Recent Results on J/ψ, ψ' and ψ'' Decays from BESII

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Outline

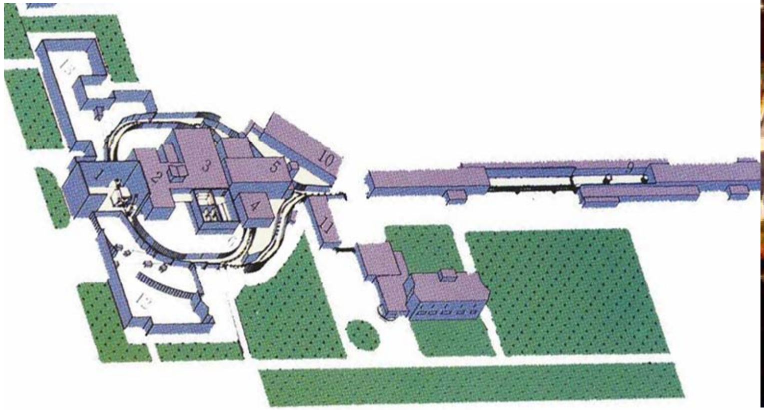
- Results on Y(2175)
- Results on 0^{++} meson
- Results on $K\Lambda$ mass threshold structure $N_X(1610)$
- Measurements of ψ' radiative decays
- Measurements of ψ' to $B\bar{B}$ etc.
- ψ'' non-$D\bar{D}$ decays
- Summary

Beijing Electron Positron Collider (BEPC)

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

at J/ψ

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

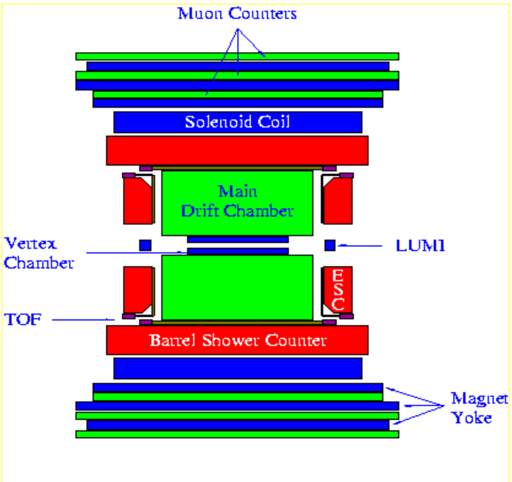


BESI started running in 1989

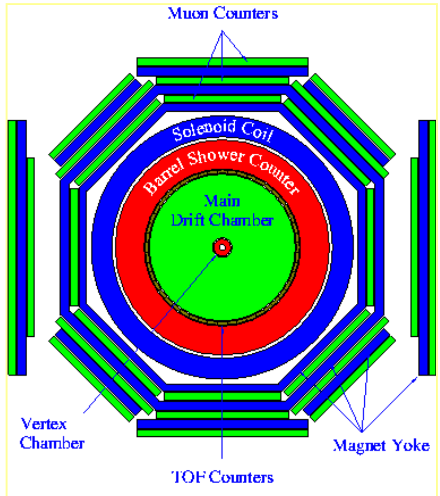
BESII started in 1997

BESIII will start in 2008

BESII Detector



Side view of the BES detector

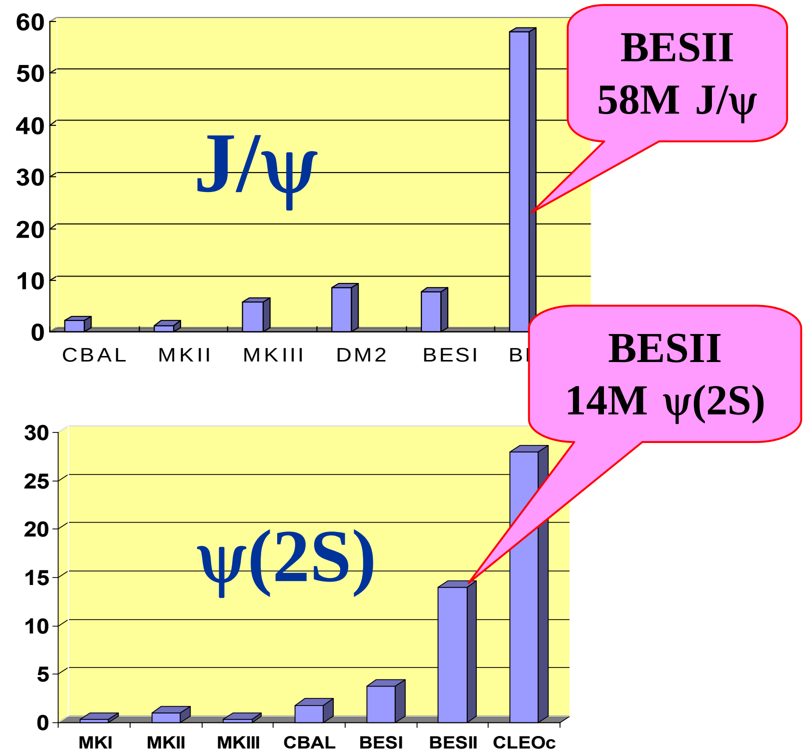


End view of the BES detector

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

TOF: $\sigma_T = 180$ ps
BSC: $\Delta E/\sqrt{E} = 21\ \%$
$\sigma_\phi = 7.9$ mr
$\sigma_z = 2.3$ cm
B field: 0.4 T

World J/ψ and ψ(2S) Samples ($\times 10^6$)



33 pb^{-1} ψ(3770) data

Observation of Y(2175) in $J/\psi \rightarrow \eta\phi f_0(980)$ at BESII

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

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

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

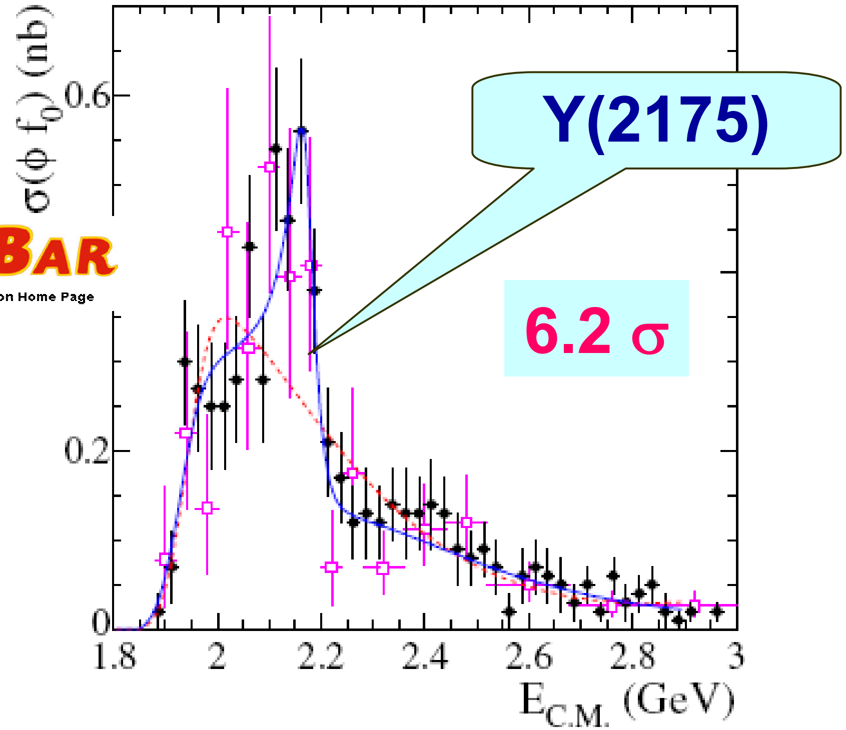


FIG. 6 (color online). The $e^+e^- \rightarrow \phi(1020)f_0(980)$ cross section, with about 10% of the $\phi\pi\pi$ contribution, obtained via ISR in the $K^+K^-\pi^+\pi^-$ (circles) and $K^+K^-\pi^0\pi^0$ (squares) final states. The curves represent results of the fits described in the text.

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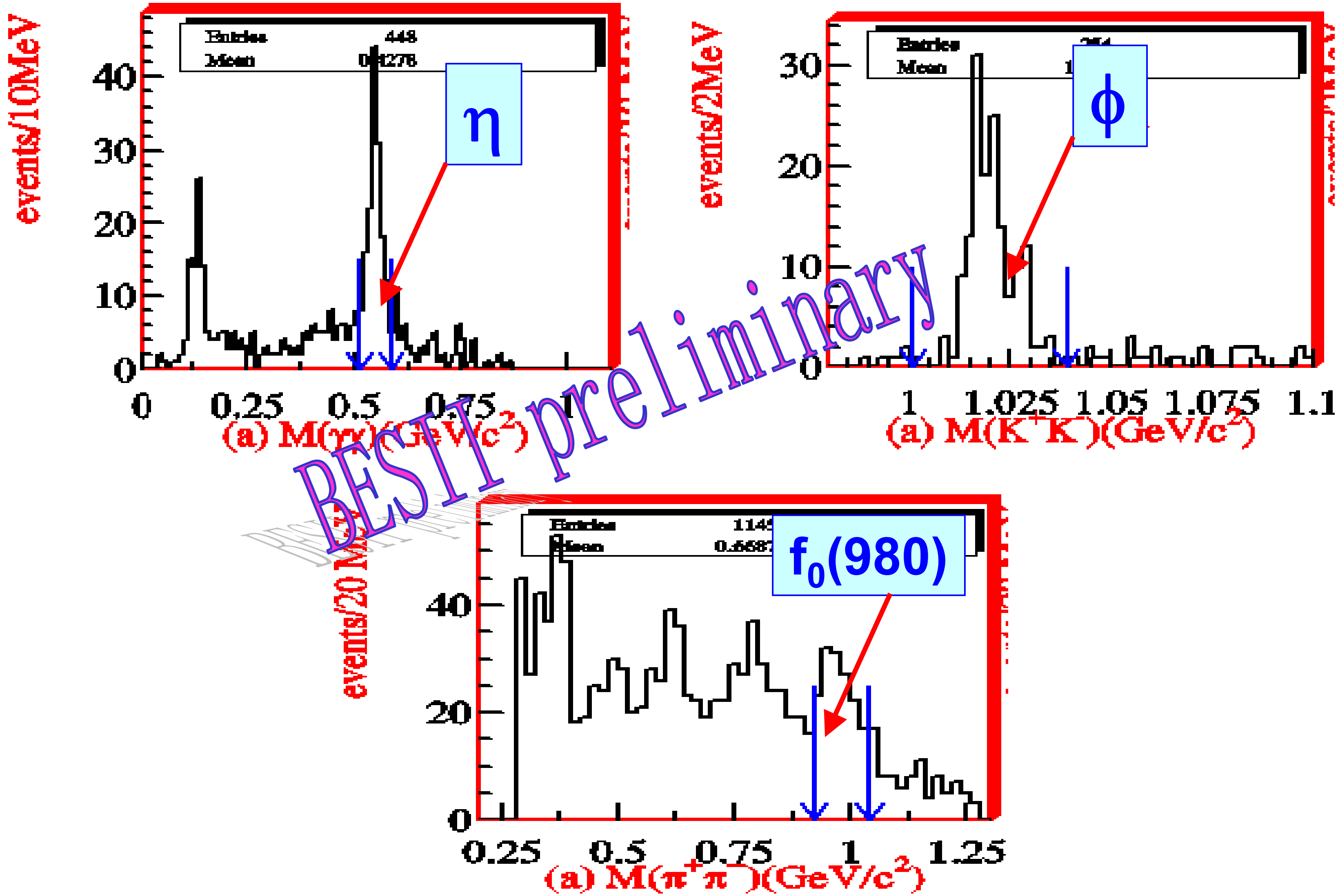
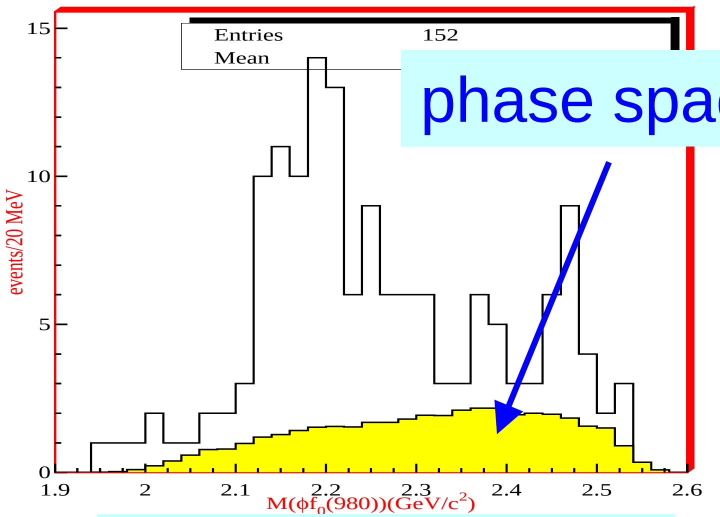
$J/\psi \rightarrow \eta\phi f_0(980)$

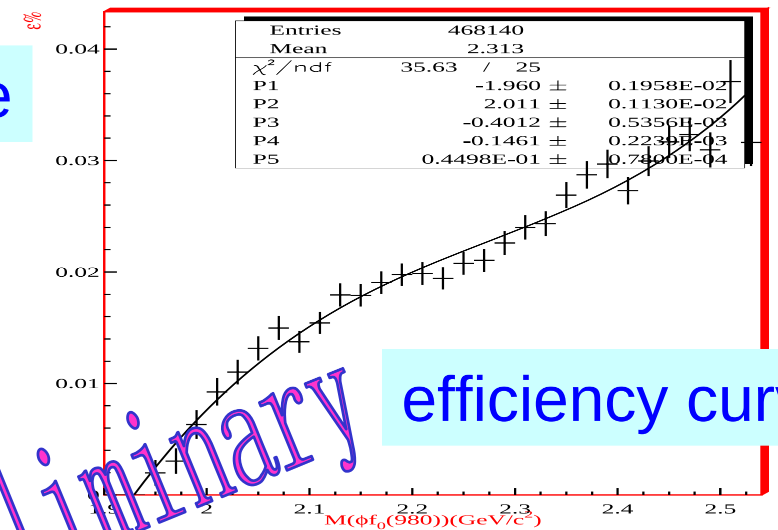


A peak around 2175 MeV/c^2 is observed in $J/\psi \to \eta\phi f_0(980)$



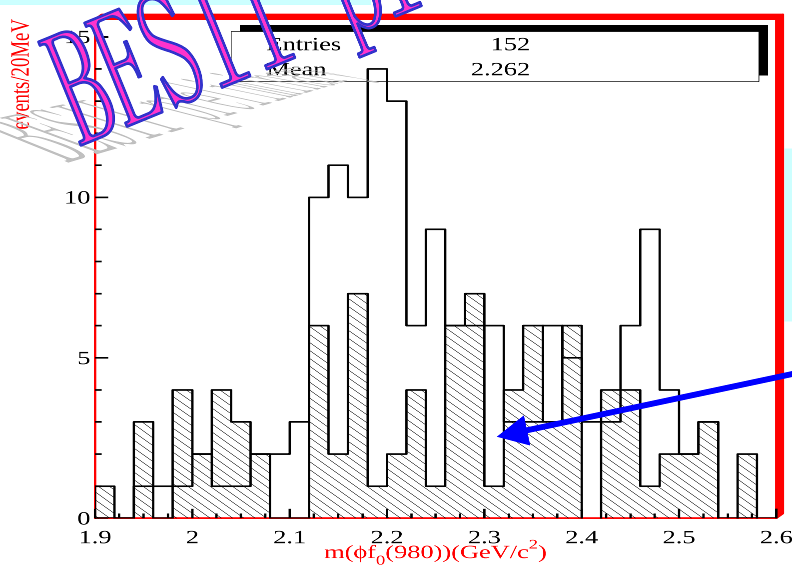
phase space

M(ϕf_0(980)) GeV/c^2



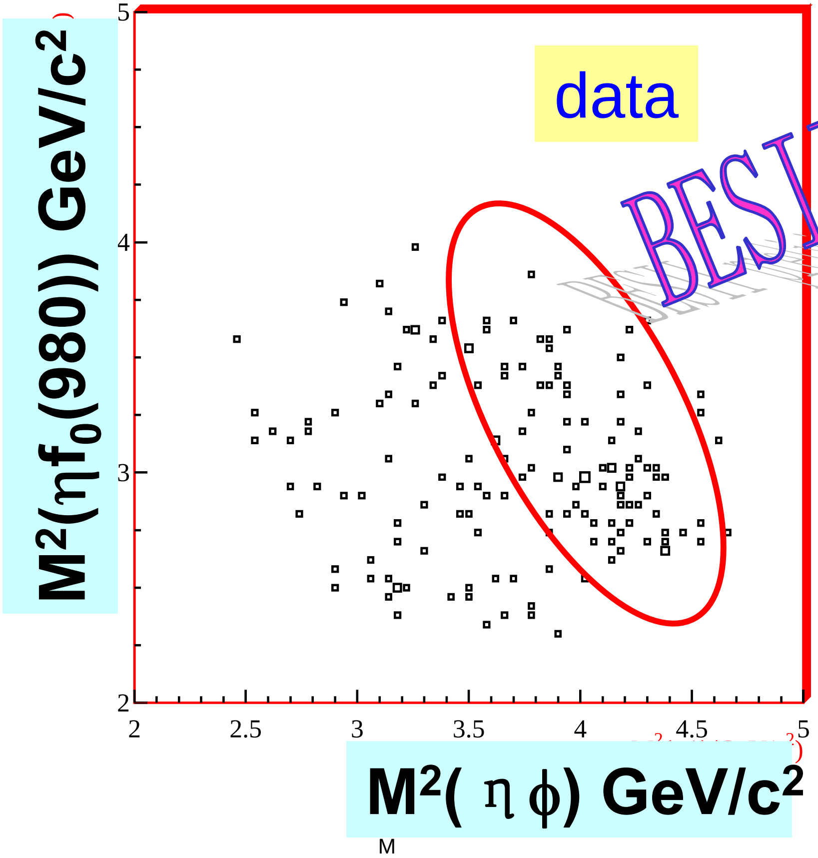
efficiency curve

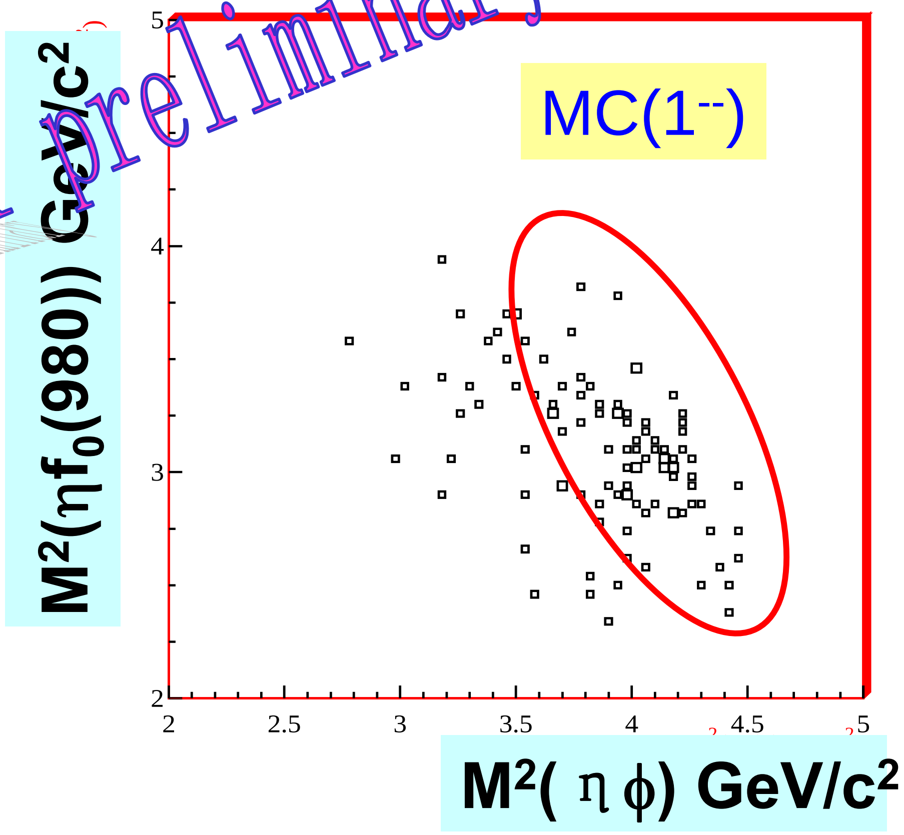
BESII preliminary



Backgrounds from sideband estimation

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

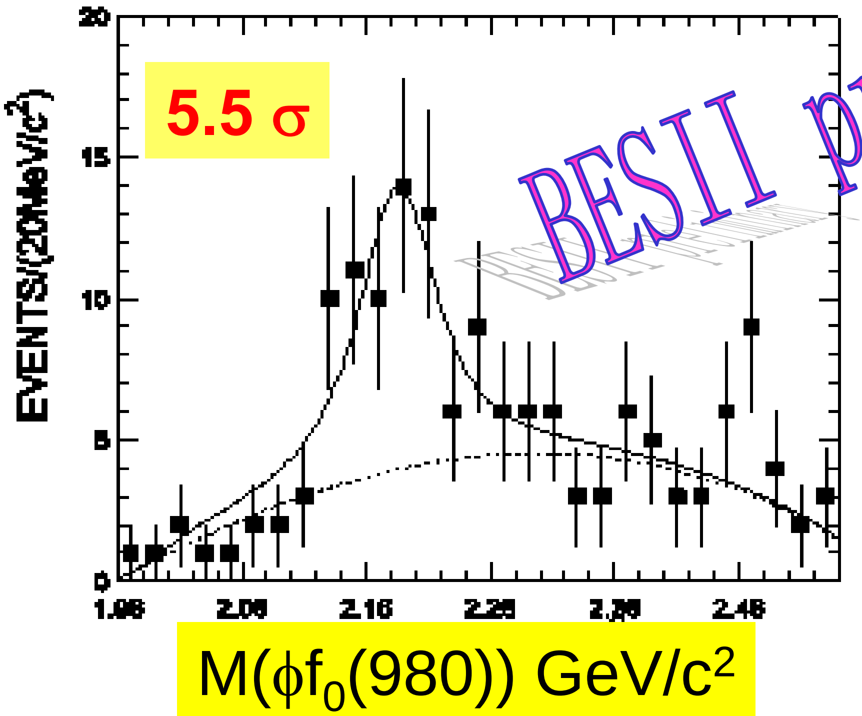




BESII preliminary

Fit with one resonance

- BG shape is fixed to sideband BG



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

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

$N_{events} = 52 \pm 12$

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

- 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)?

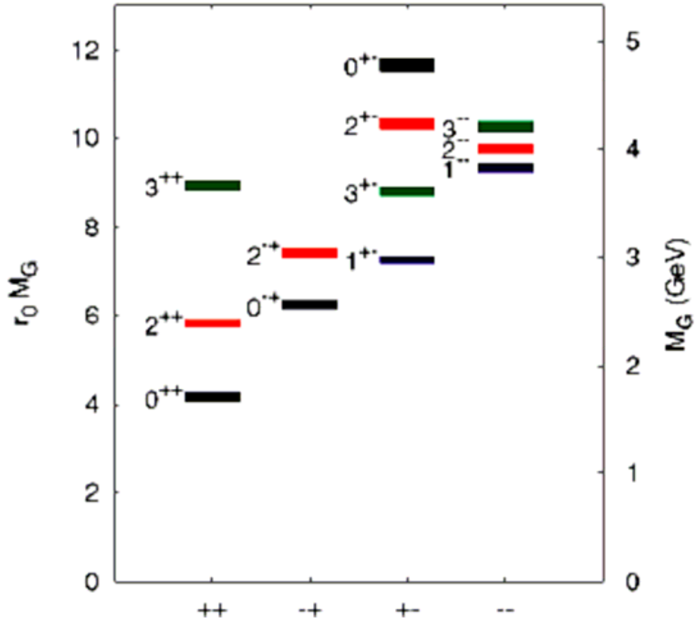
Some theoretical interpretations:

- 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.

Results on 0^{++} mesons

- Lattice QCD predicts the 0^{++} scalar glueball mass in the range **1.5 - 1.7 GeV**.



Spectrum from quenched LQCD

Y. Chen *et al.*
PRD73:014516,2006
(updates Morningstar & Peardon, '99)

0^{++} : 1710 ± 50 ± 80

Also:
1611 ± 30 ± 160 Michael '98
1550 ± 50 ± ? Bali et al. '93

$f_0(1500)$ and $f_0(1710)$ are good candidates.

PWA of $J/\psi \to \gamma\pi^+\pi^-$ and $\gamma\pi^0\pi^0$ at BESII

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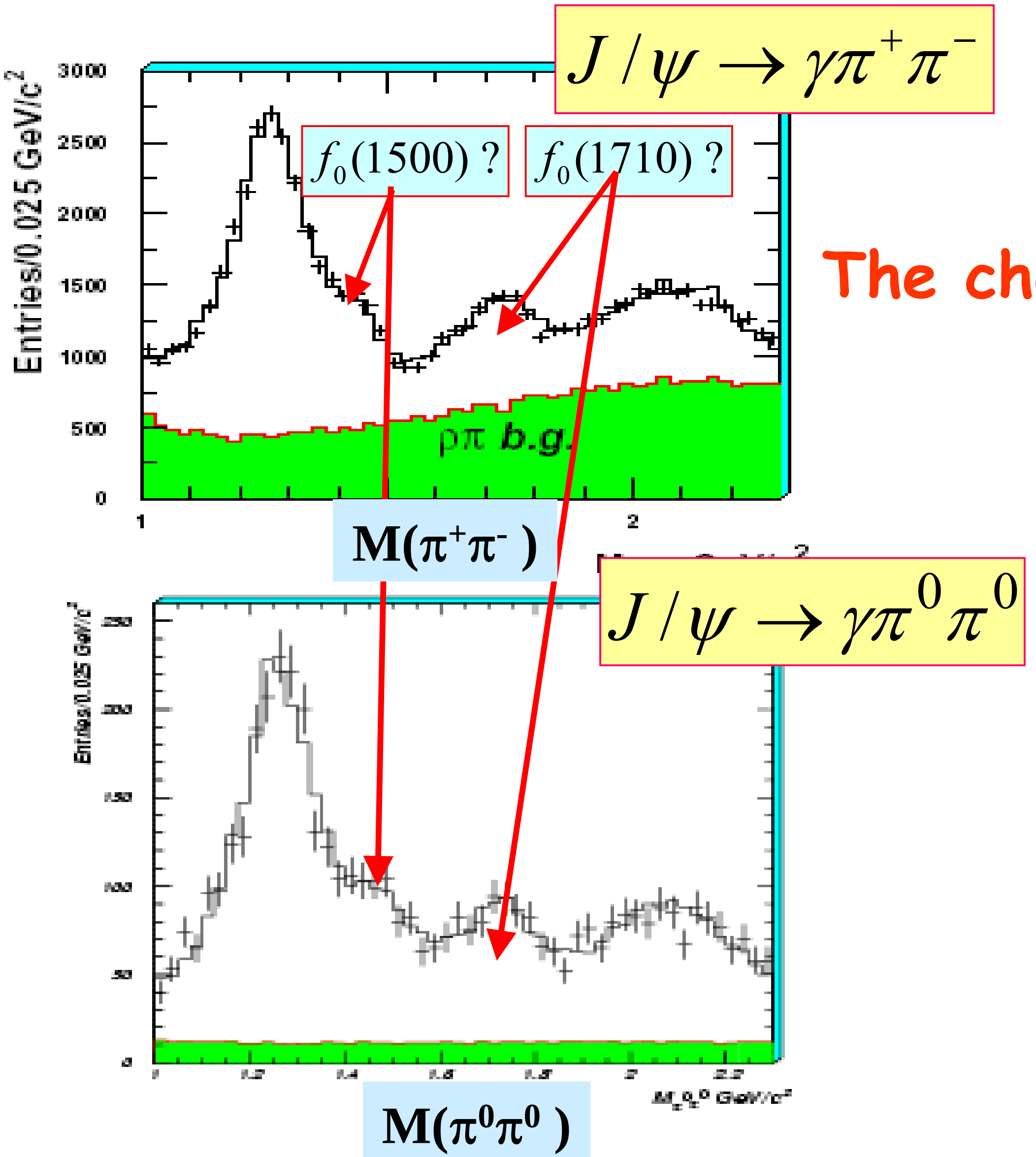
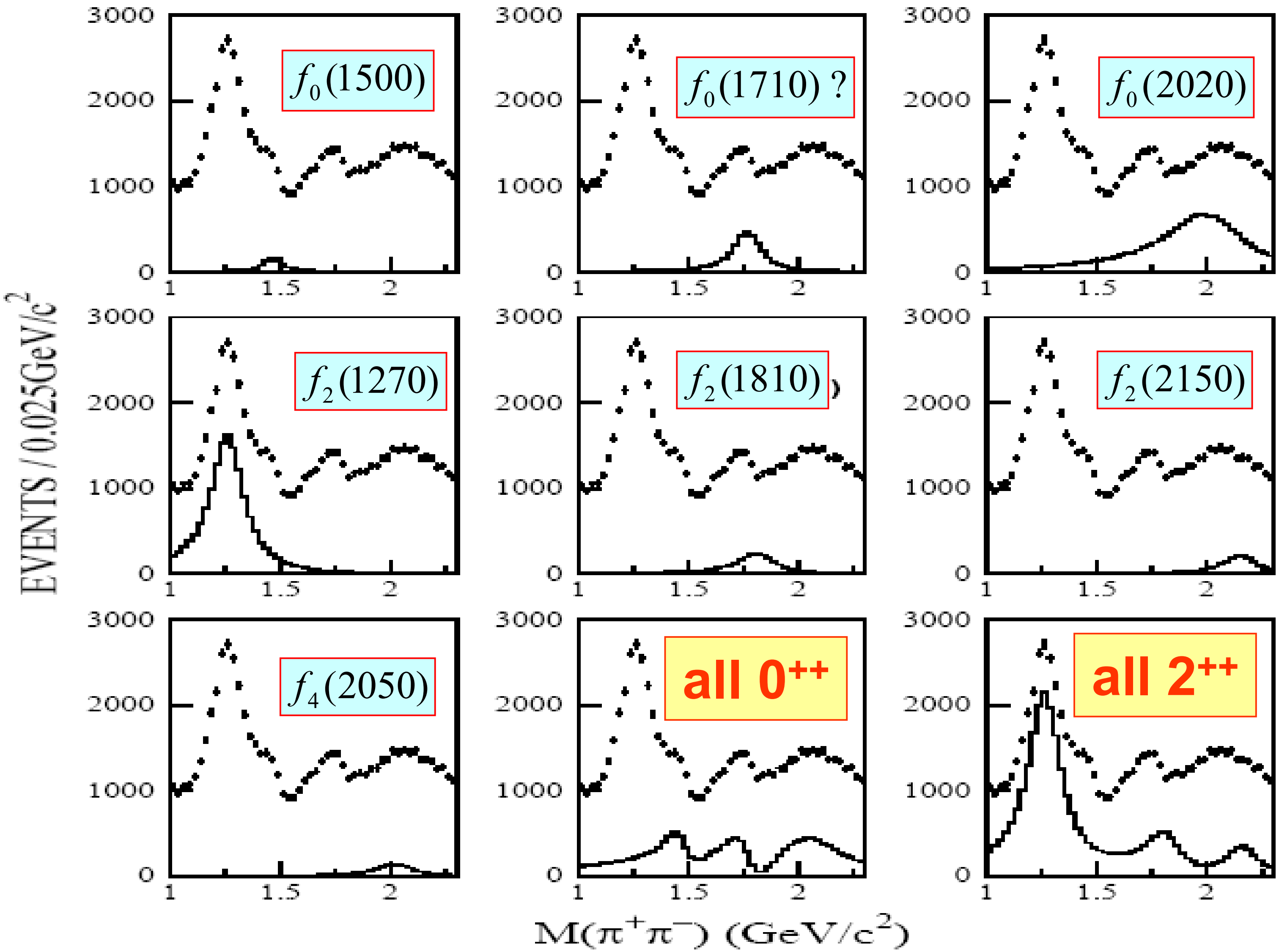
PWA of $J/\psi \to \gamma\pi^+\pi^-$ and $\gamma\pi^0\pi^0$



The channels fitted in PWA:

$$
\begin{aligned}
J/\psi &\to \gamma f_2(1270) \\
&\to \gamma f_0(1500) \\
&\to \gamma f_0(1710) \\
&\to \gamma f_2(1810) \\
&\to \gamma f_0(2020) \\
&\to \gamma f_2(2150) \\
&\to \gamma f_4(2050).
\end{aligned}
$$

PWA components:



PWA results

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

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

- $f_0(1370)$ cannot be excluded.

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

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

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

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

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

	$J/\psi \to \gamma X,\ X \to \pi^0\pi^0$	
	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	$1.33 \pm 0.05 \pm 0.88$

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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:

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

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

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

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

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

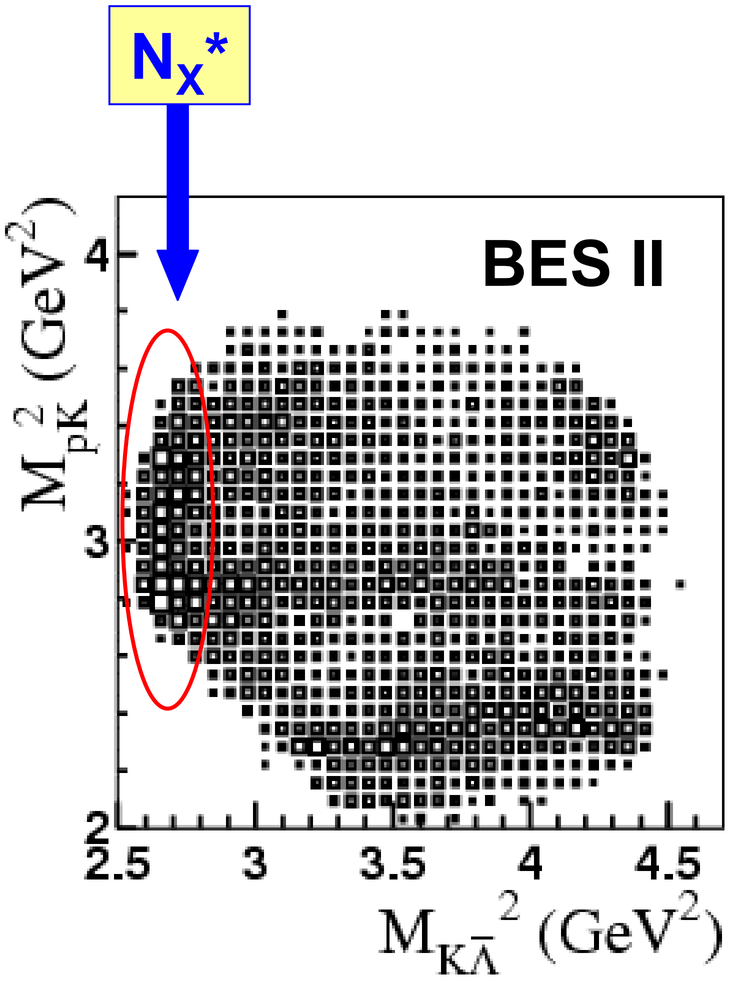
$$BR(J/\psi \to \gamma f_0(1710)) > 9\times 10^{-4}$$

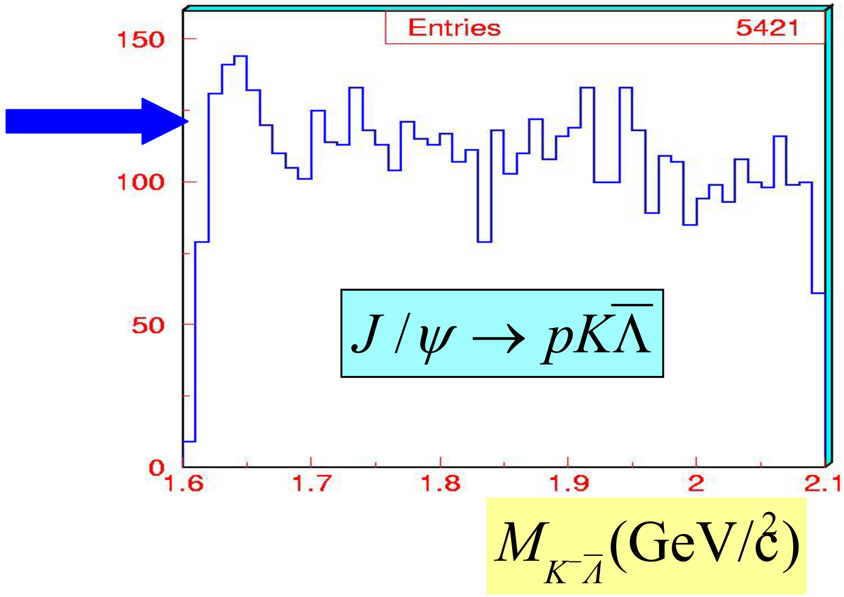
$$(PDG)$$

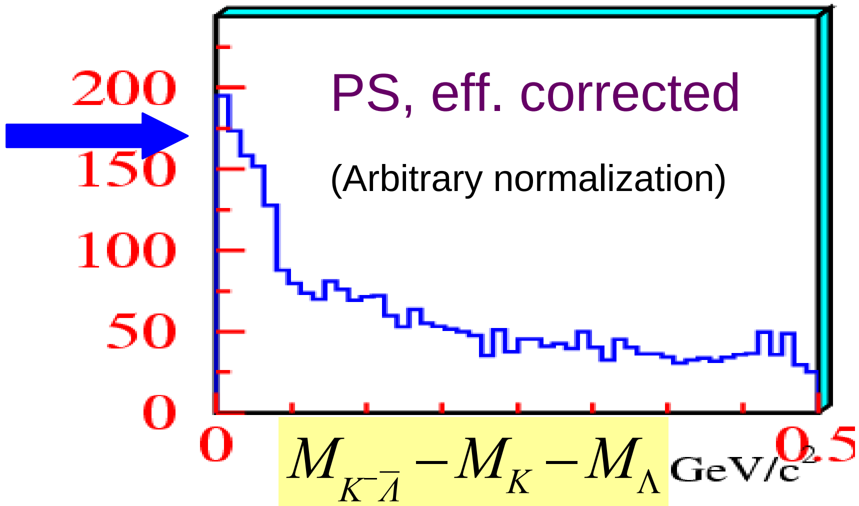
- It may indicate: $f_0(1710)$ has stronger coupling to gluons than $f_0(1500)$ → which one contains more glueball content?

New results on baryons at BESII

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)**

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

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

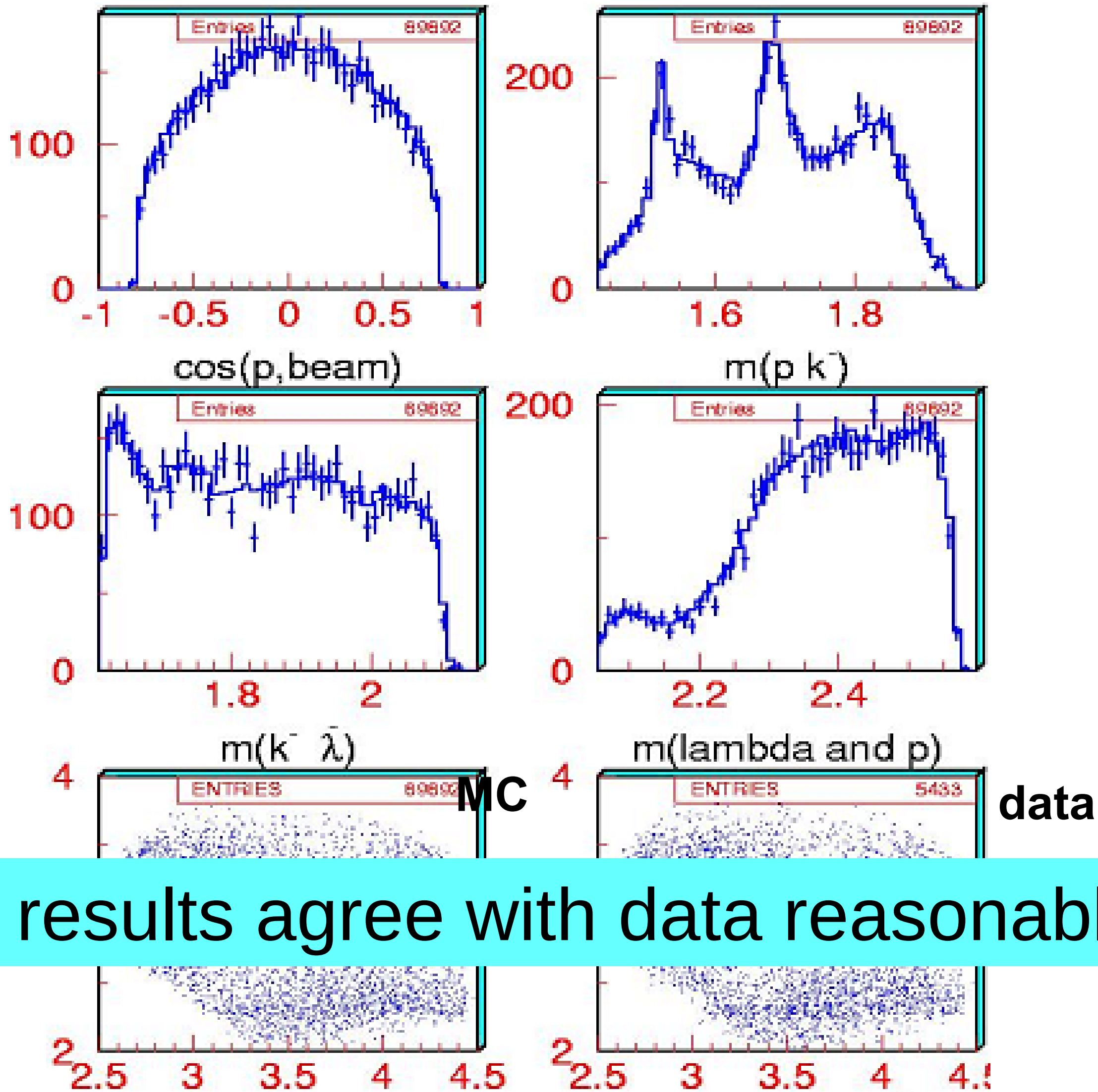
- **Fitted as N(1535)** (becomes worse by about 5 σ ($\Delta\chi^2$=28 with *d.o.f.*=2)).

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

Big Br.

BESII preliminary

Comparison between data and PWA fit projections



Fit results agree with data reasonably.

N_x^* is N(1535)?

- From BESII measurements:

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

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

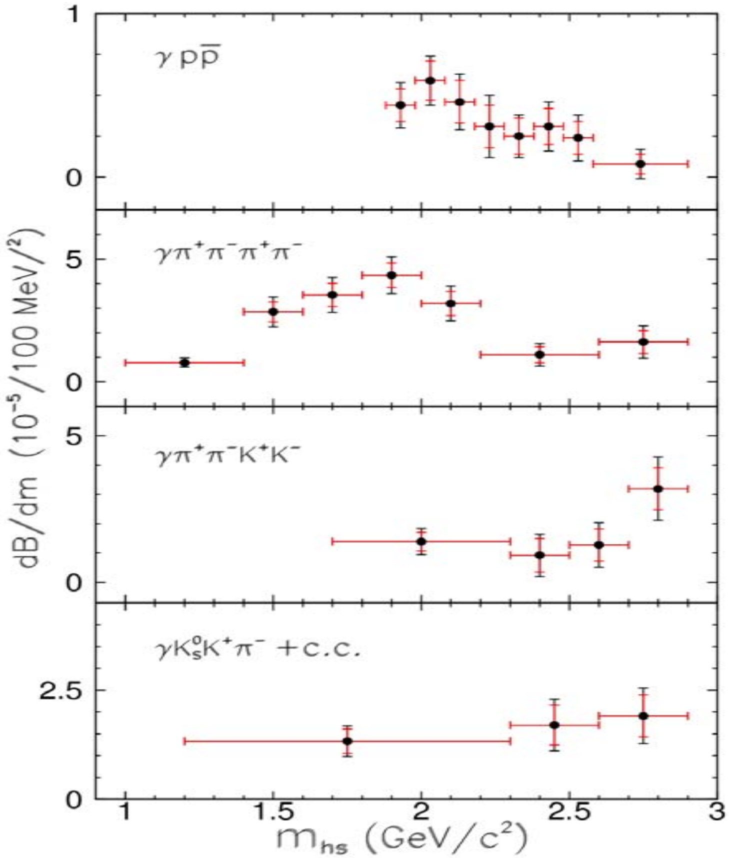
If N_x^* is N(1535), its coupling to $K\Lambda$ is much stronger than to $p\pi$.

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

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 ($\times10^{-5}$) [$m<2.9$ GeV/c^2]
γ pp-bar	2.9 ± 0.4 ± 0.4
$\gamma\ \eta'$	12.6 ± 2.9 ± 1.5
$\gamma\ 2(\pi^+\pi^-)$	39.6 ± 2.8 ± 5.0
$\gamma\ K_S K^+\pi^-$+c.c.	25.6 ± 3.6 ± 3.6
$\gamma\ \pi^+\pi^- K^+K^-$	19.1 ± 2.7 ± 4.3
$\gamma\ \pi^+\pi^-$ppbar	2.8 ± 1.2 ± 0.7
$\gamma\ 2(K^+K^-)$	< 4.0
$\gamma\ 3(\pi^+\pi^-)$	< 17
$\gamma\ 2(\pi^+\pi^-)K^+K^-$	< 22



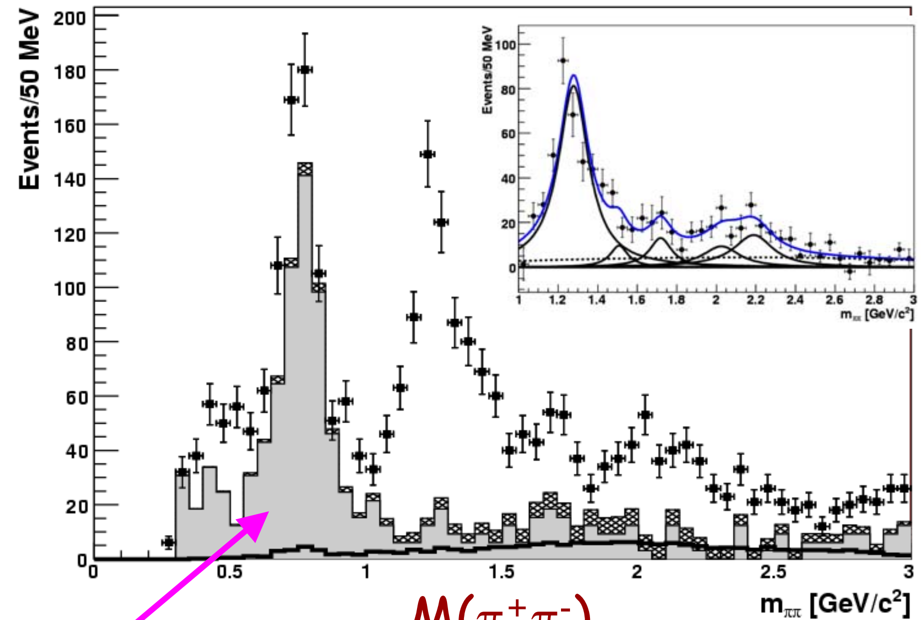
PRL99, 011802 (2007)

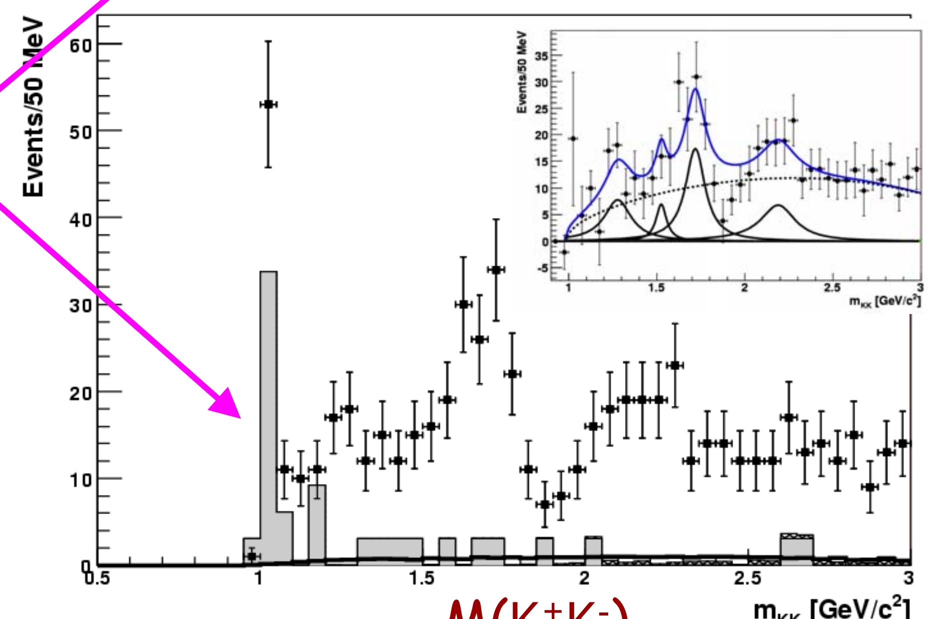
$\psi' \rightarrow \gamma\pi^+\pi^-$ and γK^+K^-

hep-ex/07102324

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





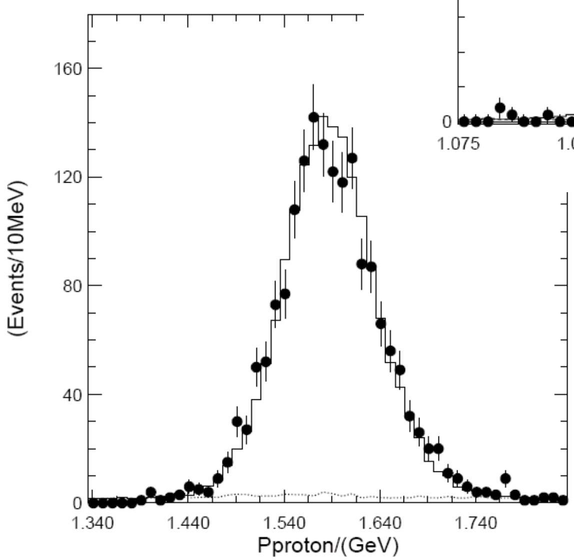
$\gamma f_2(1270) \rightarrow \gamma\pi^+\pi^-$ helicity amplitudes

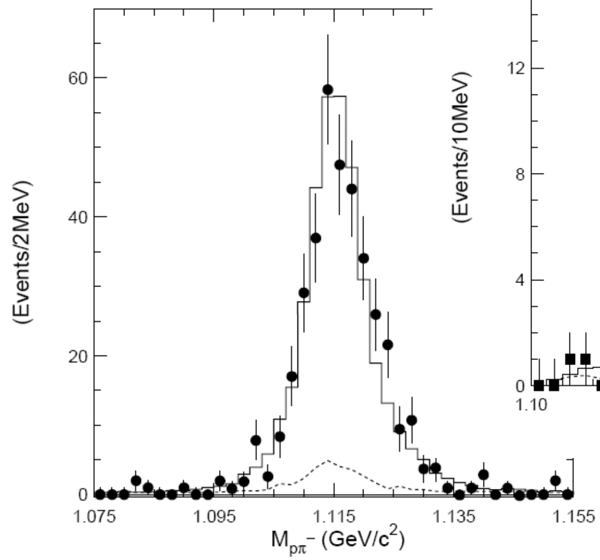
Positive solution	Negative solution
$x = 0.20 \pm 0.09 \pm 0.25$	$x = -0.26 \pm 0.09 \pm 0.24$
$y = -0.26 \pm 0.08 \pm 0.05$	$y = -0.25 \pm 0.09 \pm 0.06$
$\rho_{stat} = 0.53$	$\rho_{stat} = -0.43$
$\rho_{sys} = 0.44$	$\rho_{sys} = -0.41$

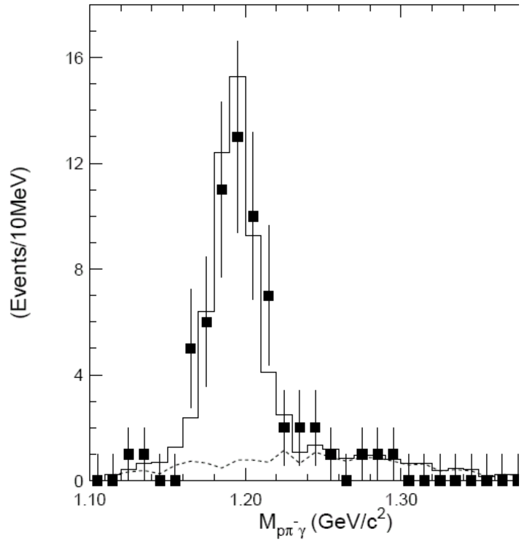
ψ'→BBbar

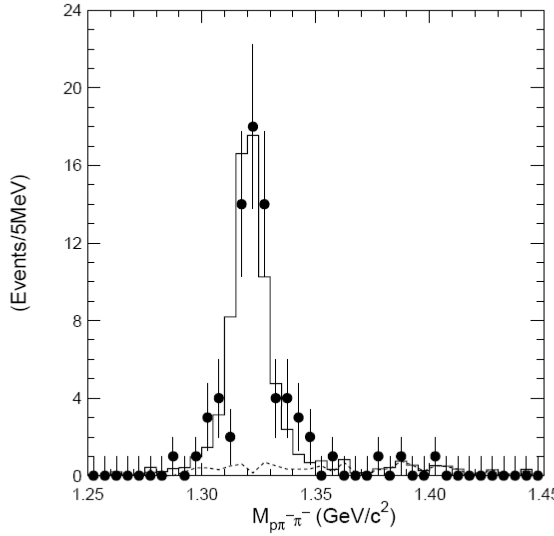
PLB648, 149 (2007)

- **First measurement by BESI, re-measure BR with a larger ψ' data sample. SU(3) symmetry observed.**
- **"12% rule" tested.**









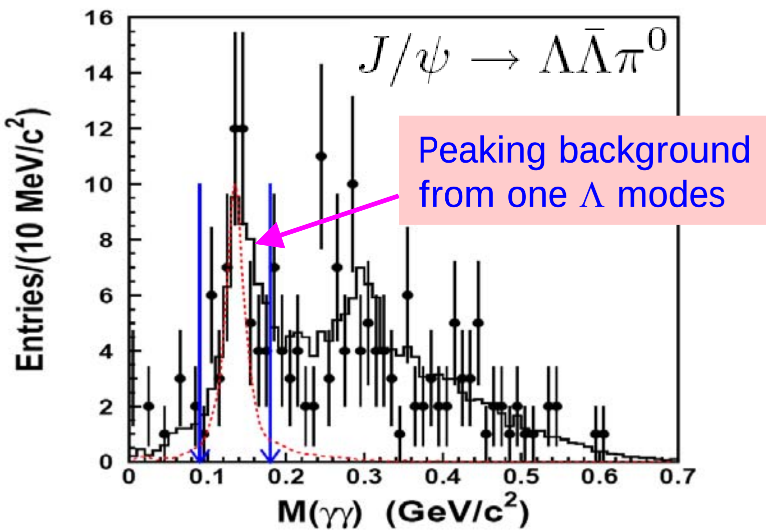
Agree with CLEOc results

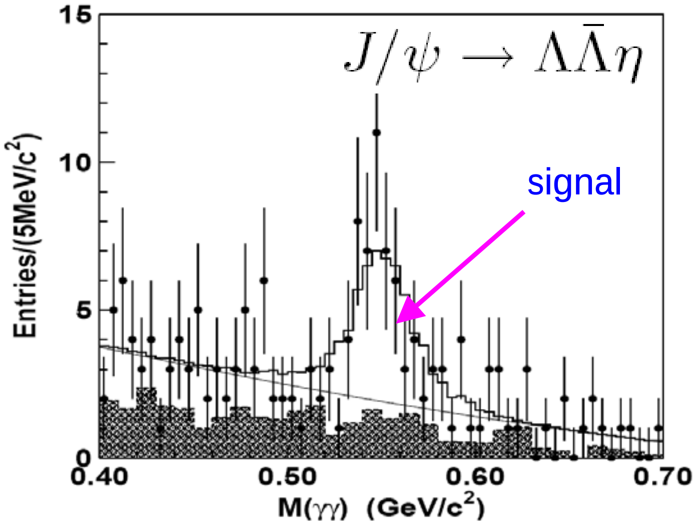
Modes	BRs ($\times 10^{-4}$)	Q (%)
$p\bar{p}$	$3.36 \pm 0.09 \pm 0.25$	14.9 ± 1.4
$\Lambda\bar{\Lambda}$	$3.39 \pm 0.20 \pm 0.32$	16.7 ± 2.1
$\Sigma^0\bar{\Sigma}^0$	$2.35 \pm 0.36 \pm 0.32$	16.8 ± 3.6
$\Xi^-\bar{\Xi}^+$	$3.03 \pm 0.40 \pm 0.32$	16.8 ± 4.7

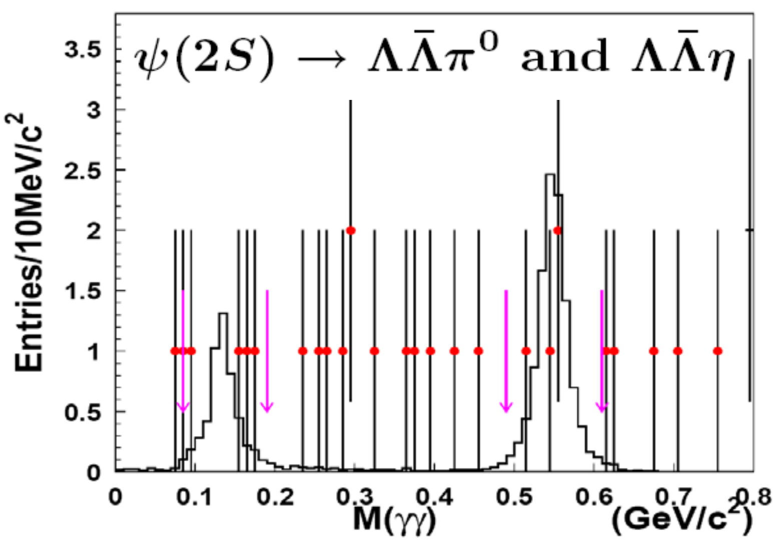
$\psi'(J/\psi) \rightarrow \Lambda\Lambda+\pi^0/\eta$

arXiv: 0707.1127 [hep-ex]
To appear in PRD

- BESI/DMII: $B(\Lambda\Lambda\pi^0)\sim 2\times10^{-4}$: Isospin-violation!







Channels	Number of events	Branching fraction $(\times10^{-4})$
$J/\psi \rightarrow \Lambda\bar{\Lambda}\pi^0$	<10	<0.64
$J/\psi \rightarrow \Lambda\bar{\Lambda}\eta$	44 ± 10	$2.62\pm0.60\pm0.44$
$\psi(2S) \rightarrow \Lambda\bar{\Lambda}\pi^0$	<7.0	<0.49
$\psi(2S) \rightarrow \Lambda\bar{\Lambda}\eta$	<7.6	<1.2
$J/\psi \rightarrow \Sigma^+\pi^-\bar{\Lambda}$	335 ± 22	$7.70\pm0.51\pm0.83$
$J/\psi \rightarrow \bar{\Sigma}^-\pi^+\Lambda$	254 ± 19	$7.47\pm0.56\pm0.76$

First measurement!

$\psi(3770)$ non-$D\bar{D}$ decays

- $\psi(3770)$ decays most copiously into $D\bar{D}$.

- $\psi(3770)$ is a mixture of the 1^3D_1 and 2^3S_1, other $\psi(2S)$-like decays for $\psi(3770)$ are expected. (mixing angle 12 ± 2^o).

- Many theoretical calculations estimate the partial width for $\psi(3770) \to \pi^+\pi^- J/\psi$. (Lipkin, Yan, Lane, Kuang, Rosner)

- BES observed $\psi(3770) \to \pi^+\pi^- J/\psi$ decays. Further confirmed by CLEO-c.

Determination of

BF[ψ(3770) → $D^0\bar{D}^0$, D^+D^-, $D\bar{D}$ and non-$D\bar{D}$]

with the measured R values at 3.650, 3.6648 and 3.773 GeV

Single tag method

$$\sigma^{obs}_{D\bar{D}} = \frac{N_{D_{tag}}}{2\ L\ Br\ \varepsilon}$$

$$\sigma^{Born}_{\psi(3770)} = 9.323 \pm 0.253 \pm 0.801 \ \ \text{nb}$$

$$\sigma^{obs}_{D\bar{D}} = 6.14 \pm 0.12 \pm 0.50 \text{nb}$$

PLB 603(2004)130

$$BF(\psi(3770) \to D\bar{D}) = \frac{N^{prd}_{D\bar{D}}}{N^{prd}_{\psi(3770)}} = \frac{\sigma^{Born}_{D\bar{D}}}{\sigma^{Born}_{\psi(3770)}} = \frac{\sigma^{obs}_{D\bar{D}}}{g_{\text{BES-II}}\ \sigma^{Born}_{\psi(3770)}}$$

Some systematic uncertainties can be canceled out

Radiative correction factor $g = \frac{\sigma^{obs}}{\sigma^{B}}$

$$g_{\text{BES-II}} = 0.770 \pm 0.014$$

Radiative correction factor obtained based on new ψ(3770) resonance parameters measured by BES-II, hep/0605107.

$$BF(\psi(3770) \to D^0\bar{D}^0) = (49.9 \pm 1.3 \pm 3.8)\%$$

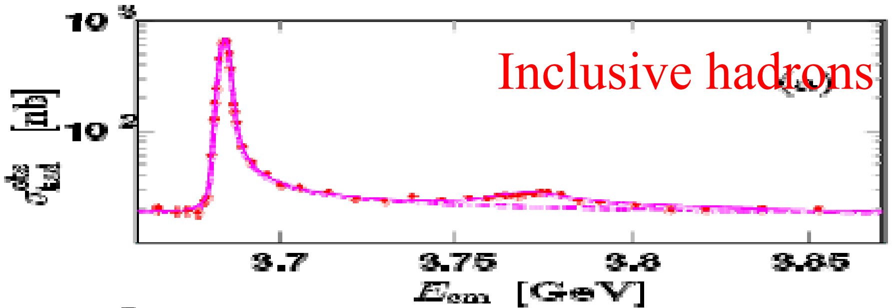
$$BF(\psi(3770) \to D^+D^-) = (35.7 \pm 1.1 \pm 3.4)\%$$

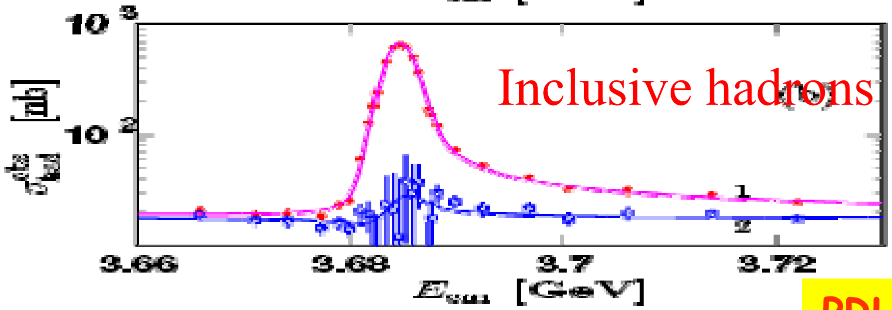
$$BF(\psi(3770) \to D\bar{D}) = (85.5 \pm 1.7 \pm 5.8)\%$$

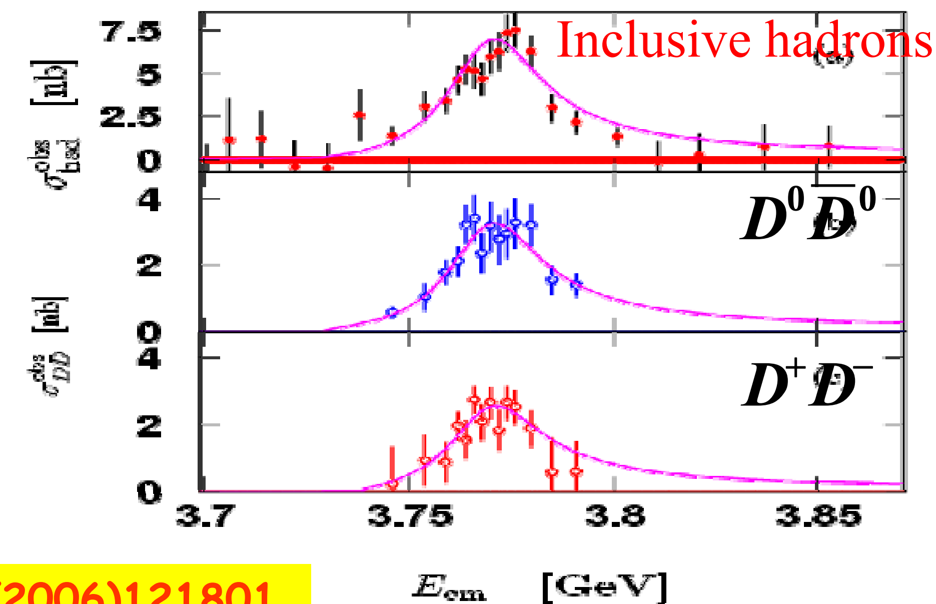
$$BF(\psi(3770) \to non-D\bar{D}) = (14.5 \pm 1.7 \pm 5.8)\%$$

PLB641(2006)145

Line shape of the cross sections for hadron and DD-bar production







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Mar. 2003 data set

Simultaneously.fitting to the inclusive hadron and the DD-bar production cross sections

◆Branching fractions

$$BF(\psi(3770) \to D^0\bar{D}^0) = (46.7 \pm 4.7 \pm 2.3)\%$$

$$BF(\psi(3770) \to D^+D^-) = (36.9 \pm 3.7 \pm 3.1)\%$$

$$BF(\psi(3770) \to D\bar{D}) = (83.6 \pm 7.3 \pm 4.7)\%$$

$$BF(\psi(3770) \to non-D\bar{D}) = (16.4 \pm 7.3 \pm 4.7)\%$$

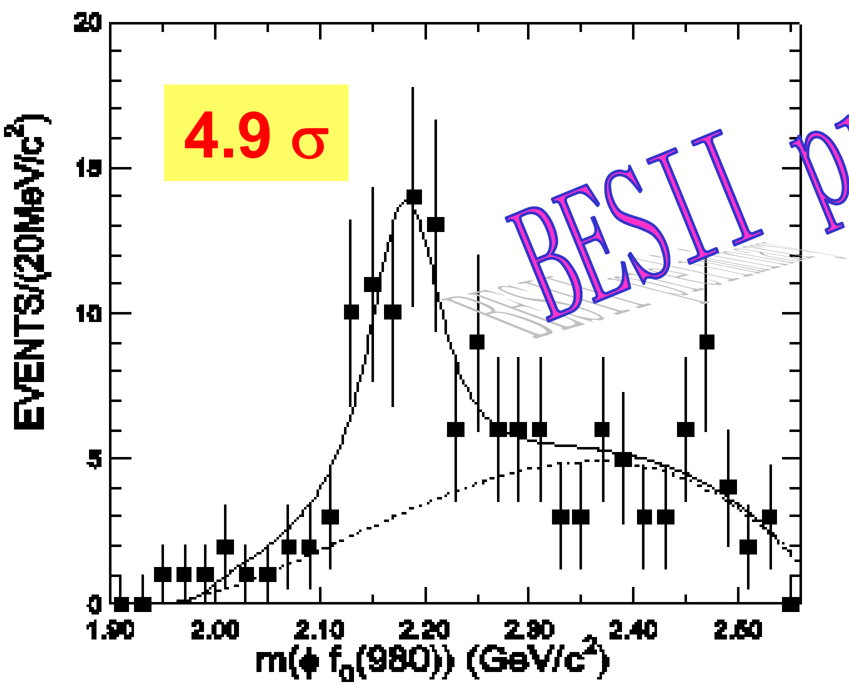
Summary

- Y(2175) at BESII
- Light 0^{++} mesons are studied in J/ψ radiative decays
- $K\Lambda$ threshold enhancement is observed in $J/\psi \rightarrow pK\Lambda$
- The measurements of ψ' decays are presented.
- ψ'' non-DDbar decays
- We are expecting more new results at BESIII.

Backup Slides

Fit with one resonance

- BG is represented by a 3rd-order polynomial



M $=2.182 \pm 0.010$ GeV/c^2

$\Gamma = 0.073 \pm 0.024$ GeV/c^2

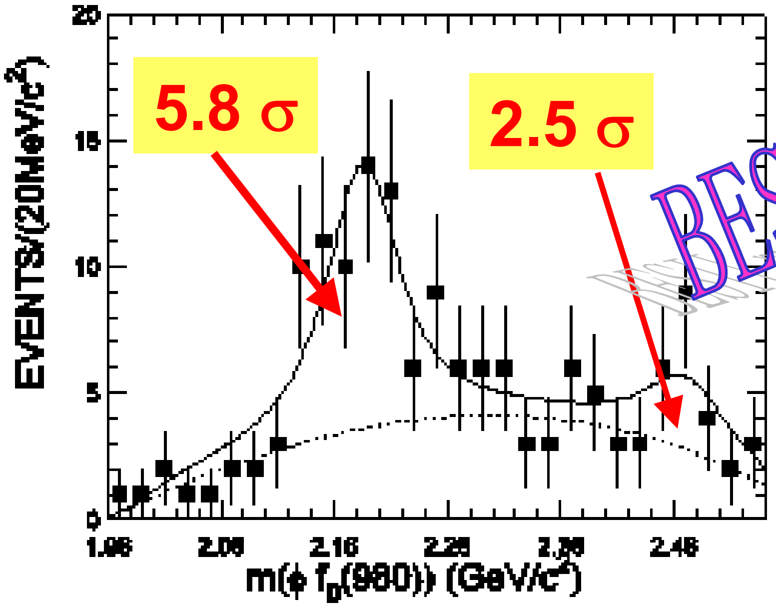
$N_{events} = 61 \pm 14$

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

$$(3.79 \pm 0.87(stat)) \times 10^{-4}$$

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 ± 0.010GeV/c^2

Γ= 0.065 ± 0.022GeV/c^2

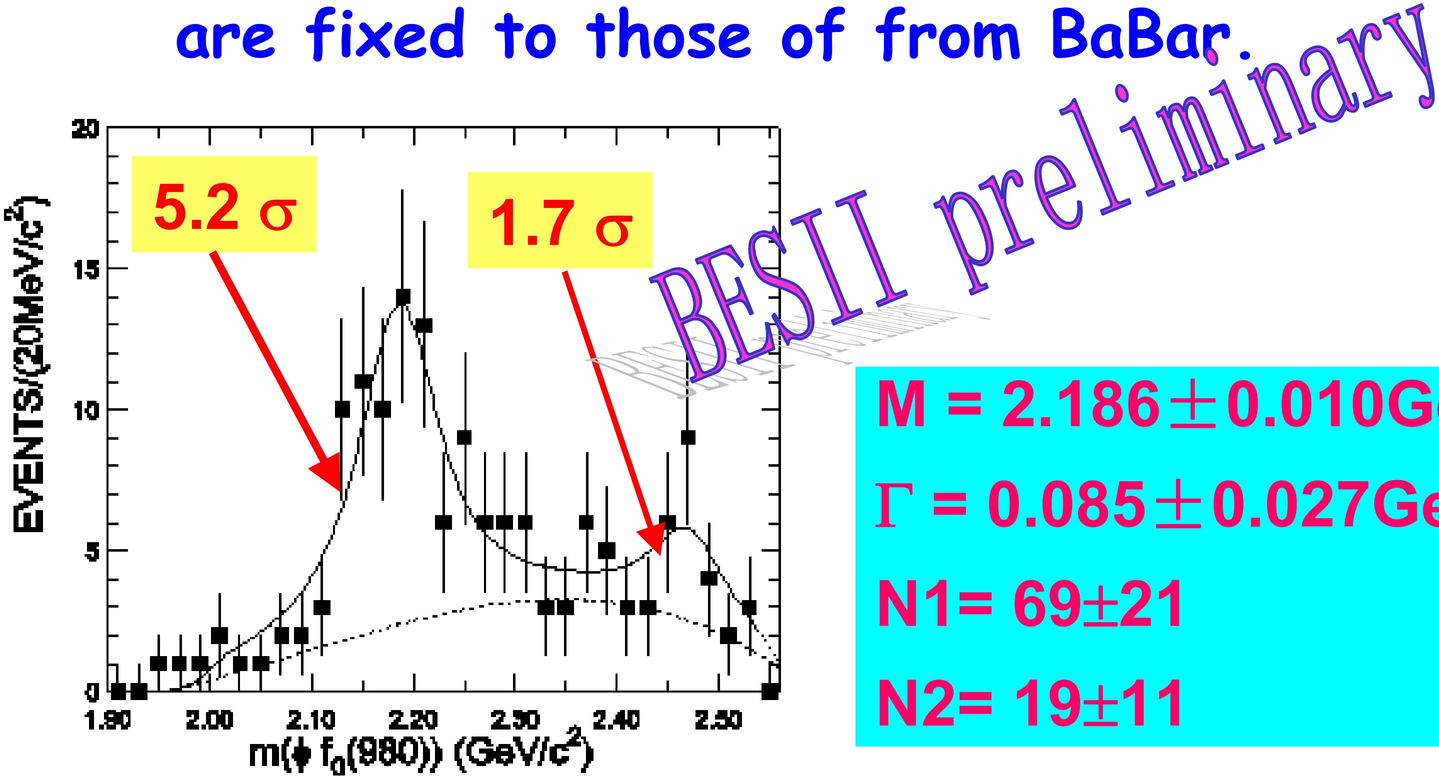
N1 events= 47±14

N2 events= 22±11

$$B(J/\psi \to \eta Y(2175) B(Y(2175) \to \varphi f_0(980)) B(f_0(980) \to \pi^+\pi^-) =$$
$$(2.92 \pm 0.87(stat)) \times 10^{-4}$$

Fit with two resonances

- BG is represented by a 3rd-order polynomial
- the mass and width of the second peak are fixed to those of from BaBar.



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

$\Gamma = 0.085 \pm 0.027 GeV/c^2$

N1= 69±21

N2= 19±11

$$B(J/\psi \to \eta Y(2175)B(Y(2175) \to \varphi f_0(980))B(f_0(980) \to \pi^+\pi^-) = (4.29 \pm 1.30(stat)) \times 10^{-4}$$