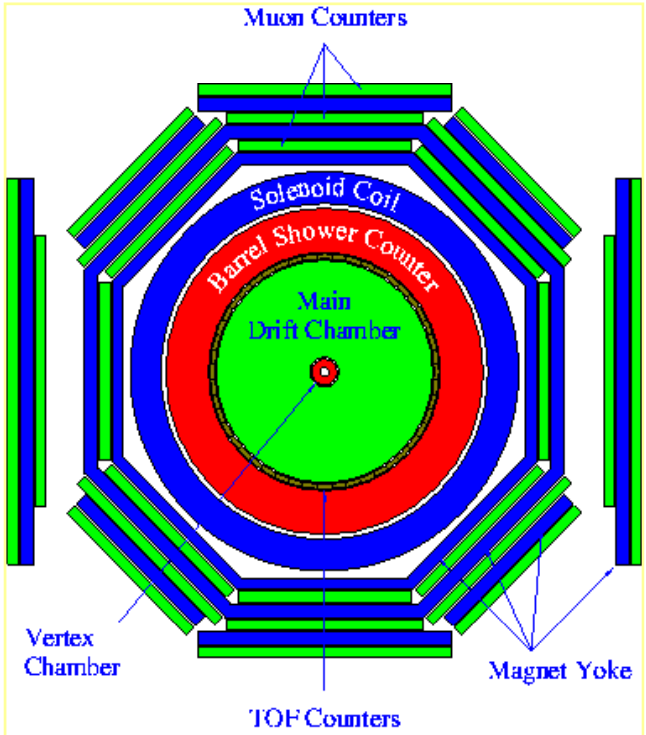
BESII: run from 1999-2004

BESIII: will start running in July of 2008

BESII @ BEPC



Side view of the BES detector



End view of the BES detector

VC: σ_{xy} = 100 μm TOF: σ_T = 180 ps μ counter: $\sigma_{r\phi}$= 3 cm

MDC: σ_{xy} = 220 μm BSC: $\Delta E/\sqrt{E}$= 22 % σ_z = 5.5 cm

$\sigma_{dE/dx}$= 8.5 % σ_ϕ = 7.9 mr B field: 0.4 T

$\Delta p/p = 1.7\%\sqrt{(1+p^2)}$ σ_z = 3.1 cm

BESII data samples in this talk

Data	BESII	CLEOc
J/ψ	58 M	--
$\psi(2S)$	14 M	27 M
$\psi(3770)$	33 pb^{-1}	572 pb^{-1}

- Y(2175)
- $\eta(2225)\rightarrow\phi\phi$
- $X(1440)\rightarrow KK\pi$
- ψ' radiative decays
- ψ'' resonance parameters, non-DDbar decays

BESIII (See Fred Harris's talk)

Y(2175)

arXiv: 0712.1143, PRL 100, 102003 (2008)

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

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

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

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

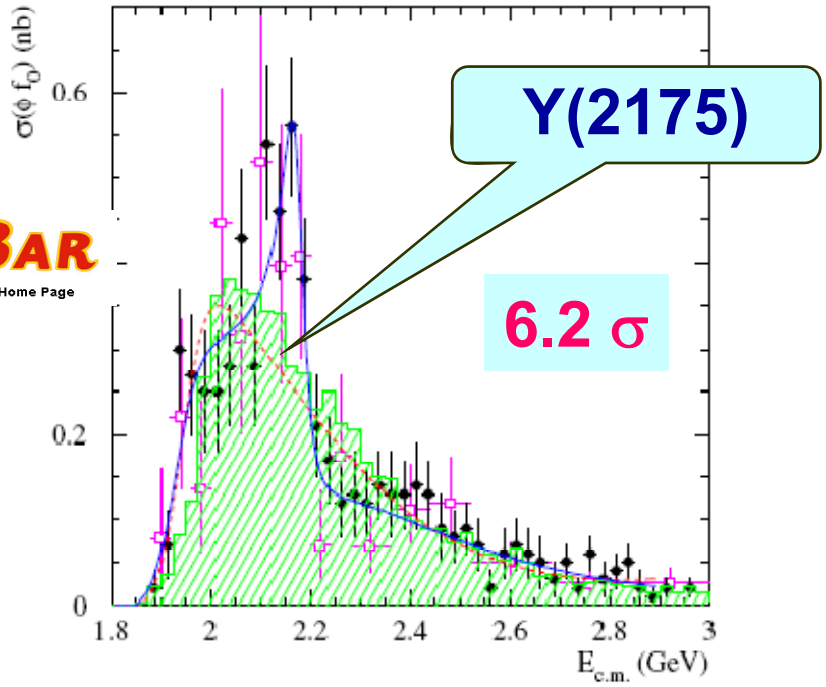


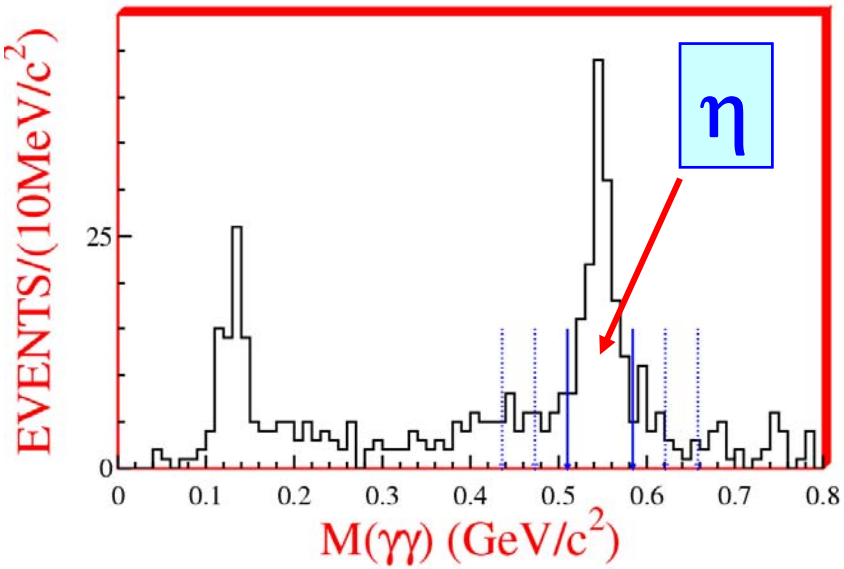
FIG. 27 (color online). The $e^+e^- \rightarrow \phi(1020) f_0(980)$ cross section measured in the $K^+K^-\pi^+\pi^-$ (circles) and $K^+K^-\pi^0\pi^0$ (squares) final states. The hatched histogram shows the simulated cross section, assuming no resonant structure. The solid (dashed) line represents the result of the one-resonance (no-resonance) fit described in the text.

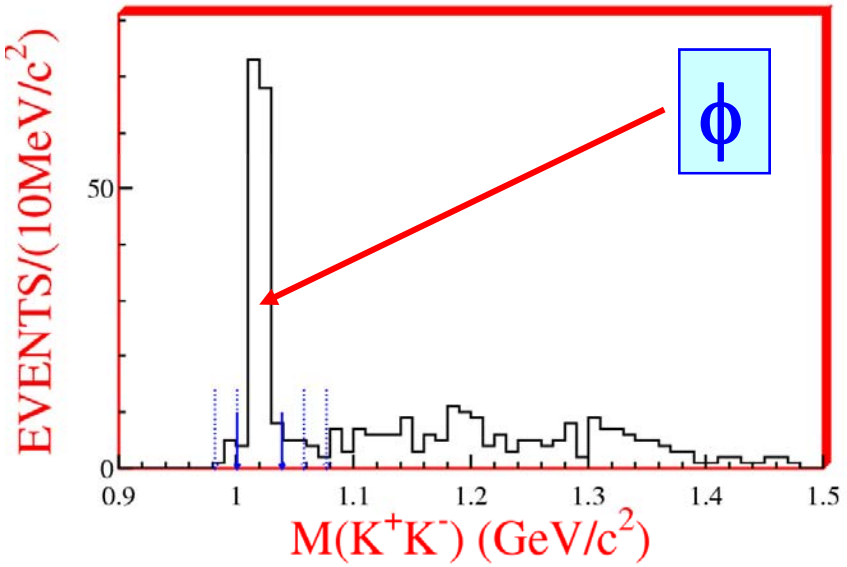
Phys. Rev. D 74 (2006) 091103(R)

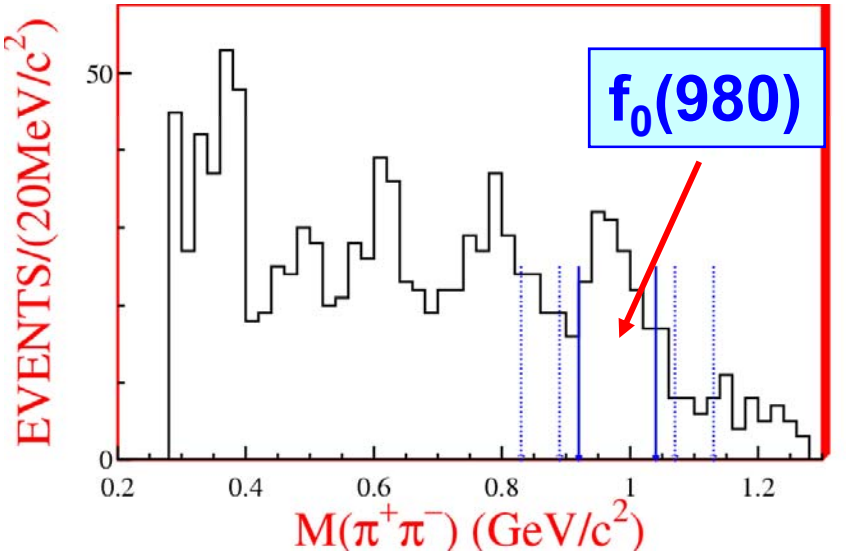
$J/\psi \rightarrow \eta\phi f_0(980)$ at BESII

Final states:

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



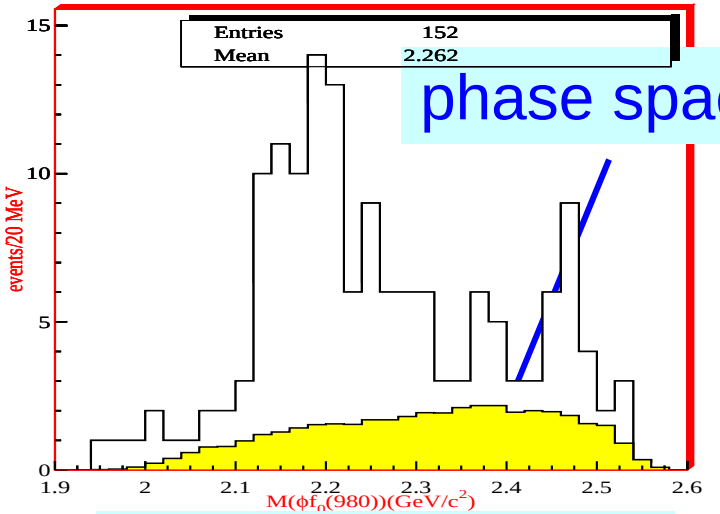




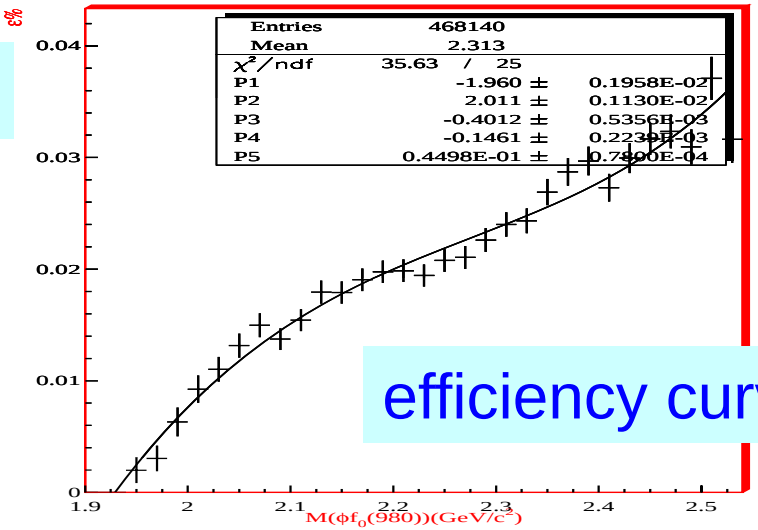
Define η, ϕ, $f_0(980)$ signal and sideband regions.

PRL 100, 102003 (2008)

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

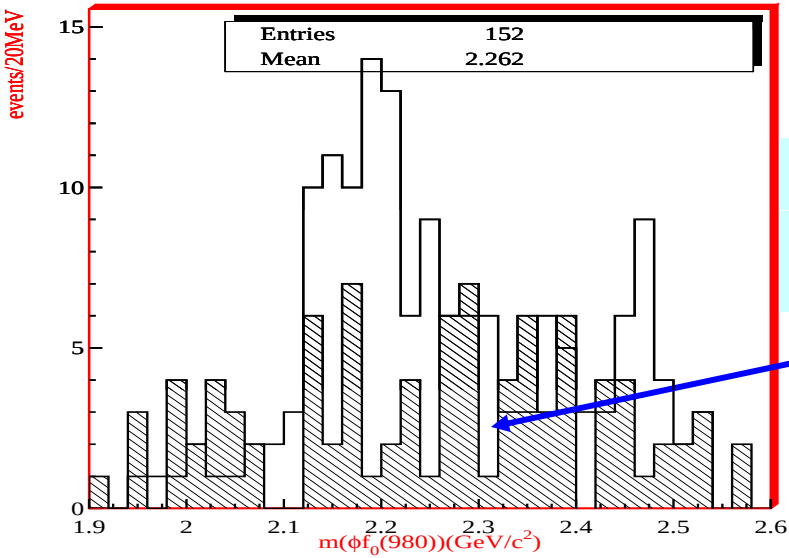


phase space



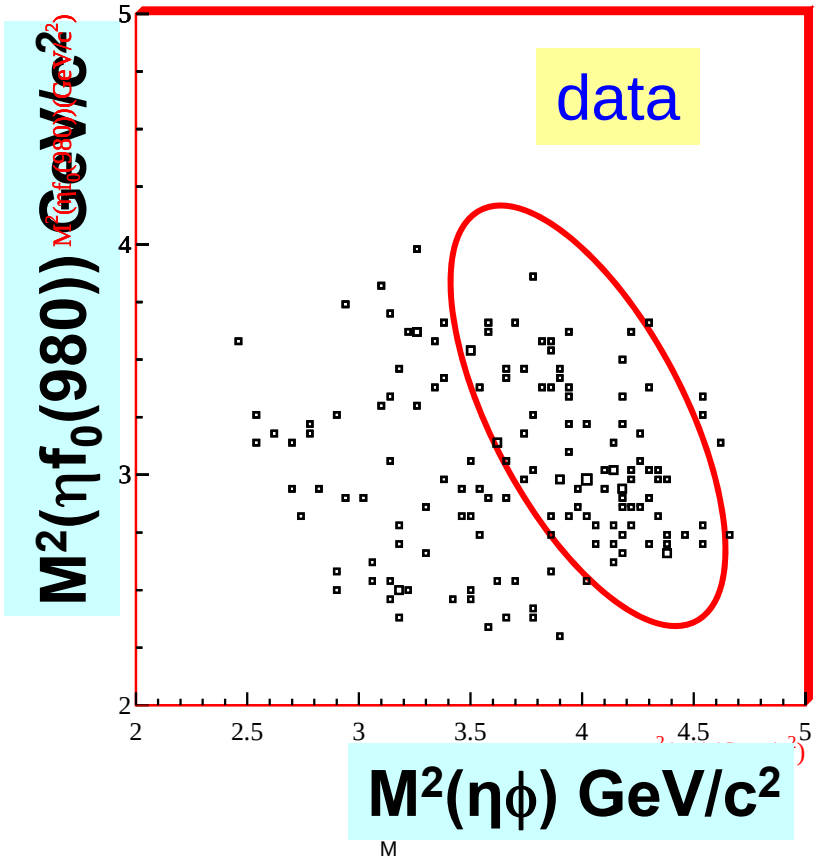
efficiency curve

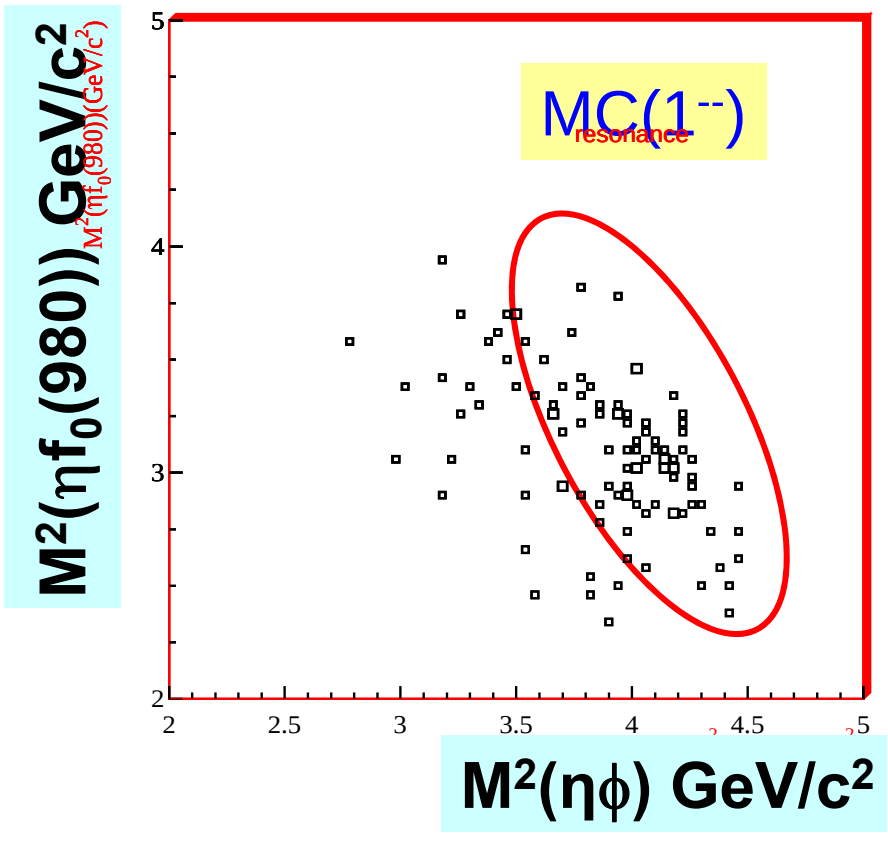
$M(\phi f_0(980))$ GeV/c^2



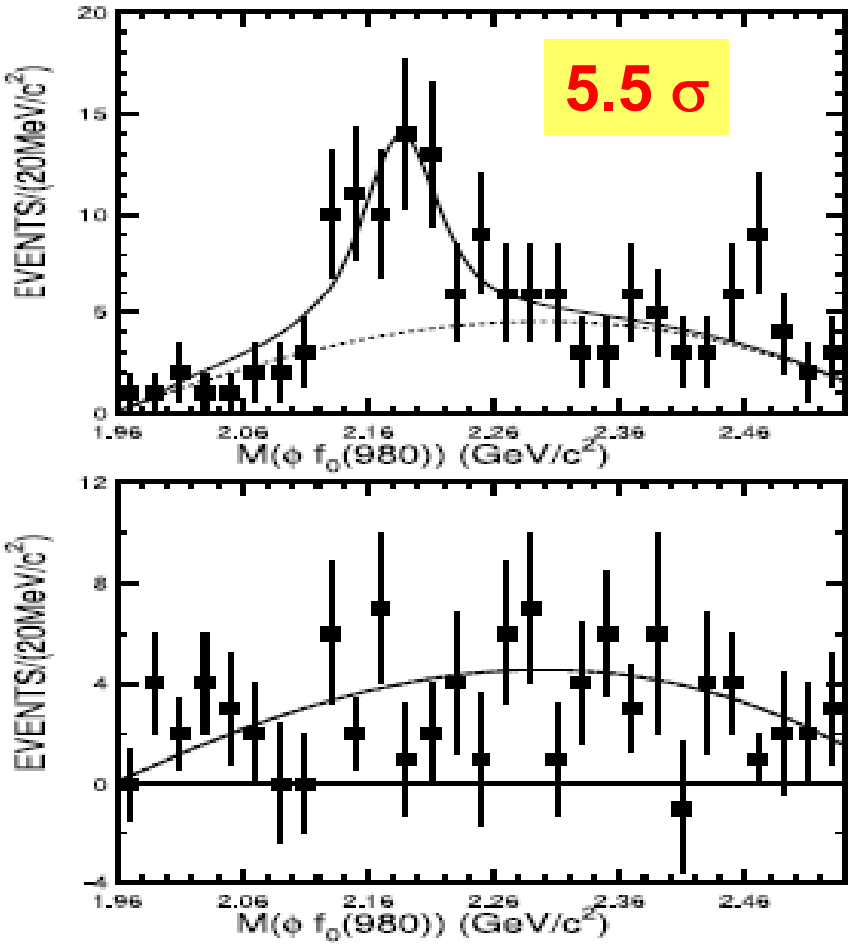
Backgrounds from sideband estimation

$M^2(\eta f_0(980))$ vs. $M^2(\eta\phi)$ (Dalitz plot)





Fit with one resonance:



Simultaneous fit to signal and sideband events with BW +p3

$M = 2.186 \pm 0.010 \pm 0.006$ GeV/c^2

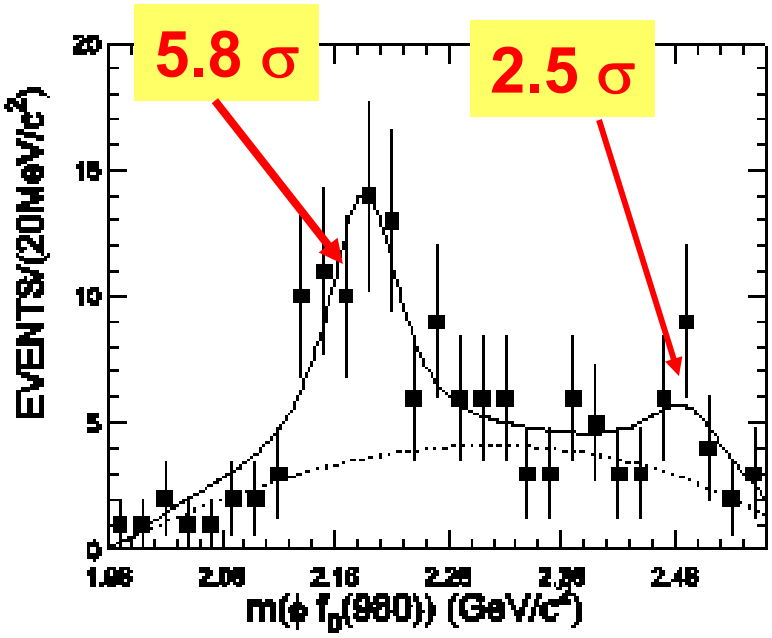
$\Gamma = 0.065 \pm 0.023 \pm 0.017$ GeV/c^2

$N_{events} = 52 \pm 12$

$M(\phi f_0(980))$ GeV/c^2

Fit with two resonances

- BG shape is fixed to sideband BG
- the mass and width of the second peak are fixed to those of from BaBar.



$M = 2.186 \pm 0.010 GeV/c^2$

$\Gamma = 0.065 \pm 0.022 GeV/c^2$

N_1 events $= 47 \pm 14$

N_2 events $= 22 \pm 11$

$$B(J/\psi \to \eta Y(2175) B(Y(2175) \to \varphi f_0(980)) B(f_0(980) \to \pi^+\pi^-) =$$

$$(2.92 \pm 0.87(stat)) \times 10^{-4}$$

- **A resonance at 2175 MeV/c^2 is observed with significance ~ 5σ in $\phi f_0(980)$ mass spectrum.**

	Mass (GeV/c^2)	Width (GeV/c^2)
BES	**$2.186 \pm 0.010 \pm 0.006$**	**$0.065 \pm 0.023 \pm 0.017$**
BABAR	**$2.175 \pm 0.010 \pm 0.015$**	**$0.058 \pm 0.016 \pm 0.020$**

- **Branching ratio obtained:**

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

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.

$\eta(2225)$ in $J/\psi \to \gamma\,\phi\,\phi$ at BESII

- A pseudoscalar signal near threshold was observed in $\phi\phi$ invariant mass spectrum by MARKIII and DM2.

- Known as $\eta(2225)$ in PDG with

  $M = 2220 \pm 18$ MeV/c^2

  $\Gamma = 150^{+300}_{-60} \pm 60$ MeV/c^2.

  - MRK3 $J/\psi \to \gamma K^+K^-K^+K^-$ 168 events

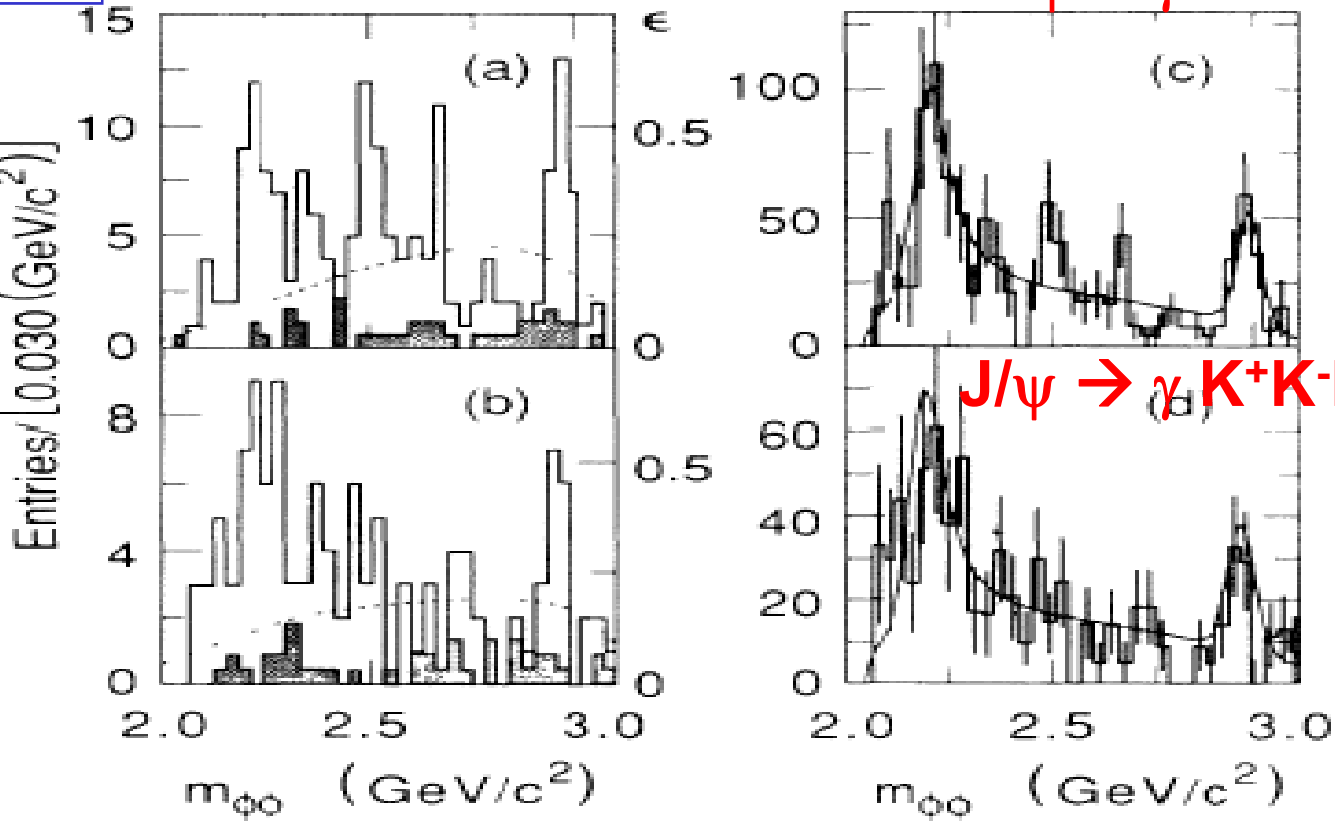
    $J/\psi \to \gamma K^+K^-K^0_SK^0_L$ 119 events

  - DM2 $J/\psi \to \gamma K^+K^-K^+K^-$ 92 events

    $J/\psi \to \gamma K^+K^-K_S^0K_L^0$ 33 events

MARKIII

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



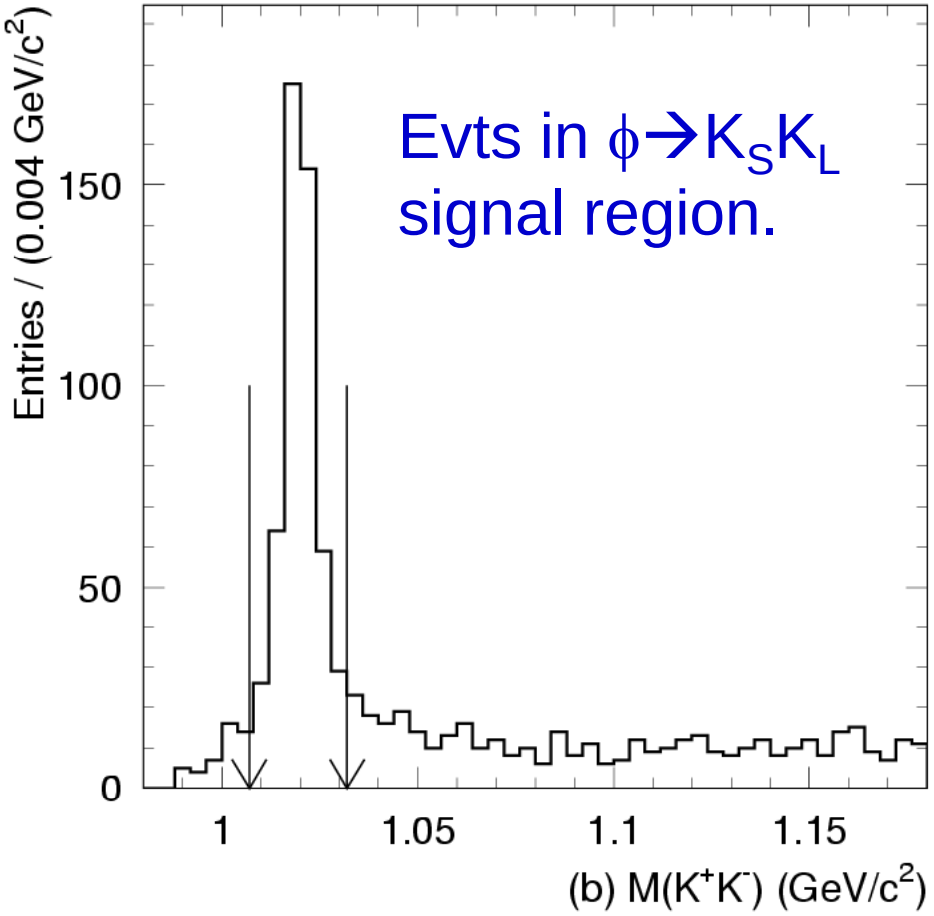
$J/\psi \rightarrow \gamma K^+K^-K^0_SK^0_L$

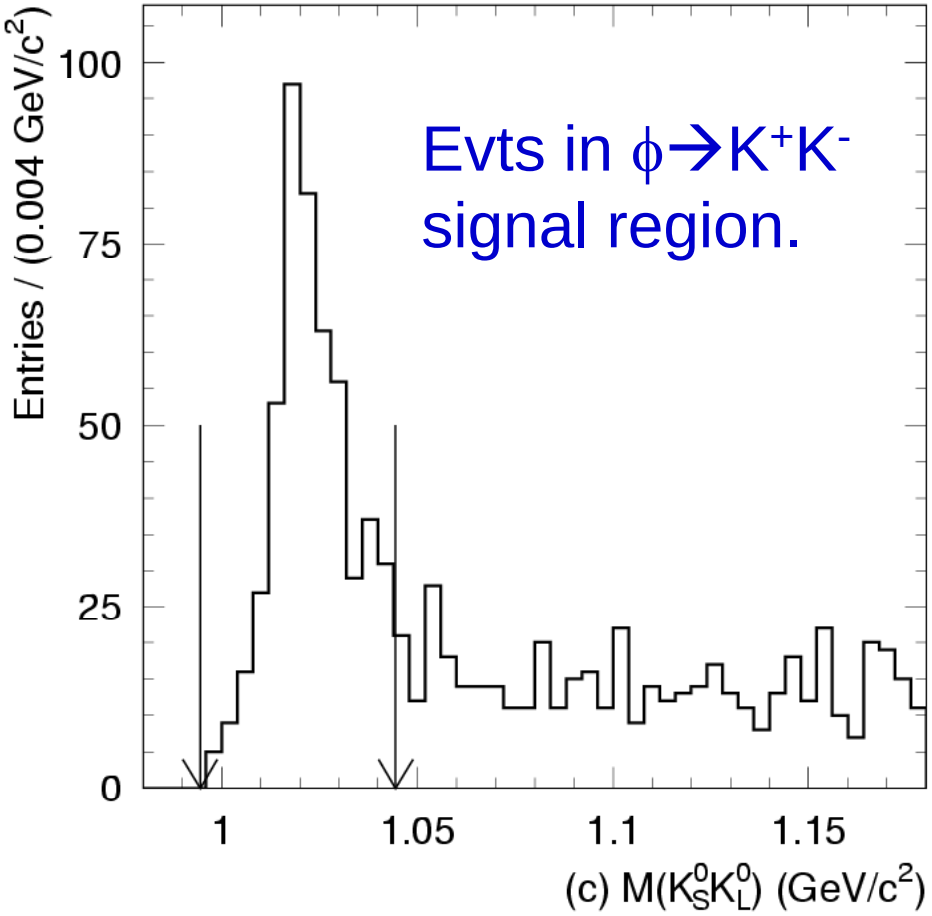
FIG. 2. The observed $\phi\phi$ invariant-mass spectra from (a) $J/\psi \rightarrow \gamma K^+K^-K^+K^-$ and (b) $J/\psi \rightarrow \gamma K^+K^-K^0_SK^0_L$; (c),(d) the corresponding $\phi\phi$ invariant-mass spectra after efficiency correction. Shaded histograms show background estimates; dashed curves show detection efficiencies denoted by ϵ; solid curves show fits described in the text.

$\eta(2225)$ in $J/\psi \rightarrow \gamma\phi\phi$

Final states:

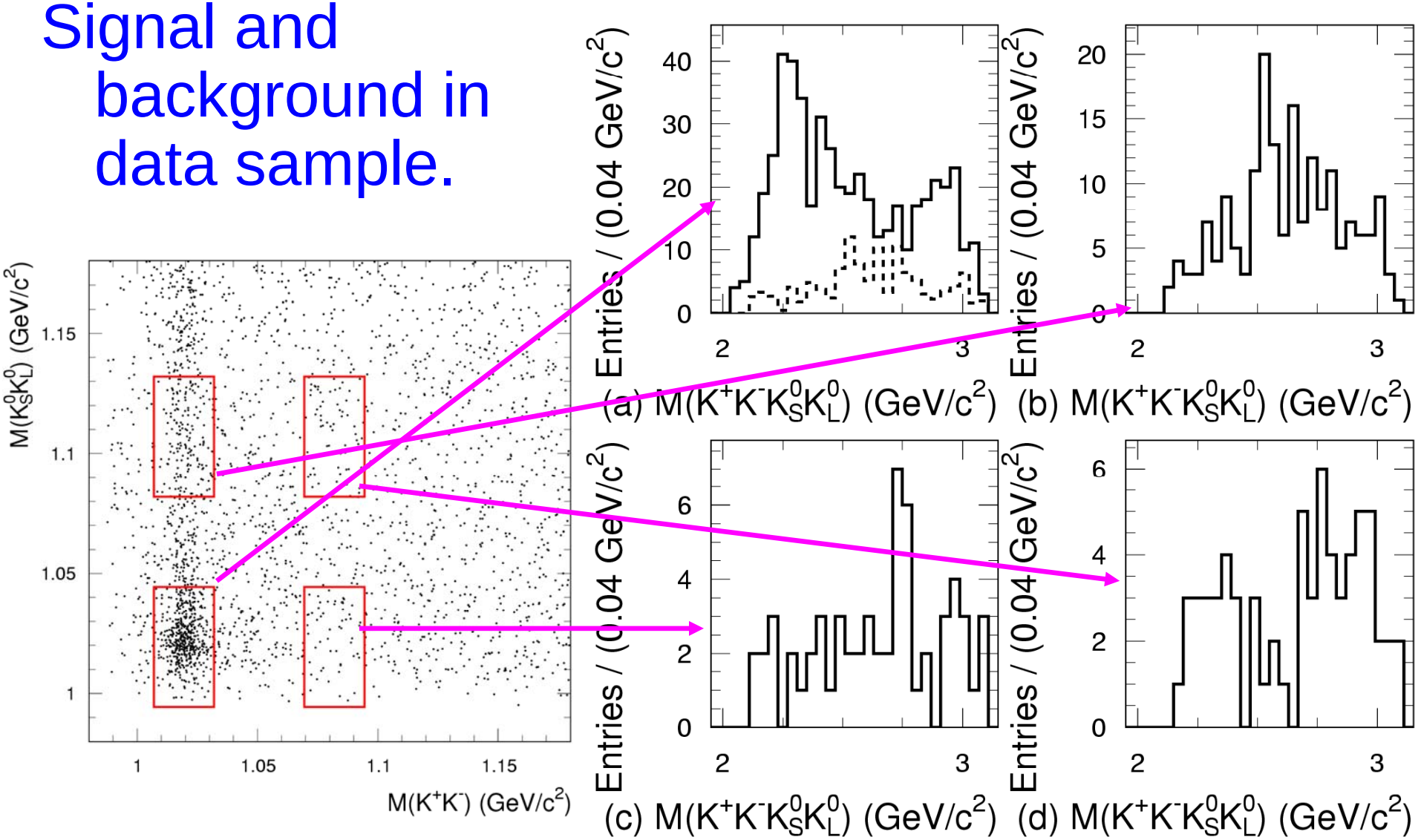
$\phi_1 \rightarrow K^+K^-$, $\phi_2 \rightarrow K_SK_L$ ($K_S \rightarrow \pi^+\pi^-$, K_L is missing) 2C-fit is applied.



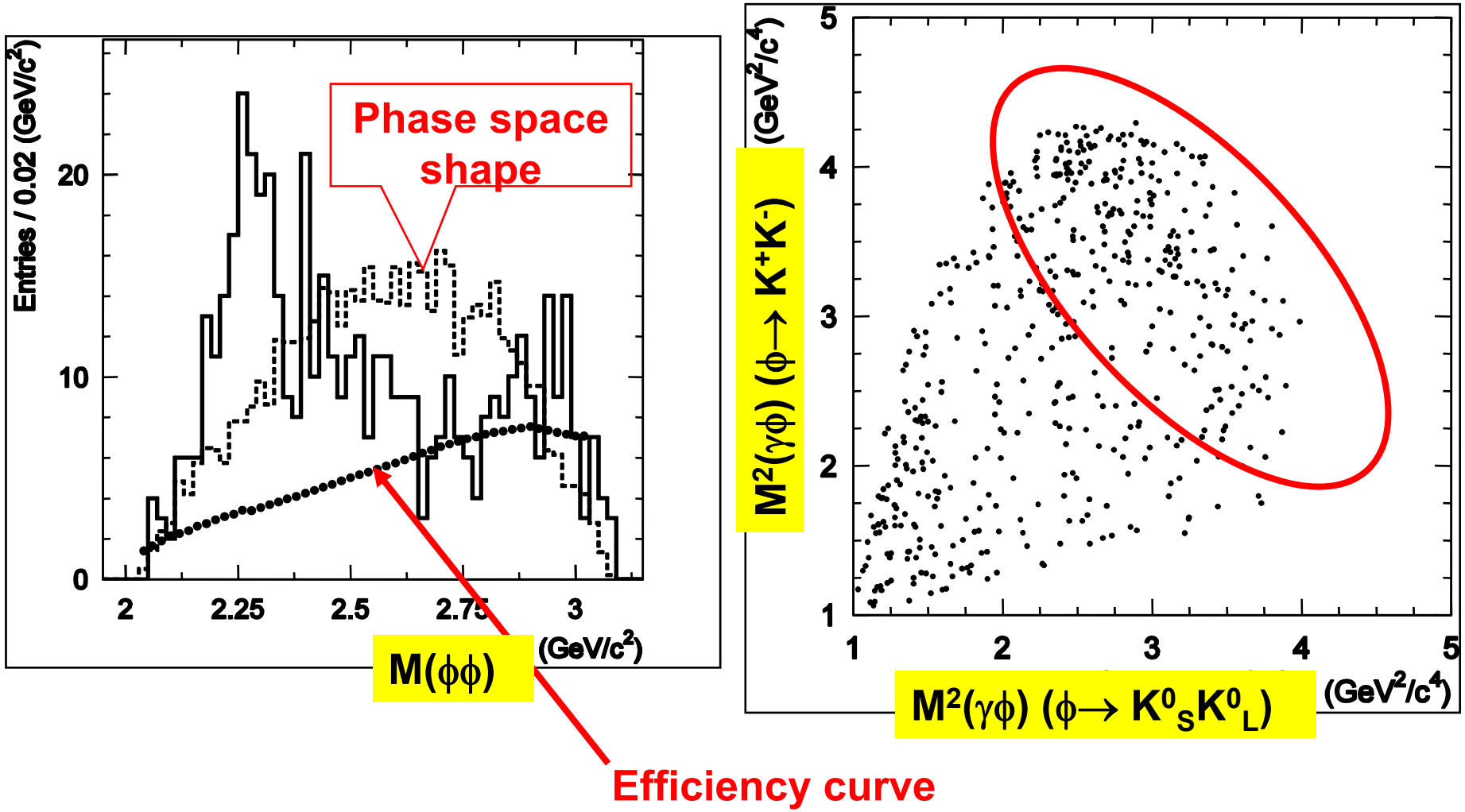


$\eta(2225)$ in $J/\psi \rightarrow \gamma\phi\phi$

Signal and background in data sample.



Near threshold enhancement observed



PWA of $J/\psi \to \gamma\phi\phi$ at BESII

PWA shows the structure is dominated by a 0^{-+} state: $\eta(2225)$ (>10 σ).

Do extra resonances exist?

	Resonance	Mass (GeV/c^2)	Width (GeV/c^2)	Num. of events	Sign.
0^-+0^-	$\eta(2225)$	$2.28^{+0.02}_{-0.02}$	$0.18^{+0.04}_{-0.04}$	$323.3^{+21.9}_{-22.9}$	>10 σ
	extra 0^-	$2.36^{+0.02}_{-0.03}$	$0.07^{+0.11}_{-0.05}$	$31.2^{+13.1}_{-12.5}$	0.8 σ
0^-+0^+	$\eta(2225)$	$2.25^{+0.01}_{-0.01}$	$0.19^{+0.04}_{-0.02}$	$199.6^{+18.4}_{-18.5}$	>10 σ
	extra 0^+	$2.01^{+0.08}_{-0.11}$	$0.14^{+0.17}_{-0.10}$	$23.8^{+10.4}_{-9.1}$	2.1 σ
0^-+2^+	$\eta(2225)$	$2.24^{+0.01}_{-0.02}$	$0.23^{+0.04}_{-0.02}$	$204.2^{+20.9}_{-18.6}$	>10 σ
	extra 2^+	$2.25^{+0.02}_{-0.01}$	$0.05^{+0.04}_{-0.02}$	$47.0^{+9.8}_{-11.3}$	3.3 σ

Resonance parameters of a pseudoscalar:

$$m = 2.24^{+0.03+0.03}_{-0.02-0.02}\ \text{GeV}$$

$$\Gamma = 0.19 \pm 0.03^{+0.06}_{-0.04}\ \text{GeV}$$

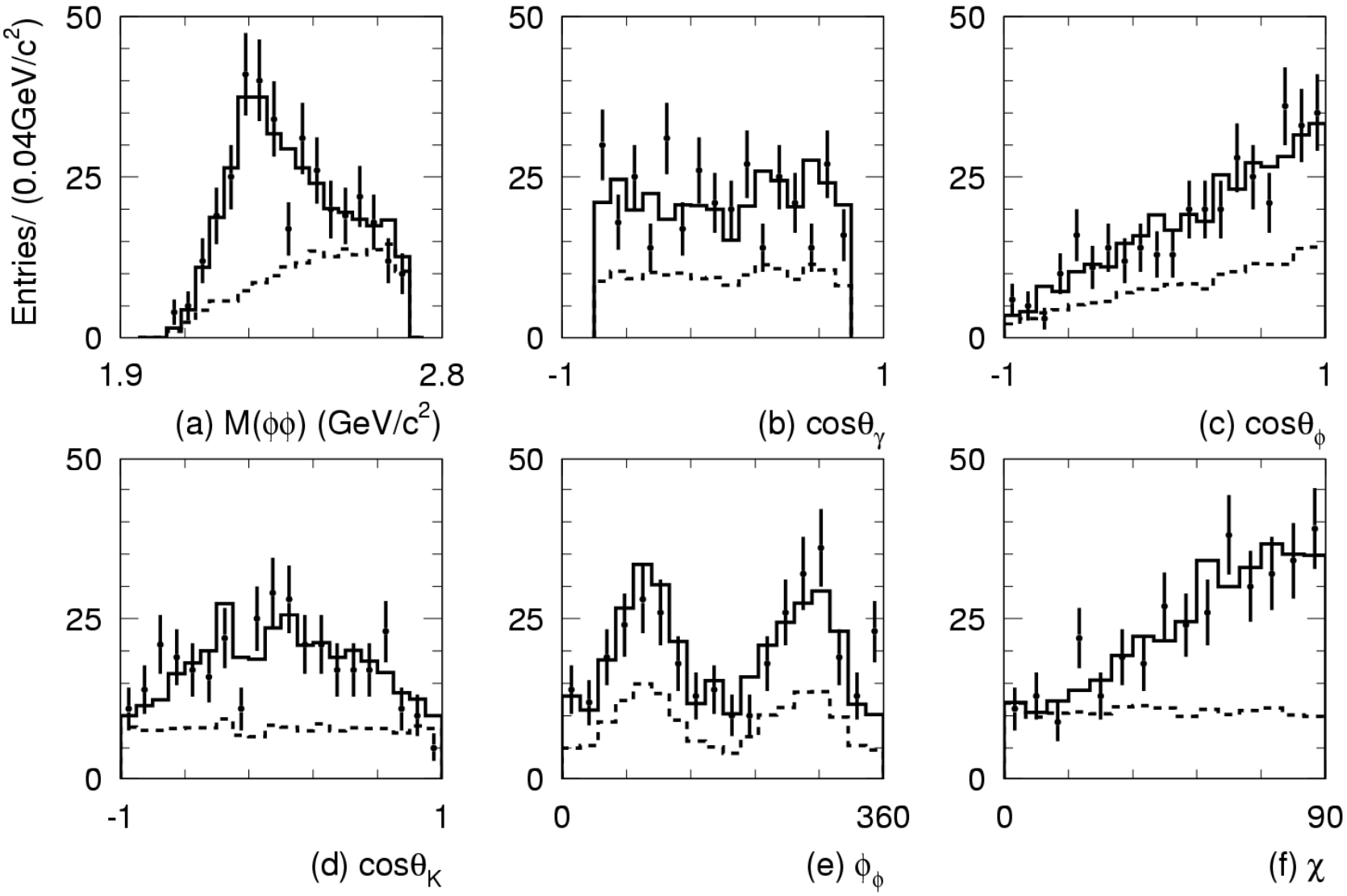
$$B(J/\psi \to \gamma\eta(2225))B(\eta(2225) \to \gamma\phi\phi)$$

$$= (4.4 \pm 0.4 \pm 0.8) \times 10^{-4}$$

PDG value:

M=2.220 ± 0.018 GeV/c^2;
Γ= 0.150 $^{+0.300}_{-0.060}$ ± 0.060 GeV/c^2;
Br: (2.9 ± 0.6) × 10^{-4}

$\eta(2225)$ in $J/\psi \rightarrow \gamma\phi\phi$



E/ι(1440), η(1405), η(1475)

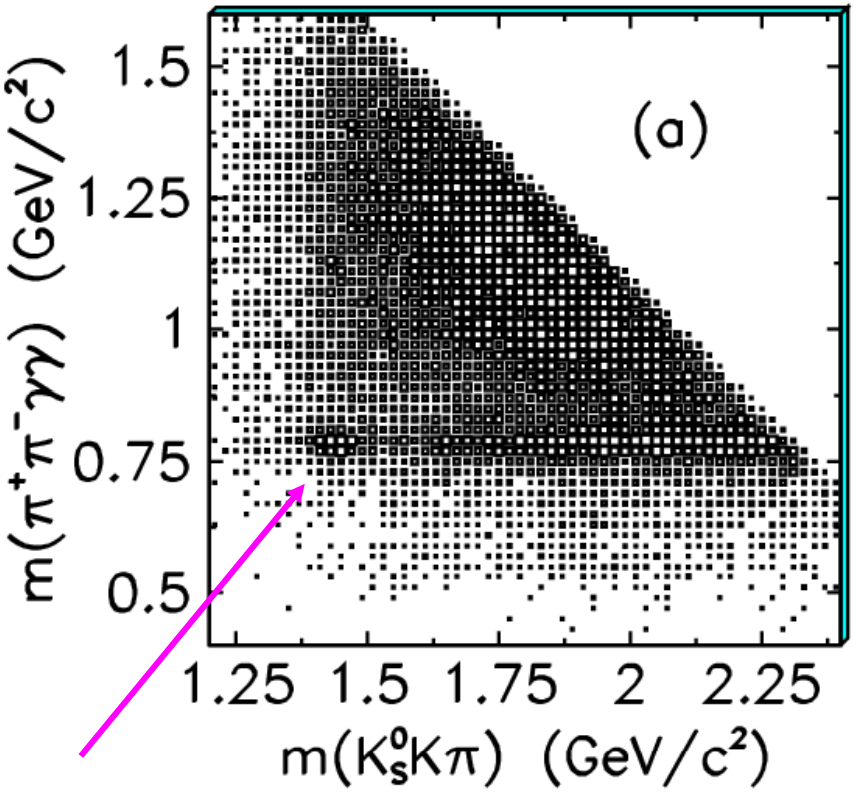
- One structure (E/ι(1440)) near 1.44 GeV, may due to two states, one couples to a(980)π and KKπ, the other couples to K*K.
- Masses, widths and decay modes are not well measured.
- Radial excited η or η' state? Glueball?
- J/ψ decays:
  - J/ψ→γX(1440)→ γ KKπ, γ ηππ
  - J/ψ→ ω/φ X(1440)→ ω/φ KKπ
  - J/ψ→ ω/φ X(1440)→ ω/φ ηππ

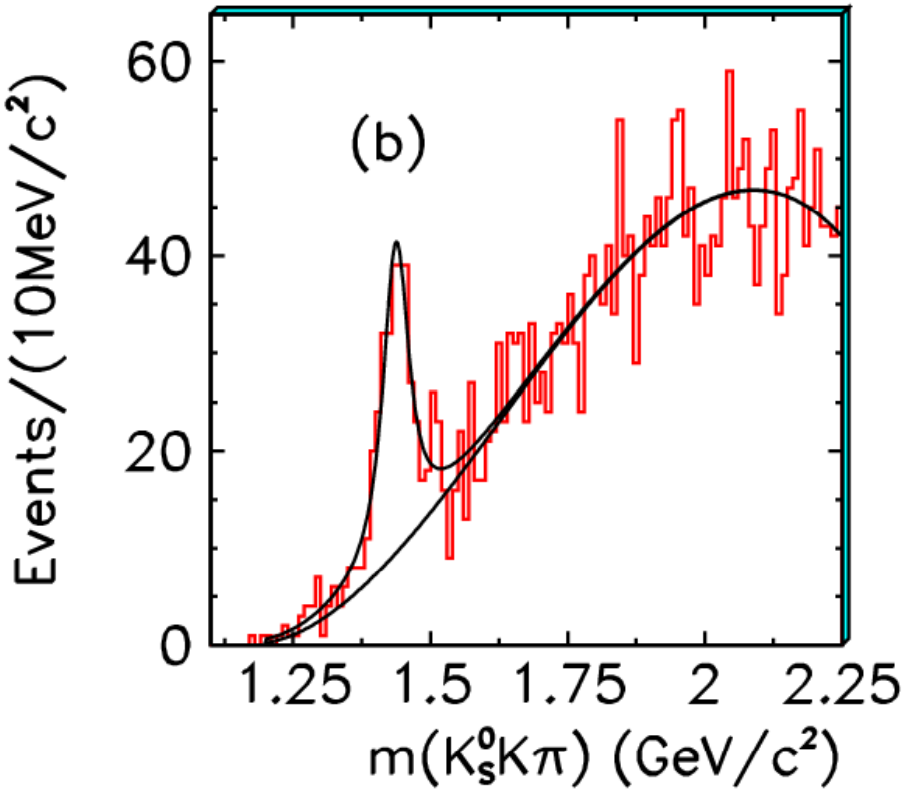
PRD77, 032005 (2008)

(this talk)

X(1440) in J/ψ → ω+KKπ

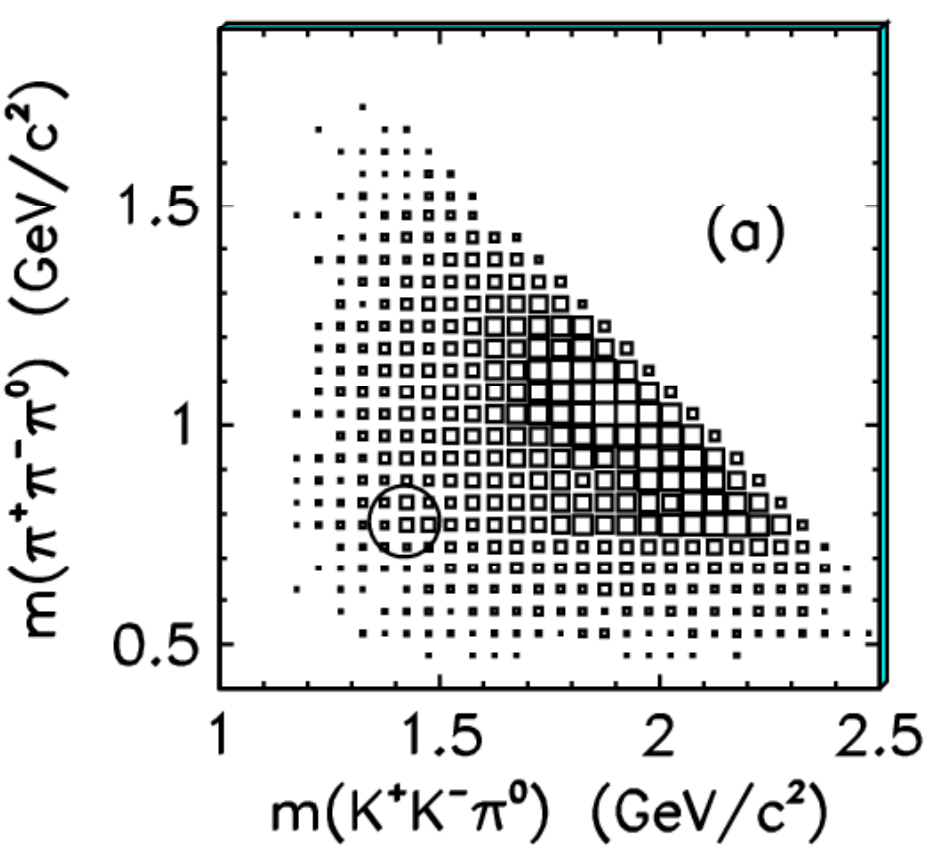
- Final states: $\omega \rightarrow \pi^+\pi^-\pi^0$, $KK\pi = K_S K\pi$

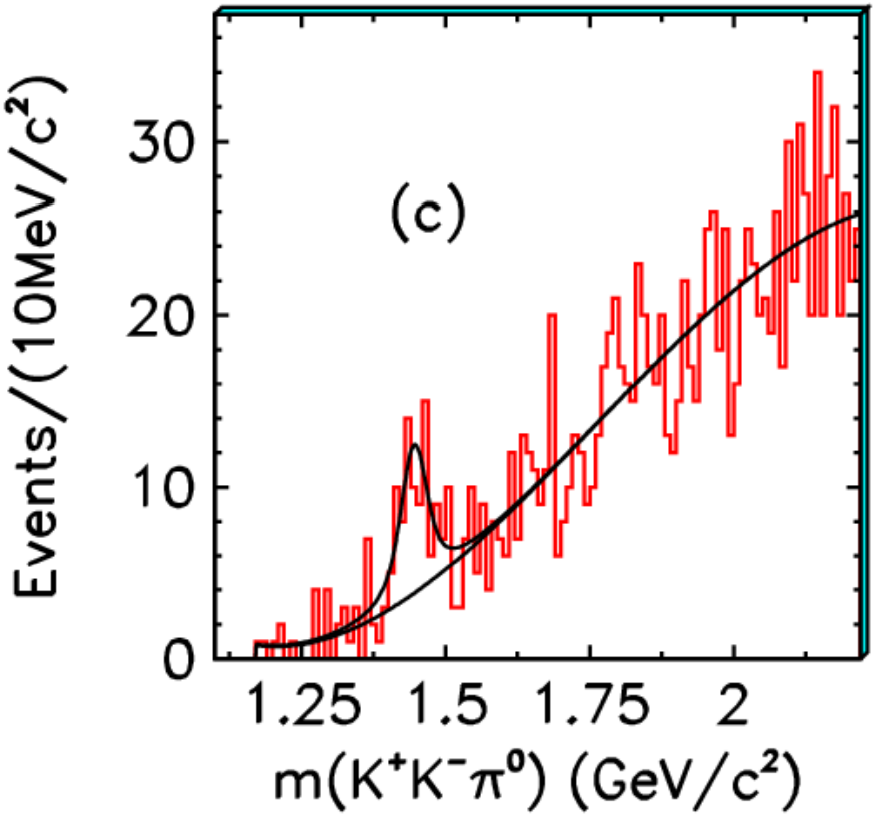




X(1440) in J/ψ → ω+KKπ

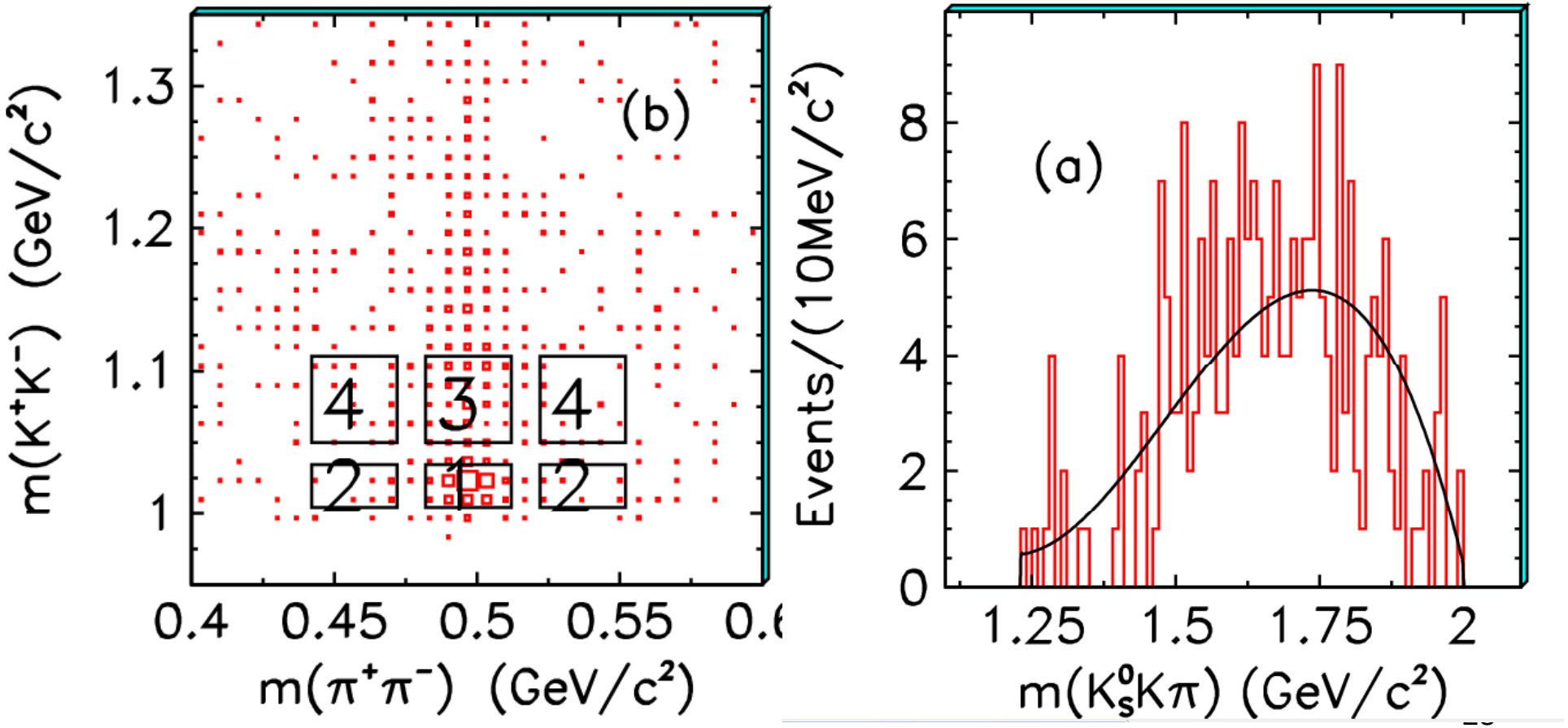
- Final states: $\omega \rightarrow \pi^+\pi^-\pi^0$, $KK\pi = K^+K^-\pi^0$





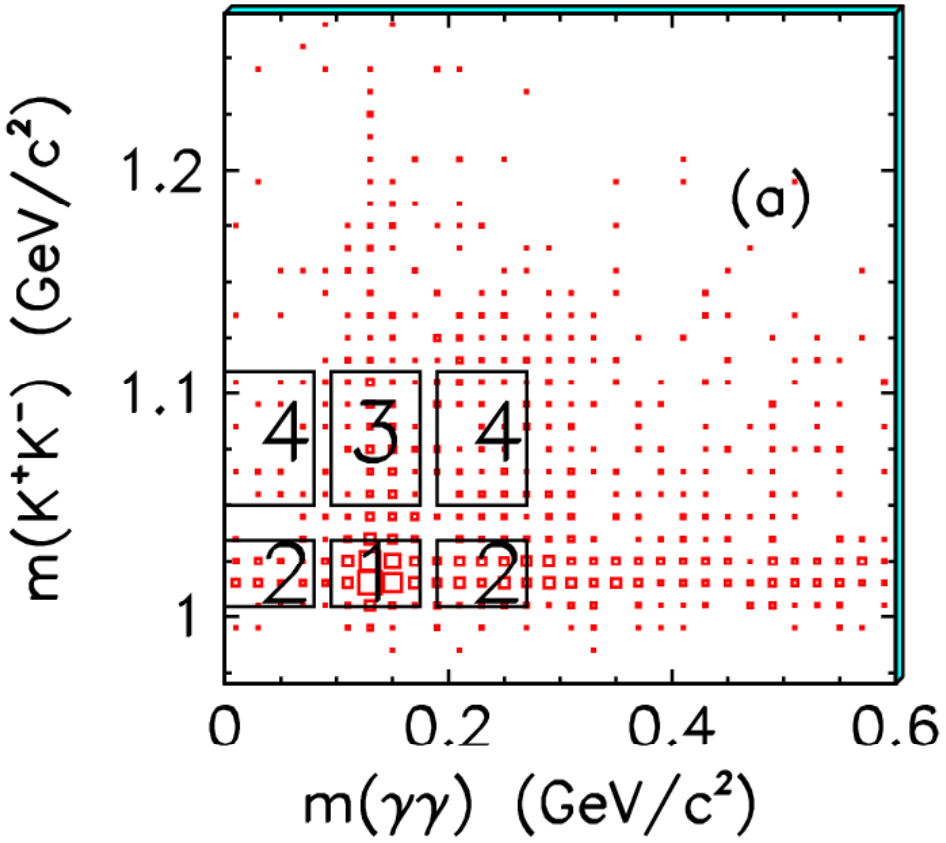
X(1440) in J/ψ →φ+KKπ

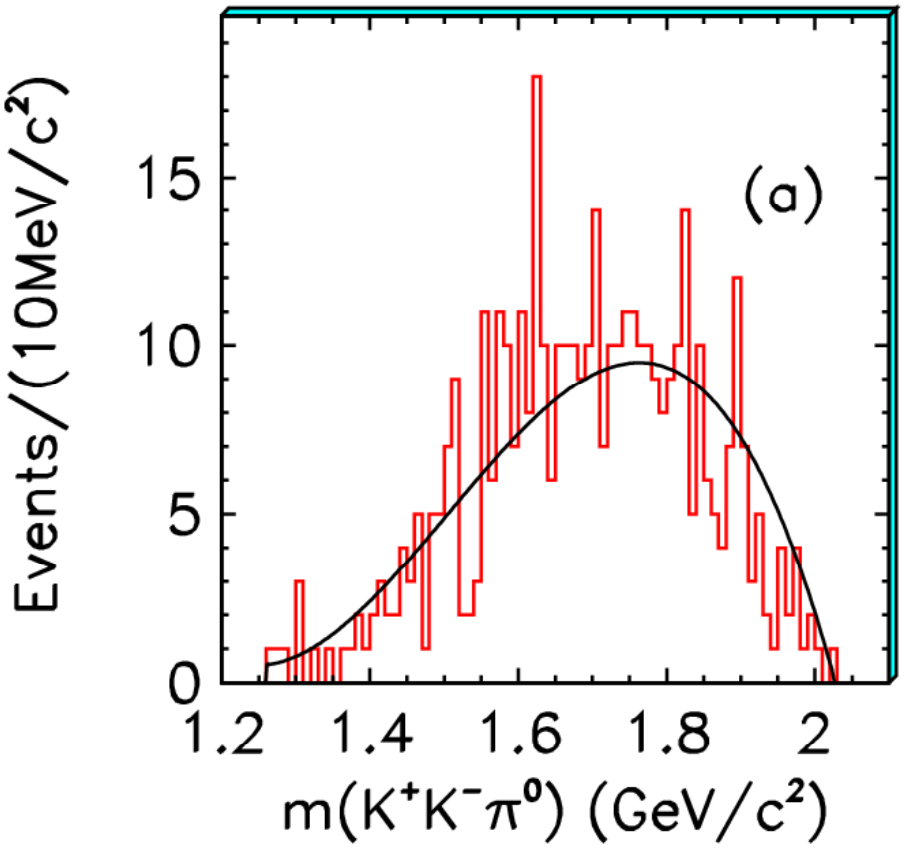
- Final states: $\phi \rightarrow K^+K^-$, $KK\pi = K_S K\pi$



X(1440) in J/ψ →φ+KKπ

- Final states: $\phi \rightarrow K^+K^-$, $KK\pi = K^+K^-\pi^0$





X(1440) in J/ψ → ω/ϕ+KKπ

TABLE V. The mass, width, and branching fractions of J/ψ decays into $\{\omega, \phi\}X(1440)$.

$J/\psi \to \omega X(1440)$	$J/\psi \to \omega X(1440)$
$(X \to K_S^0 K^+ \pi^- + \text{c.c.})$	$(X \to K^+ K^- \pi^0)$
$M = 1437.6 \pm 3.2\ \text{MeV}/c^2$	$M = 1445.9 \pm 5.7\ \text{MeV}/c^2$
$\Gamma = 48.9 \pm 9.0\ \text{MeV}/c^2$	$\Gamma = 34.2 \pm 18.5\ \text{MeV}/c^2$

$B(J/\psi \to \omega X(1440) \to \omega K_S^0 K^+ \pi^- + \text{c.c.}) = (4.86 \pm 0.69 \pm 0.81) \times 10^{-4}$

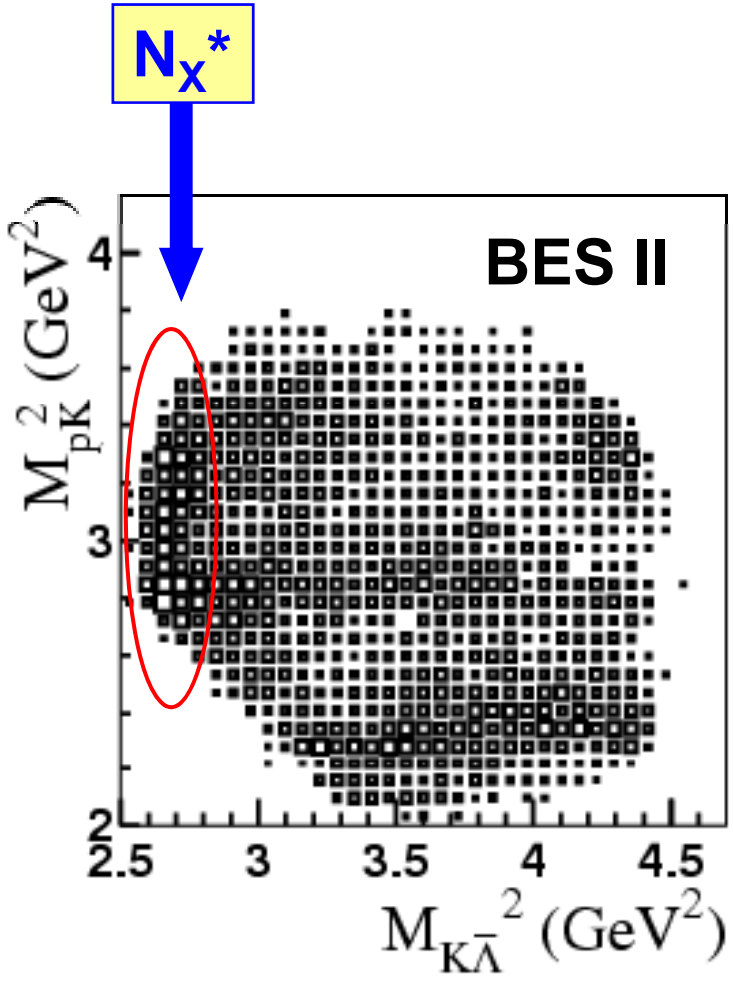
$B(J/\psi \to \omega X(1440) \to \omega K^+ K^- \pi^0) = (1.92 \pm 0.57 \pm 0.38) \times 10^{-4}$

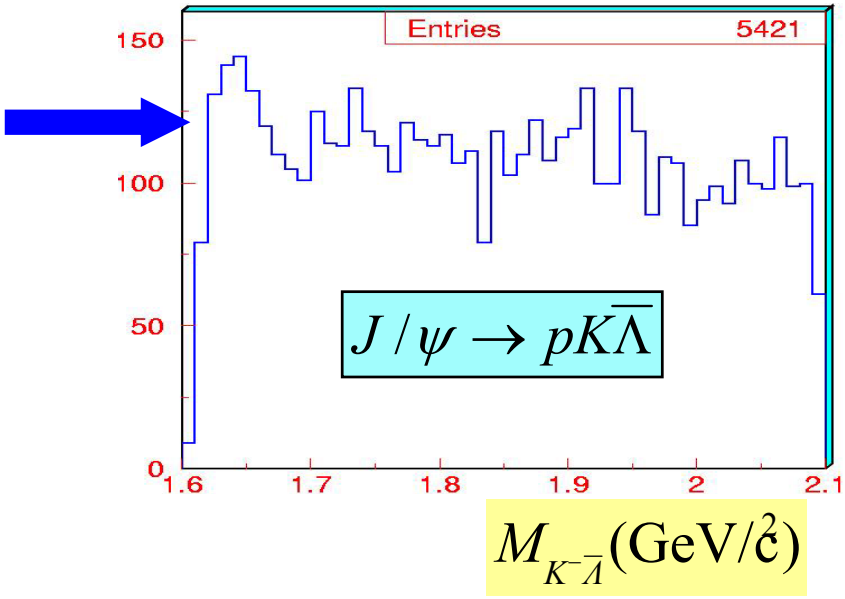
$B(J/\psi \to \phi X(1440) \to \phi K_S^0 K^+ \pi^- + \text{c.c.}) < 1.93 \times 10^{-5}$ (90% C.L.)

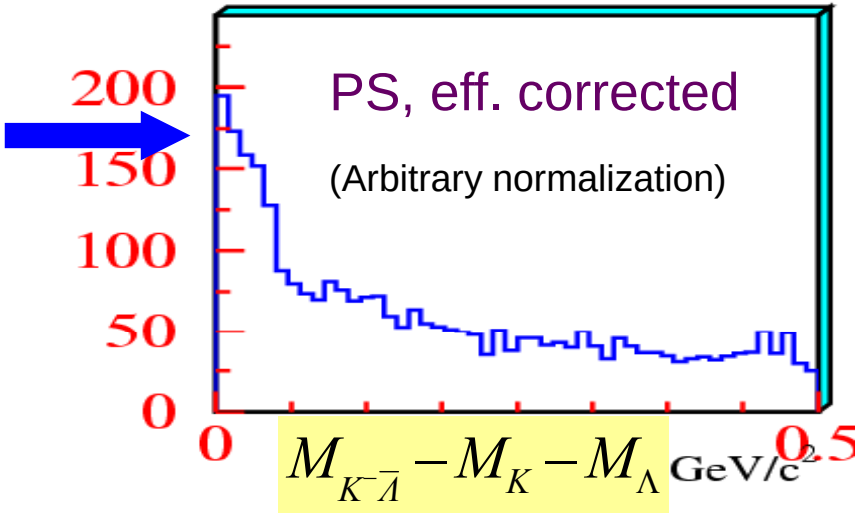
$B(J/\psi \to \phi X(1440) \to \phi K^+ K^- \pi^0) < 1.71 \times 10^{-5}$ (90% C.L.)

- B(ωX)/B(ϕX)>20! X(1440) couples to ω much stronger than to ϕ
- More statistics is needed to determine whether there are 2 structures or only one.

Observation of a strong enhancement near the threshold of $K^-\overline{\Lambda}$ mass spectrum at BES II







- **Best PWA fit: ($J^P=½^-$ is favored)**

$$m = 1625^{+5+13}_{-7-23}\,MeV \qquad \Gamma = 43^{+10+28}_{-7-11}\,MeV$$

$$Br(J/\psi \to pNx)\times Br(Nx \to K\Lambda) = 9.14^{+1.30+4.25}_{-1.25-8.28}\times 10^{-5}$$

- **Fitted as N(1535)** (becomes worse by about 5 σ ($\Delta\chi^2$=28 with *d.o.f.*=2)).

$$Br(J/\psi \to pN(1535))\times Br(N(1535) \to K\Lambda) = 4.26^{+0.15+4.22}_{-0.14-1.70}\times 10^{-4}$$

Big Br.

BESII preliminary

N_x^* is N(1535)?

- From BESII measurements:

$$BR(J/\psi \to pN(1535)) \bullet BR(N(1535) \to p\pi) \sim (1 \sim 2) \times 10^{-4}$$

$$BR(J/\psi \to pN(1535)) \bullet BR(N(1535) \to K\Lambda) \sim 4 \times 10^{-4}$$

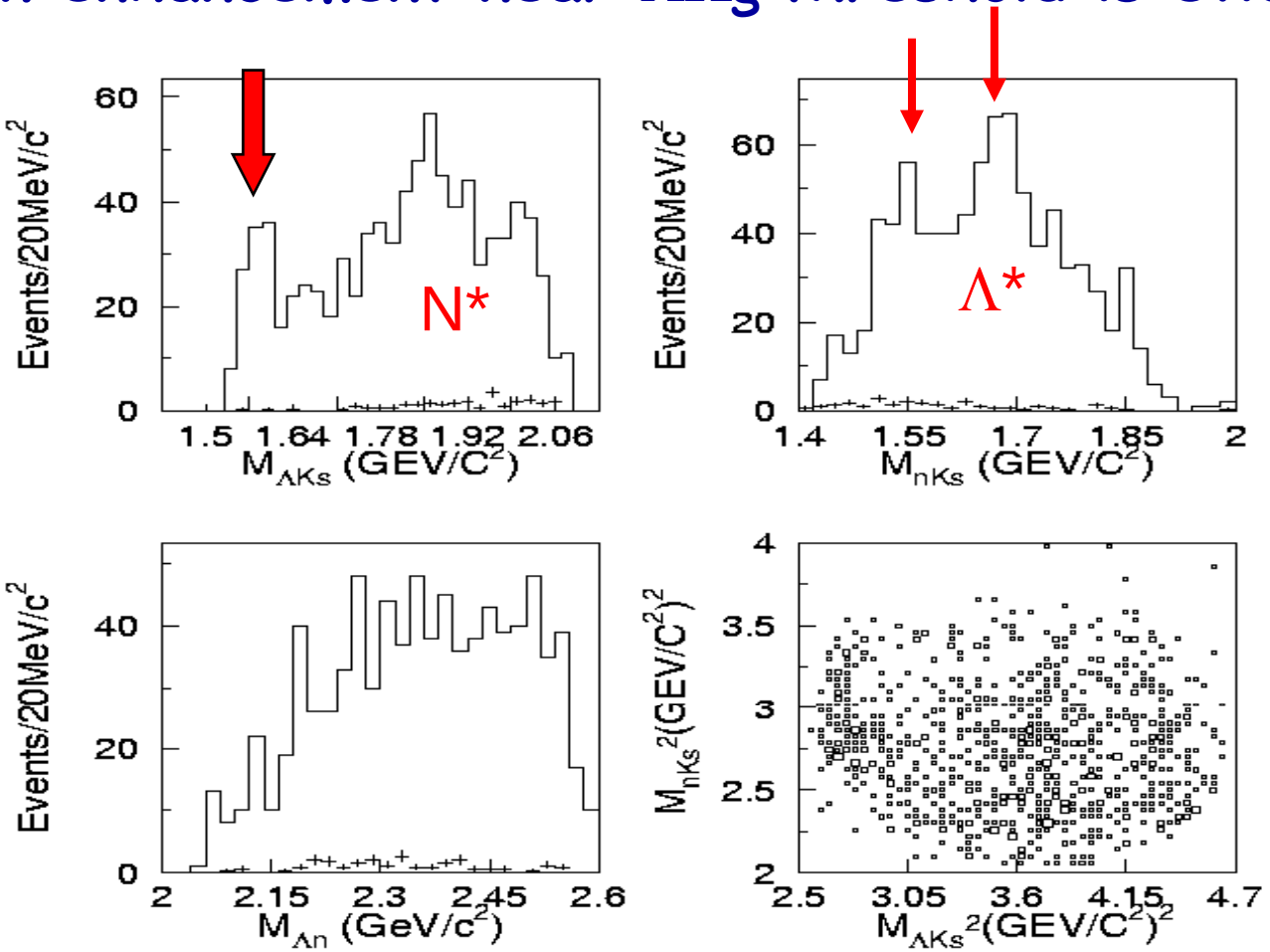
If N_x^* is N(1535), its coupling to $K\Lambda$ is much stronger than to $p\pi$.

Then N(1535) would have very large ssbar component (a 5-quark system).

$J/\psi \to nK_S^0\overline{\Lambda}$ at BESII

Phys. Lett. B659, 789 (2008)

- **An enhancement near ΛK_S threshold is evident**



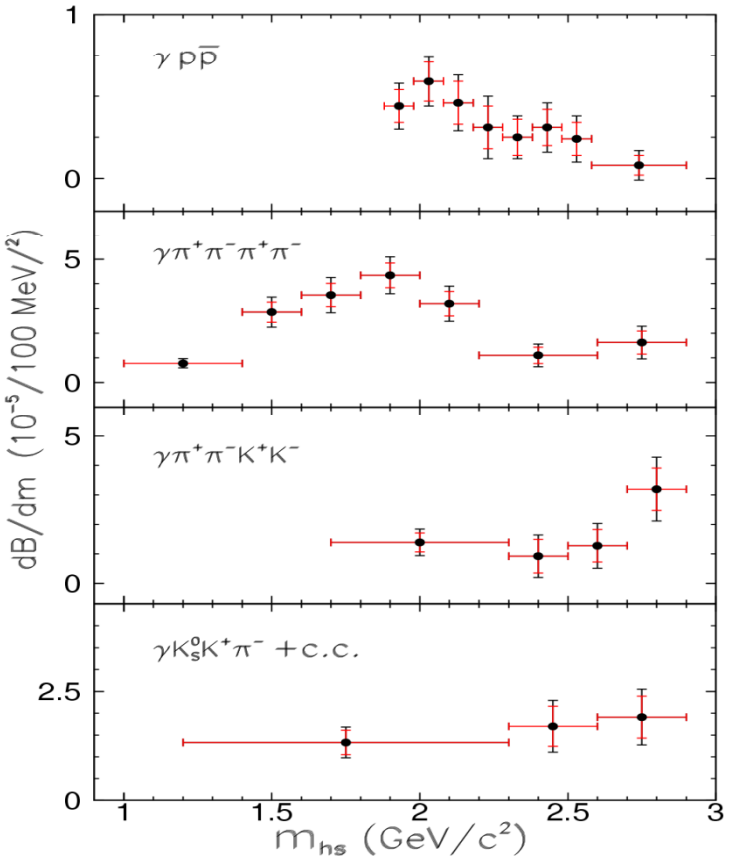
ψ' radiative decays

- Only limited modes measured by BESI
  - $\gamma\eta$, $\gamma\eta'$ [PRD58, 097101 (1998)]
  - γKK, $\gamma\pi\pi$ [PRD67, 032004 (2003)]
- Try to measure more modes
- B($\psi' \rightarrow \gamma$+X)
  - 2-prong: $\pi^+\pi^-$, K^+K^-, ppbar, $\eta\pi^+\pi^-$
  - 4-prong:2($\pi^+\pi^-$), $\pi^+\pi^-K^+K^-$, $\pi^+\pi^-$ppbar, 2(K^+K^-), $K_S K^+\pi^-$+c.c.
  - 6-prong: 3($\pi^+\pi^-$), 2($\pi^+\pi^-$)K^+K^-
- Published in
  - PRL99, 011802 (2007)
  - PRD74, 072001 (2006)

Observation of ψ' radiative decays

- Expected 1% BR, but only 0.05% observed.
- Potential channels for hadron spectroscopy study, including search for non-qqbar states, provided statistics is enough (BESIII?).
- ~ 0.1% more observed in this analysis.

Mode	BR ($\times 10^{-5}$) [m<2.9 GeV/c^2]
γ pp-bar	$2.9 \pm 0.4 \pm 0.4$
γ η'	$12.6 \pm 2.9 \pm 1.5$
γ $2(\pi^+\pi^-)$	$39.6 \pm 2.8 \pm 5.0$
γ $K_S K^+\pi^-$+c.c.	$25.6 \pm 3.6 \pm 3.6$
γ $\pi^+\pi^- K^+K^-$	$19.1 \pm 2.7 \pm 4.3$
γ $\pi^+\pi^-$ppbar	$2.8 \pm 1.2 \pm 0.7$
γ $2(K^+K^-)$	< 4.0
γ $3(\pi^+\pi^-)$	< 17
γ $2(\pi^+\pi^-)K^+K^-$	< 22



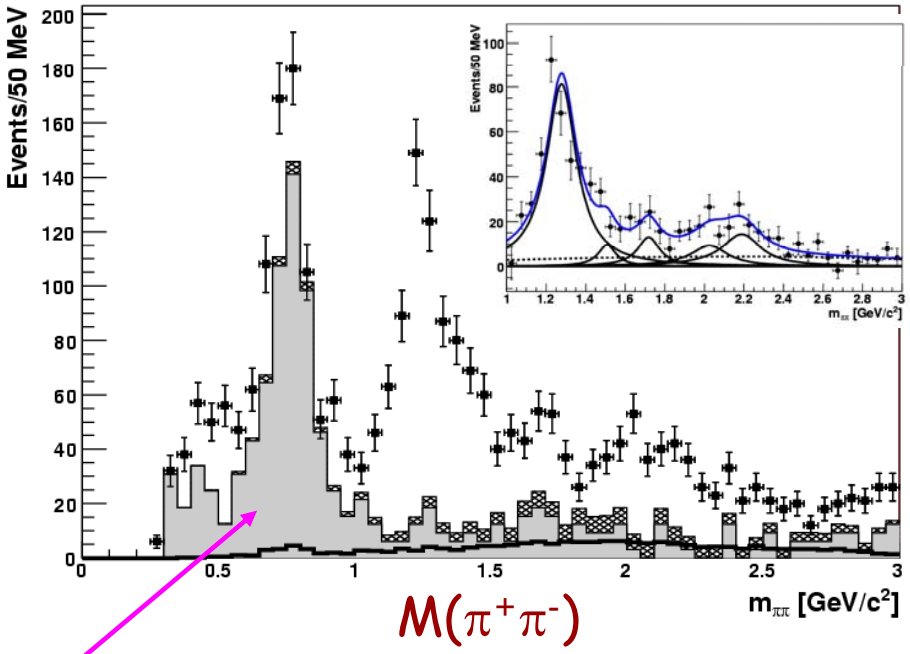
PRL99, 011802 (2007)

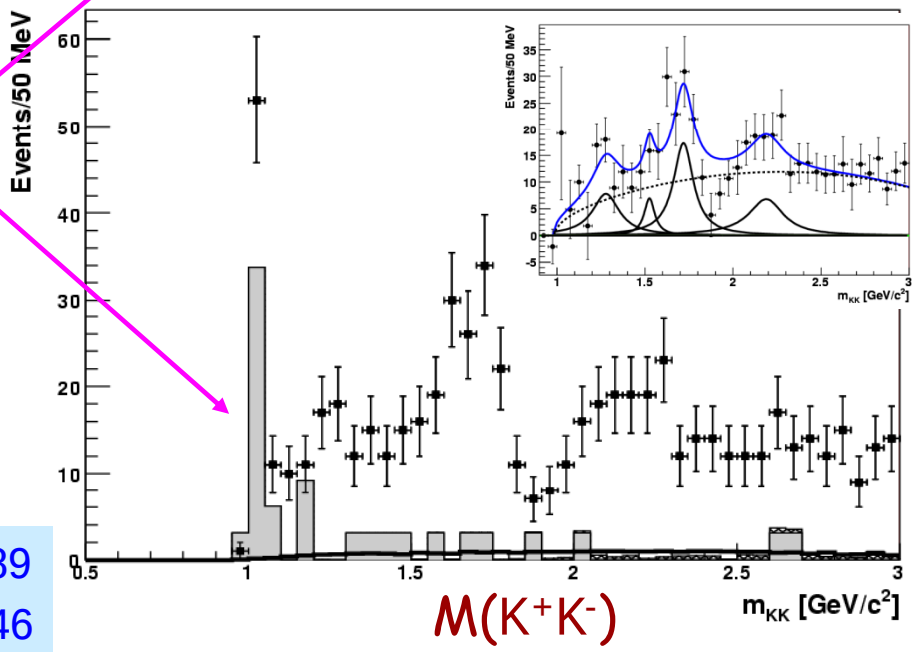
$\psi' \rightarrow \gamma\pi^+\pi^-$ and γK^+K^-

arXiv: 0710.2324

Mode	BR ($\times 10^{-5}$)
$\gamma f_2(1270) \rightarrow \gamma\pi^+\pi^-$	$22 \pm 1 \pm 2$
$\gamma f_0(1500) \rightarrow \gamma\pi^+\pi^-$	$1.5 \pm 0.7\ ^{+0.9}_{-0.4}$
$\gamma f_0(1710) \rightarrow \gamma\pi^+\pi^-$	$2.4 \pm 0.6\ ^{+0.8}_{-1.1}$
$\gamma f_4(2050) \rightarrow \gamma\pi^+\pi^-$	$2.8 \pm 0.9\ ^{+0.8}_{-0.6}$
$\gamma f_0(2200) \rightarrow \gamma\pi^+\pi^-$	$4.6 \pm 1.0\ ^{+4.5}_{-0.9}$
$\gamma f_2(1270) \rightarrow \gamma K^+K^-$	$1.9 \pm 0.6\ ^{+1.0}_{-0.6}$
$\gamma f'_2(1525) \rightarrow \gamma K^+K^-$	$0.69 \pm 0.44\ ^{+0.41}_{-0.21}$
$\gamma f_0(1710) \rightarrow \gamma K^+K^-$	$3.1 \pm 0.6\ ^{+1.1}_{-0.7}$

- Fit with incoherent BWs
- ISR produced ρ and ϕ consistent with prediction





$\gamma f_2(1270) \rightarrow \gamma\pi^+\pi^-$ helicity amplitudes

Positive solution	Negative solution
$x = 0.20 \pm 0.09 \pm 0.25$	$x = -0.26 \pm 0.09 \pm 0.24$
$y = -0.26 \pm 0.08 \pm 0.05$	$y = -0.25 \pm 0.09 \pm 0.06$
$\rho_{stat} = 0.53$	$\rho_{stat} = -0.43$
$\rho_{sys} = 0.44$	$\rho_{sys} = -0.41$

J/ψ: x=0.89
y=0.46

$D \to e^+X$, $D \to K^{+/-}X$ and $D \to \mu^+X$

$B(D \to e^+X)$

	$B(D^0 \to e^+X)(\%)$	$B(D^+ \to e^+X)(\%)$
CLEO-c	$6.46 \pm 0.17 \pm 0.13$	$16.13 \pm 0.20 \pm 0.33$
MarkIII	$7.5 \pm 1.1 \pm 0.4$	$17.0 \pm 1.9 \pm 0.7$
BES-II	$6.3 \pm 0.7 \pm 0.4$	$15.2 \pm 0.9 \pm 0.8$
PDG2007	6.55 ± 0.17	16.1 ± 0.4

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$$\frac{\Gamma(D^+ \to e^+X)}{\Gamma(D^0 \to e^+X)} = 0.95 \pm 0.12 \pm 0.07$$

$B(D \to K^{+/-}X)$

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	$B(D^+ \to K^-X)(\%)$	$B(D^+ \to K^+X)(\%)$	$B(D^0 \to K^-X)(\%)$	$B(D^0 \to K^+X)(\%)$
BES-II	$24.7 \pm 1.3 \pm 1.2$	$6.1 \pm 0.9 \pm 0.4$	$57.8 \pm 1.6 \pm 3.2$	$3.5 \pm 0.7 \pm 0.3$
PDG2007	27.5 ± 2.4	5.5 ± 1.6	53 ± 4	$3.4^{+0.6}_{-0.4}$

$B(D \to \mu^+X)$

To be published in PLB

	$B(D^0 \to \mu^+X)(\%)$	$B(D^+ \to \mu^+X)(\%)$
ARGUS	$6.0 \pm 0.7 \pm 1.2$	-
CHORUS	$6.5 \pm 1.2 \pm 0.3$	-
BES-II	$6.8 \pm 1.5 \pm 0.6$	$17.6 \pm 0.7 \pm 1.3$
PDG	6.6 ± 0.6	

the first measurement

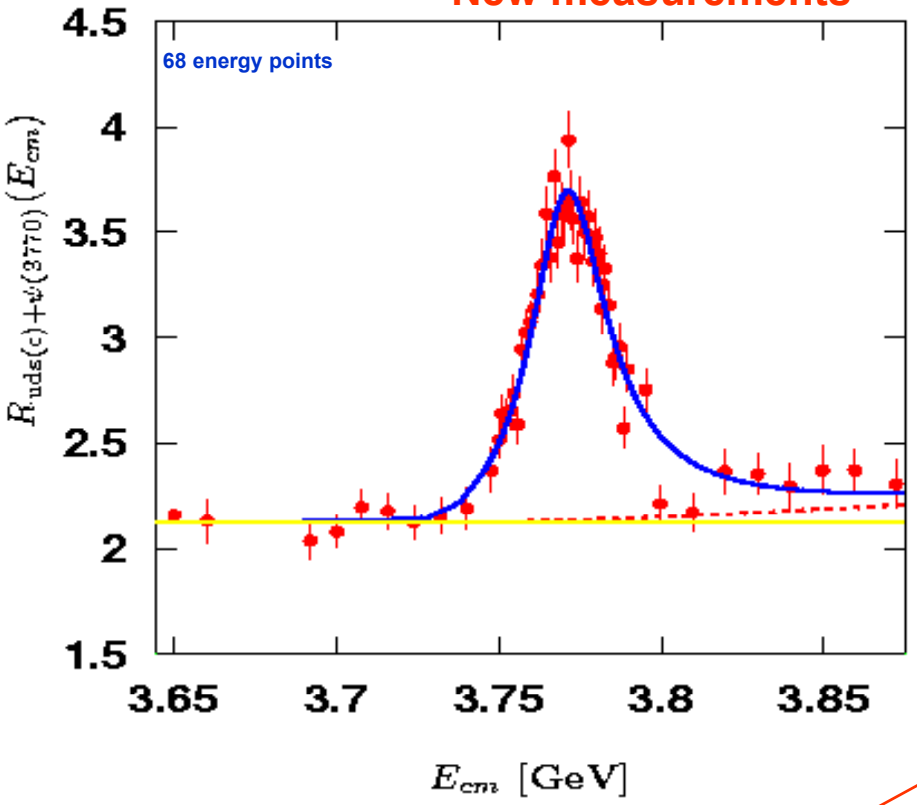
$$\frac{\tau_{D^+}}{\tau_{D^0}} = 2.54 \pm 0.02$$

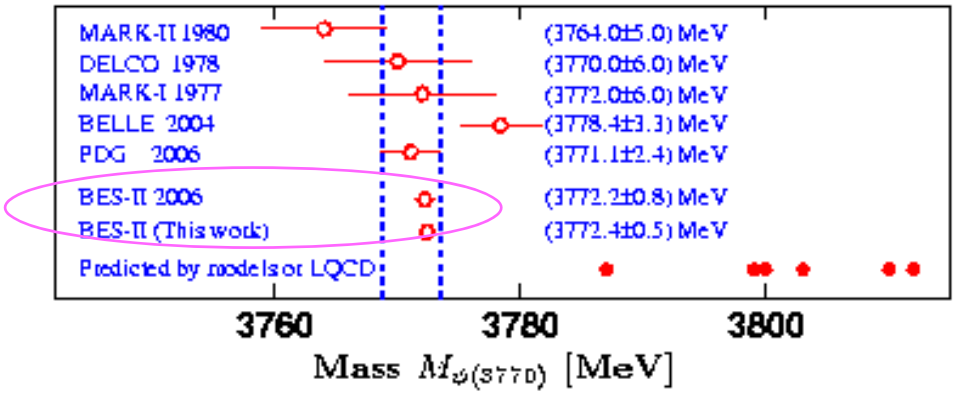
PDG

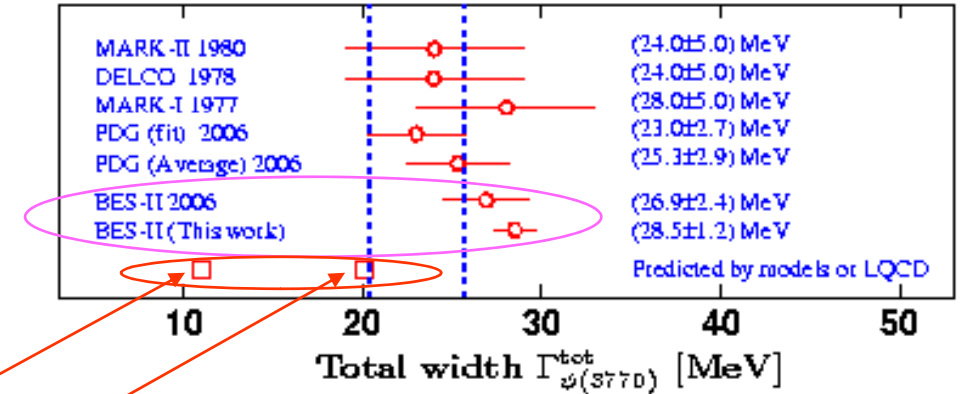
$$\frac{B(D^+ \to \mu^+X)}{B(D^0 \to \mu^+X)} = 2.59 \pm 0.70 \pm 0.15$$

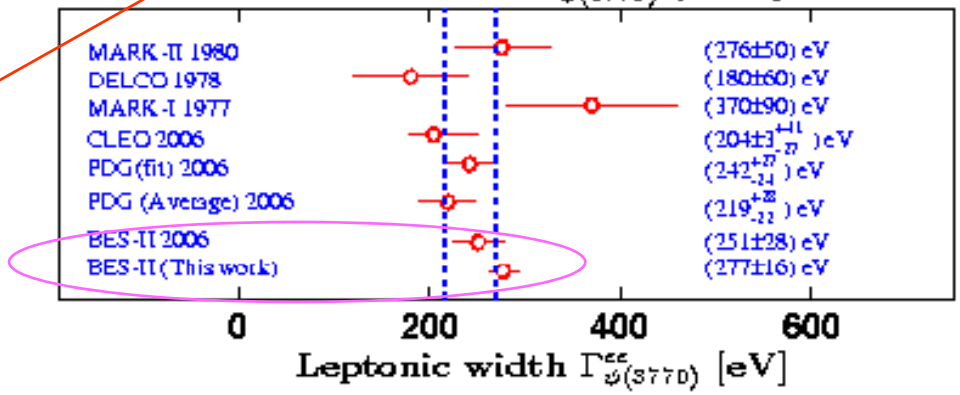
Resonance Parameters of ψ(3770)

New measurements









$\Gamma(\psi(3770) \to D\overline{D}) = 11$ MeV (Heikkila ...)

$\Gamma(\psi(3770) \to D\overline{D}) = 20.1$ MeV (Eichten ...)

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Resonance Parameters of $\psi(3770)$

Comparison with those measured by other experiments (energy scan)

Experiment	$\sigma^{prd}[e^+e^-\to\psi(3770)]$[nb]	$\sigma^{obs}[e^+e^-\to\psi(3770)]$[nb]	
BES (PLB 625 (2007) 238	10.0±0.3±0.5	7.2±0.2±0.4	Dec. 2003 data
BES [PRL 97(2006)121801]	9.6±0.7±0.4	6.9±0.5±0.3	Mar. 2003 data
MARKII		9.3±1.4	

$M_{\psi(3770)}$(MeV)	$\Gamma^{tot}_{\psi(3770)}$(MeV)	$\Gamma^{ee}_{\psi(3770)}$(eV)	Note	
3772.4±0.4±0.3	28.5±1.2±0.2	277±11±13	PLB 625 (2007) 238	Dec. 2003 data
3772.2±0.7±0.3	26.9±2.4±0.3	251±26±11	PRL 97(2006)121801	Mar. 2003 data

Experiment	BES [PLB 652(2007) 238]	BES [PRL 97(2006)121801]	PDG
$B[\psi(3770)\to e^+e^-][\times10^{-5}]$	0.97±0.03±0.05	0.93±0.06±0.03	1.05±0.14

Dec. 2003 data

Mar. 2003 data

R_{uds}=2.121 ±0.023 ±0.084 (fit to cross sections at 68 energy points)

$$B[\psi(3686)\to e^+e^-]=(0.704\pm0.122\pm0.033)\%$$ PRL 97 (2006) 121801

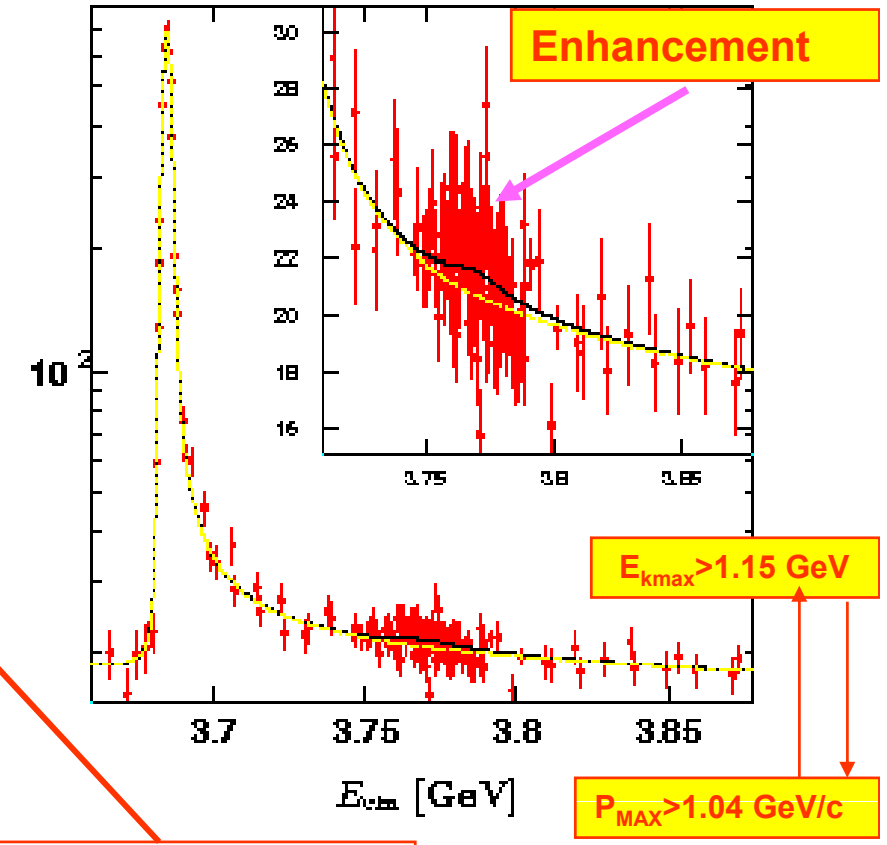
$$B[\psi(3686)\to e^+e^-]=(0.735\pm0.018)\%$$ PDG04

B[ψ(3770)→non-DD]

New measurements

cross sections measured at 156 energy points

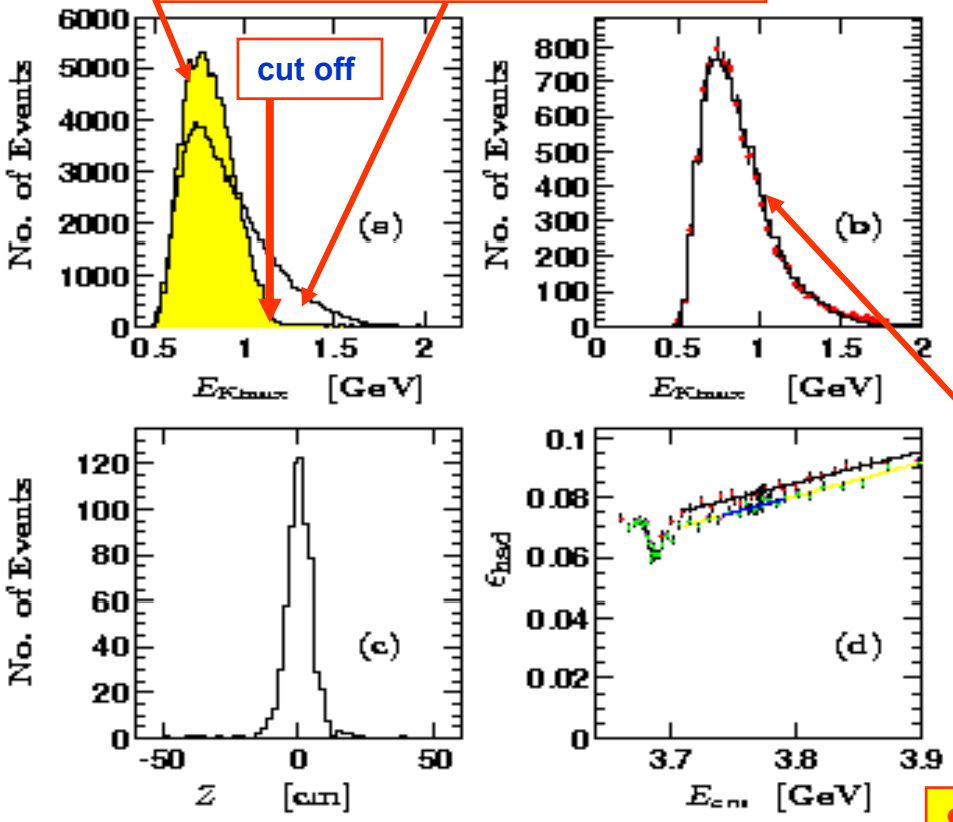
Observed non-DDbar cross section



All kinds of hadrons including non-DDbar events

From MC DD-bar events

From MC $e^+e^- \rightarrow$ hadrons



histogram is MC, point with error bars is data

The largest momentum of the charged particle from D decays is about 0.92 GeV/c.

The largest momentum of the charged track in the final states

Selection of the non-DD-bar hadronic events by tagging the largest energy of the assumed Kaon in the final states of e+e- annihilation

B[ψ(3770)→non-DD]

$$BF(\psi(3770)\to non-D\bar{D})=(15.1\pm5.6\pm1.8)\%$$

$$\sigma^{obs}_{non-D\bar{D}}=(1.08\pm0.40\pm0.15)\quad nb$$

$$\sigma^{obs}_{D\bar{D}}=(6.07\pm0.40\pm0.35)\quad nb$$

$$R_{uds}=2.199\pm0.047\pm0.119$$

cross section scan

(From the fit)

PRD 76 (2007) 122002

Analyzing data samples of 17.3 pb^{-1} @ 3.773 GeV, 5.65 pb^{-1} @ 3.650 GeV and 1 pb^{-1} data @ 3.6648 GeV yields

$$R_{uds}=2.214\pm0.031\pm0.094$$

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$$\sigma^{obs}_{\psi(3770)}=(7.07\pm0.36\pm0.48)\quad nb$$

$$\sigma^{obs}_{non-D\bar{D}}=(0.95\pm0.35\pm0.31)\quad nb$$

$$\sigma^{obs}_{D\bar{D}}=(6.12\pm0.37\pm0.23)\quad nb$$

$$BF[\psi(3770)\to non-D\bar{D}]=(13.4\pm5.0\pm3.6)\%$$

Summary

- Y(2175) observed in J/ψ decays.
- η(2225) resonance parameters from PWA.
- X(1440)
- Observation of new ψ' radiative decay modes.
- ψ(3770) resonance parameters, non-D$\underline{D}$ dacays
- More and better results are expected from BESIII in the near future (F. Harris's talk).

Thanks a lot !