Recent BESII results and BESIII status

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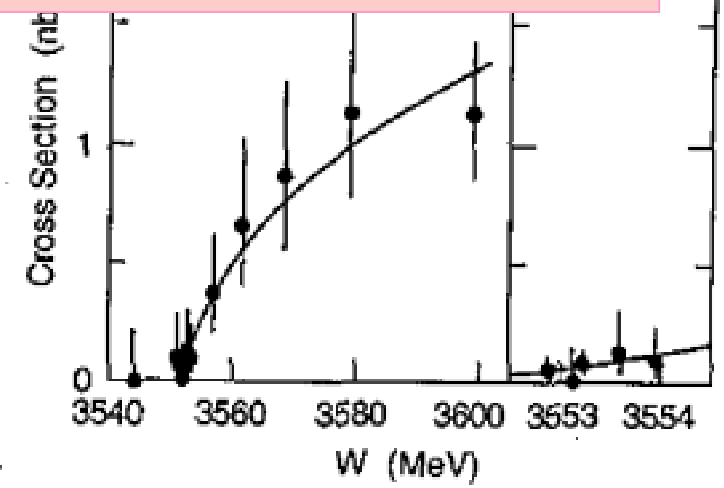
The Beijing Electron Positron Collider

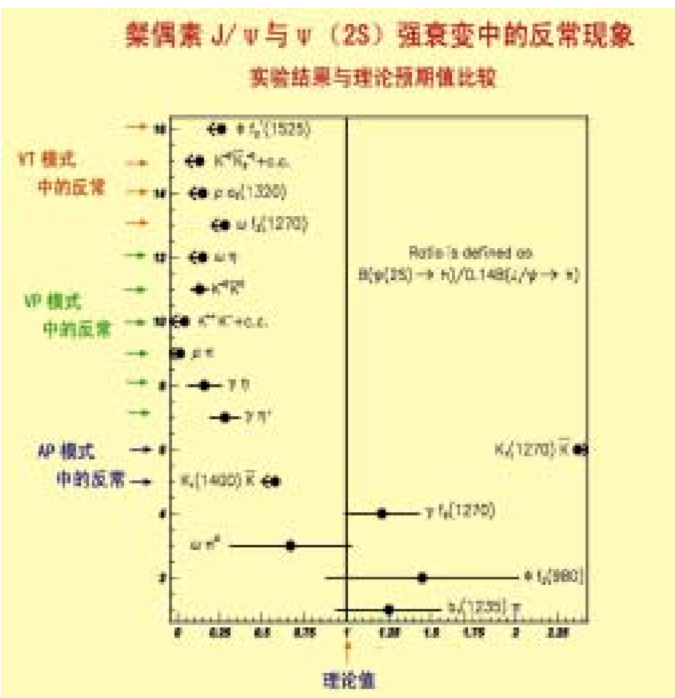
1989-2005
Ecm=2-5 GeV
$L_{peak}=10\times10^{30}/cm^2s$
@ ψ' energy

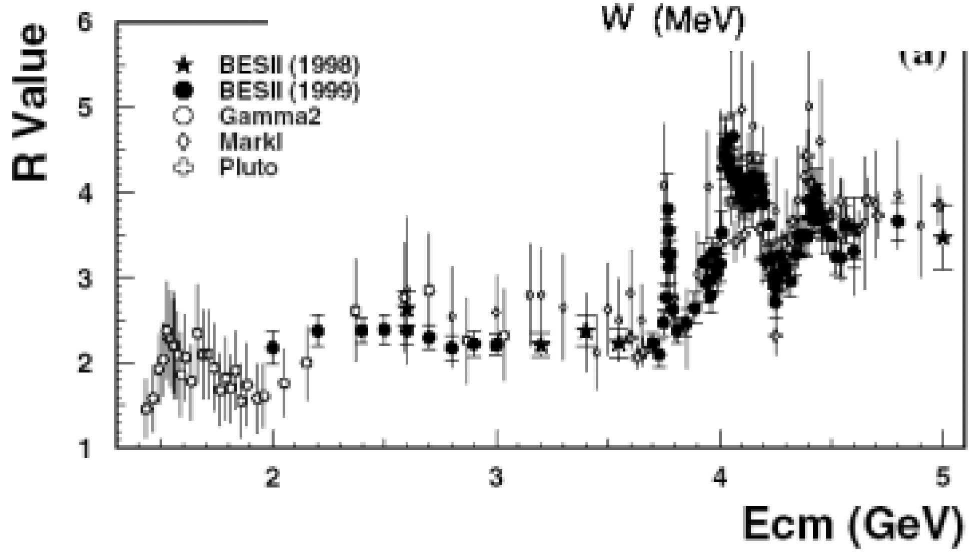
A bit of history of BES physics

- 1989-1995: BESI
  - ✓ τ mass measurement
  - ✓ ψ' and χ_{cJ} study
- 1996-2004: BESII
  - ✓ 2-5 GeV R measurement

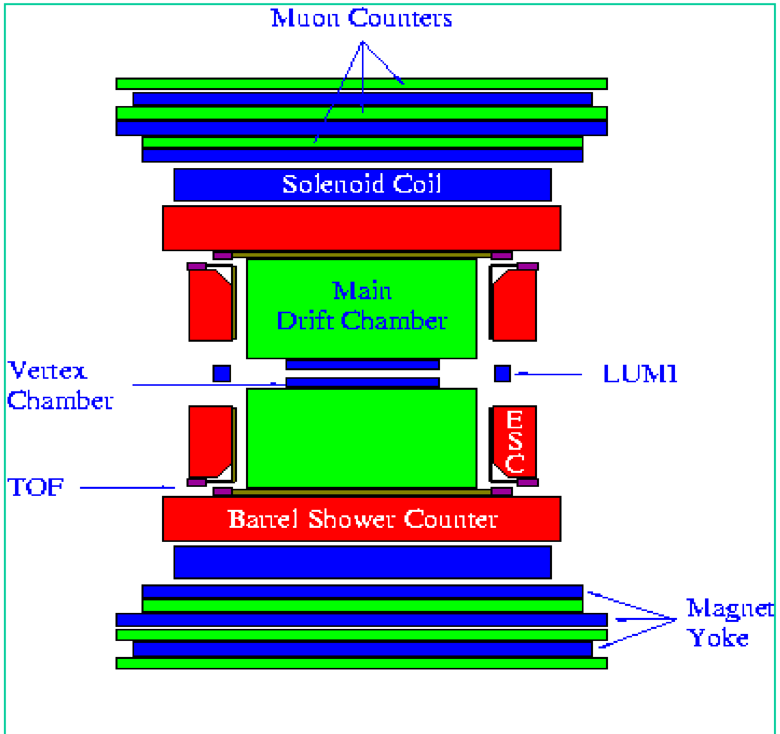
$$m_\tau = 1776.96^{+0.18+0.25}_{-0.21-0.17}\ \text{MeV}$$



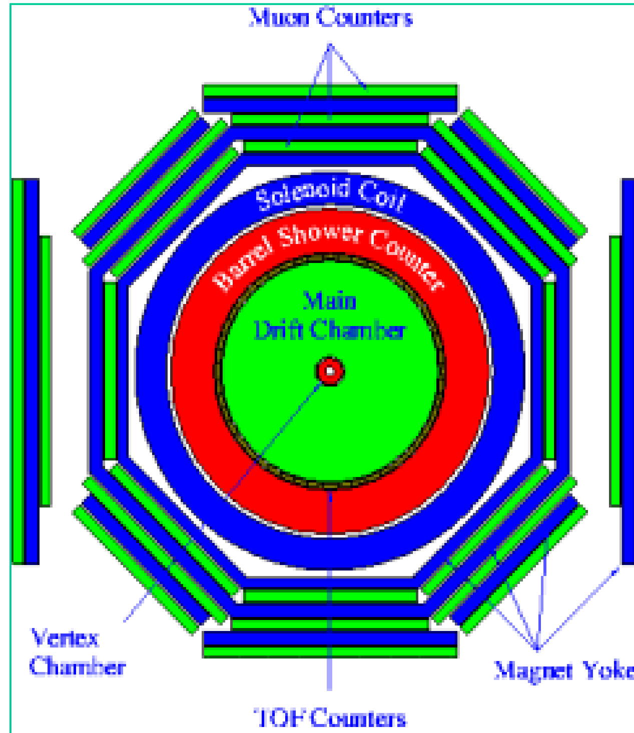




BESII Detector



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

TOF: σ_T = 180 ps
BSC: $\Delta E/\sqrt{E}$ = 22 %
σ_ϕ = 7.9 mr
σ_z = 3.1 cm

μ counter: $\sigma_{r\phi}$ = 3 cm
σ_z = 5.5 cm
B field: 0.4 T

BESII data samples

Data	BESII	CLEOc
J/ψ	58 M	--
ψ'	14 M	3 M
ψ''	33 pb^{-1}	281 pb^{-1}
Continuum	6.4 pb^{-1} ($\sqrt{s}$=3.65 GeV)	21 pb^{-1} ($\sqrt{s}$=3.67 GeV)

Performance	BESII	CLEOc
$\sigma p/p$	$1.7\%/\sqrt{1+p^2}$	0.6%@p=1GeV
$\sigma E/E$	$22\%/\sqrt{E}$	2.2%@E=1GeV
PartID	dE/dx+TOF	dE/dx+RICH
Coverage	80%	93%

CLEOc results are included when available.

I will talk about –

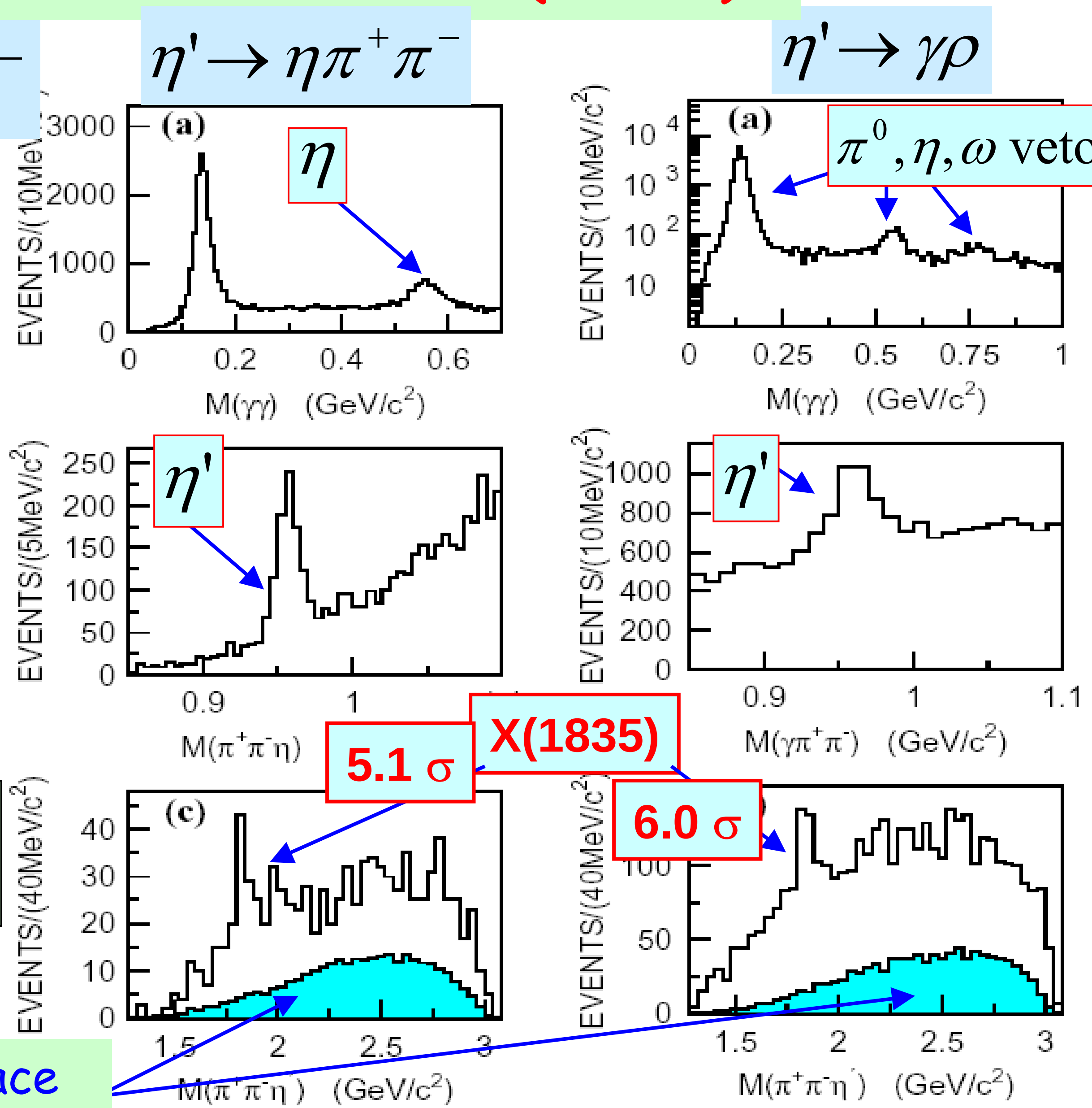
- New observations
- Light scalars
- Vector charmonia decay puzzle
- BESIII

Observation of X(1835)

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

Data selection:

- $\gamma\gamma$ mass cut
- part ID
- kinematic fit
- η' mass cut

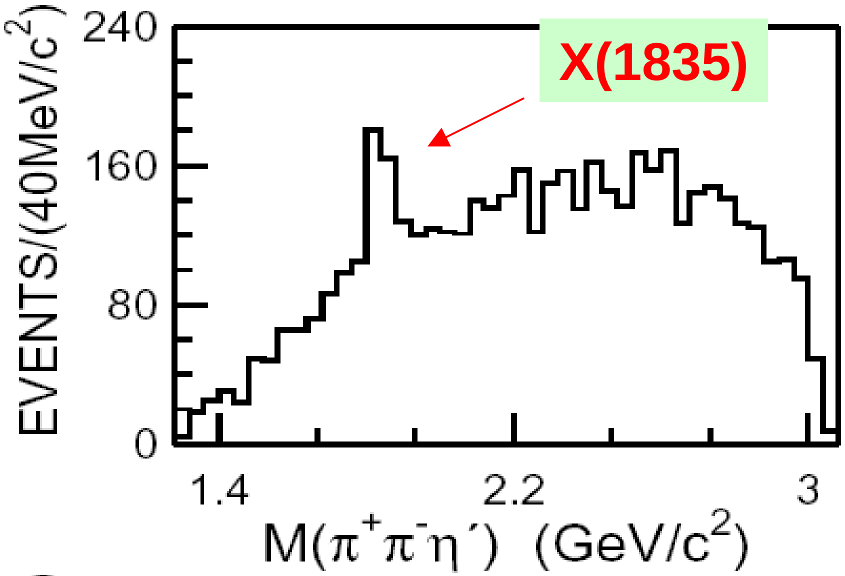


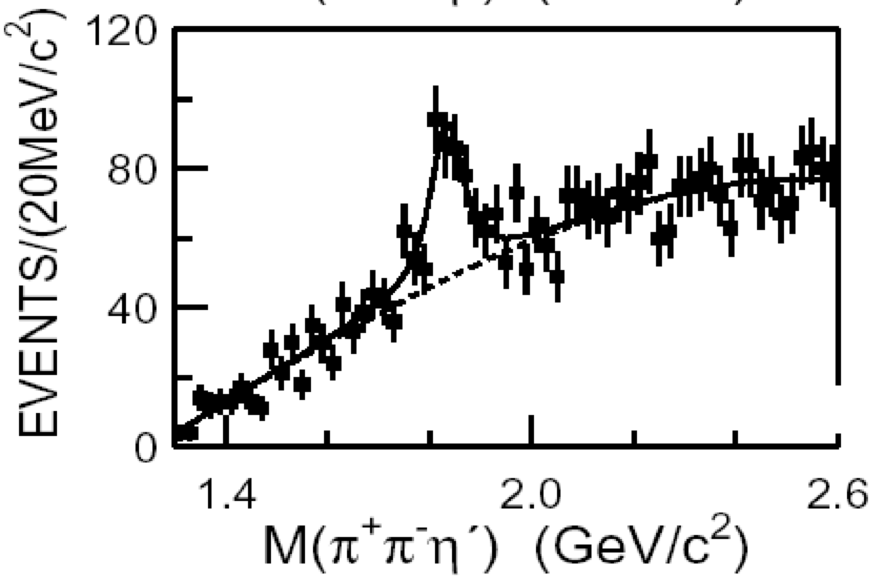
BES Preliminary
hep-ex/0508025

Shape of phase space

Combine two η′ decay modes

BES Preliminary
hep-ex/0508025





Fit with BW + polynomial backgrounds, considering mass resolution.

Statistical significance: 7.7σ

Mass res. ~ 13 MeV
Efficiency ~ 4%

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

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

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

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

What is X(1835)?

BES preliminary results:

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

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

- Mass comparable
- Width different
- No $\eta_2 \to \eta' \pi\pi$ yet
- No J^P from BES

$\eta_2(1870)$

$I^G(J^{PC}) = 0^+(2^{-+})$

In PDG'05:

OMITTED FROM SUMMARY TABLE
Needs confirmation.

$\eta_2(1870)$ MASS

1842

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1842 ± 8 OUR AVERAGE						
1835 ± 12		BARBERIS	00B			450 $pp \to p_f \eta \pi^+ \pi^- p_s$
1844 ± 13		BARBERIS	00C			450 $pp \to p_f 4\pi p_s$
1840 ± 25		BARBERIS	97B	OMEG		450 $pp \to pp 2(\pi^+ \pi^-)$
1875 ± 20 ± 35		ADOMEIT	96	CBAR	0	1.94 $\bar{p}p \to \eta 3\pi^0$
1881 ± 32 ± 40	26	KARCH	92	CBAL		$e^+ e^- \to e^+ e^- \eta \pi^0 \pi^0$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
1860 ± 5 ± 15		ANISOVICH	00E	SPEC		1.94 $\bar{p}p \to \eta 3\pi^0$

$\eta_2(1870)$ WIDTH

225

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
225 ± 14 OUR AVERAGE						
235 ± 22		BARBERIS	00B			450 $pp \to p_f \eta \pi^+ \pi^- p_s$
228 ± 23		BARBERIS	00C			450 $pp \to p_f 4\pi p_s$
200 ± 40		BARBERIS	97B	OMEG		450 $pp \to pp 2(\pi^+ \pi^-)$
200 ± 25 ± 45		ADOMEIT	96	CBAR	0	1.94 $\bar{p}p \to \eta 3\pi^0$
221 ± 92 ± 44	26	KARCH	92	CBAL		$e^+ e^- \to e^+ e^- \eta \pi^0 \pi^0$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$250 \pm 25 ^{+50}_{-35}$		ANISOVICH	00E	SPEC		1.94 $\bar{p}p \to \eta 3\pi^0$
170 ± 40		BAI	99	BES		$J/\psi \to \gamma \eta \pi^+ \pi^-$

$\eta_2(1870)$ DECAY MODES

Γ_1	$\eta \pi \pi$
Γ_2	$a_2(1320)\pi$
Γ_3	$f_2(1270)\eta$
Γ_4	$a_0(980)\pi$

What is X(1835)?

In PDG'05:

Further States

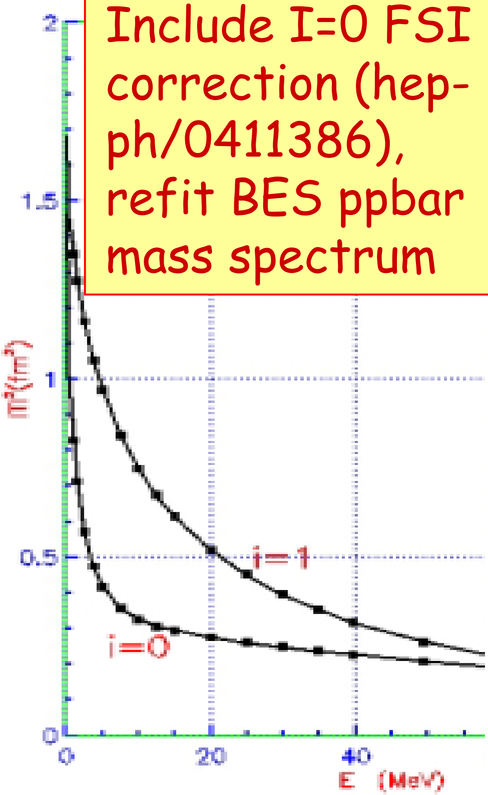
OMITTED FROM SUMMARY TABLE

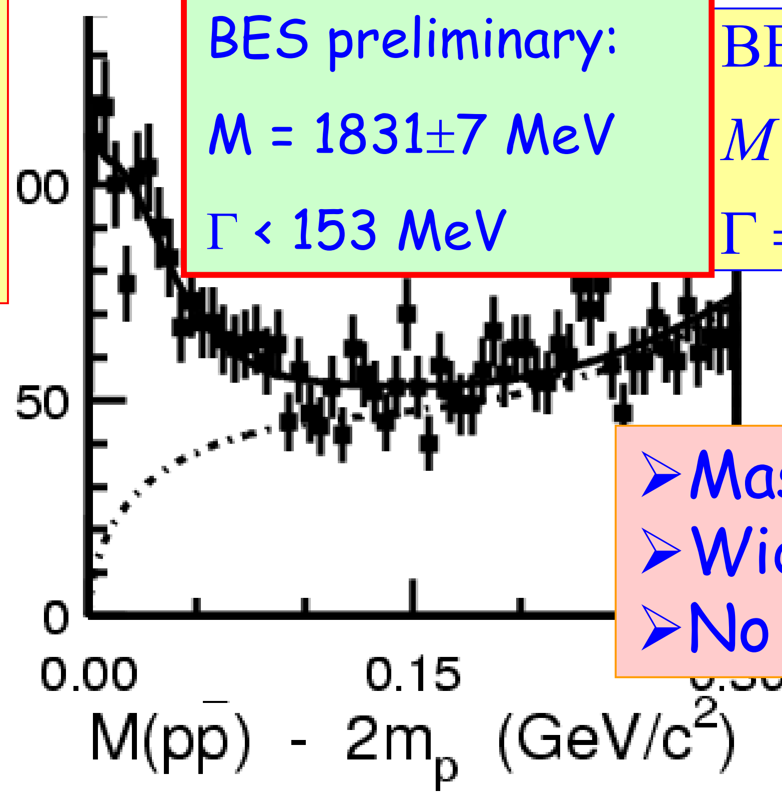
BES: PRL91, 22001 (2003)

X(1860) $I^G(J^{PC}) = ?^?(?^{??})$

MASS (MeV)	WIDTH (MeV)	DOCUMENT ID		TECN	COMMENT
1859^{+6}_{-27}	< 30	BAI	03F	BES2	$J/\psi \to \gamma p \bar{p}$

Include I=0 FSI correction (hep-ph/0411386), refit BES ppbar mass spectrum





BES preliminary:

M = 1831±7 MeV

Γ < 153 MeV

BES preliminary results :

$M = 1833.7 \pm 6.7$ MeV

$\Gamma = 67.7 \pm 21.7$ MeV

- ➢Mass agree
- ➢Width not contradict
- ➢No J^P in both cases

What is X(1835)?

Further arguments support X(1835)=X(1859)=ppbar bound state:

- **ppbar bound state couples to η'ππ large**
  [G.J.Ding and M.L. Yan, PRC72, 015208 (2005)]
- **ppbar bound state couples to ppbar strong**
  [S.L. Zhu and C.S. Gao, hep-ph/0507050]

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

$$B(J/\psi \to \gamma X)B(X \to p\bar{p}) = (7.0 \pm 0.4^{+1.9}_{-0.8})\times 10^{-5}$$

More data, more experiments, more information needed

- **mass and width, most importantly J^P**
- **more decay modes**
- **more theoretical calculations**

Light scalars

- ➢ Many scalars found in experiments
- ➢ Do the sigma and kappa really exist?
- ➢ Have we seen scalar glueball already?

I will show experimental results from BES ---
(theorists (will) give interpretations)

- States in J/ψ decays
  - phi pi pi/phi K K
  - omega pi pi/omega K K
  - gamma pi pi/gamma K K
  - K K pi pi (the kappa)
- Sigma in $\psi' \rightarrow \pi^+\pi^- J/\psi$
- χ_c decays
  - Pair production of scalars

$f_0(600)$ or σ

$f_0(980)$

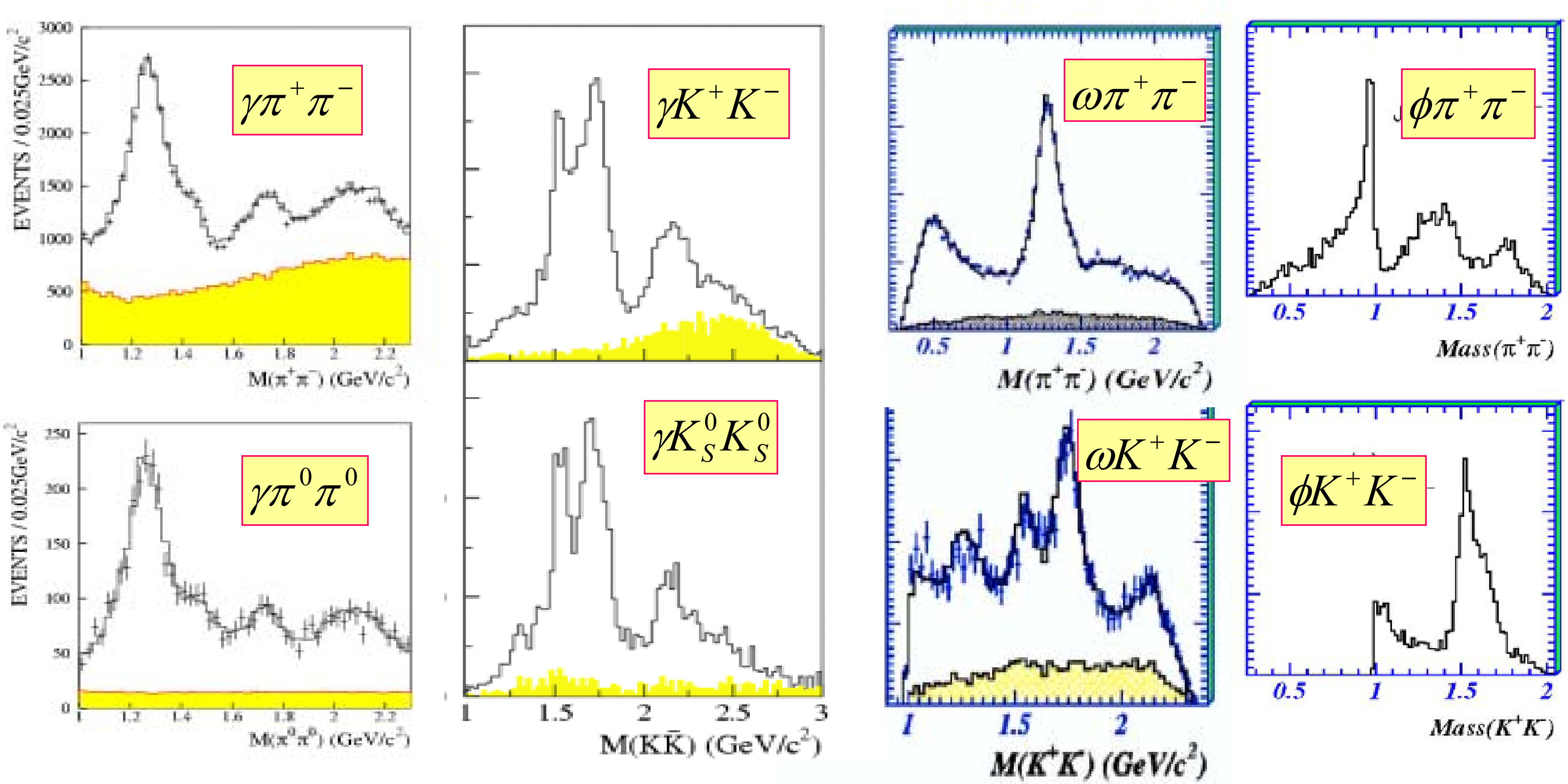
$f_0(1370)$

$f_0(1500)$

$f_0(1710)$

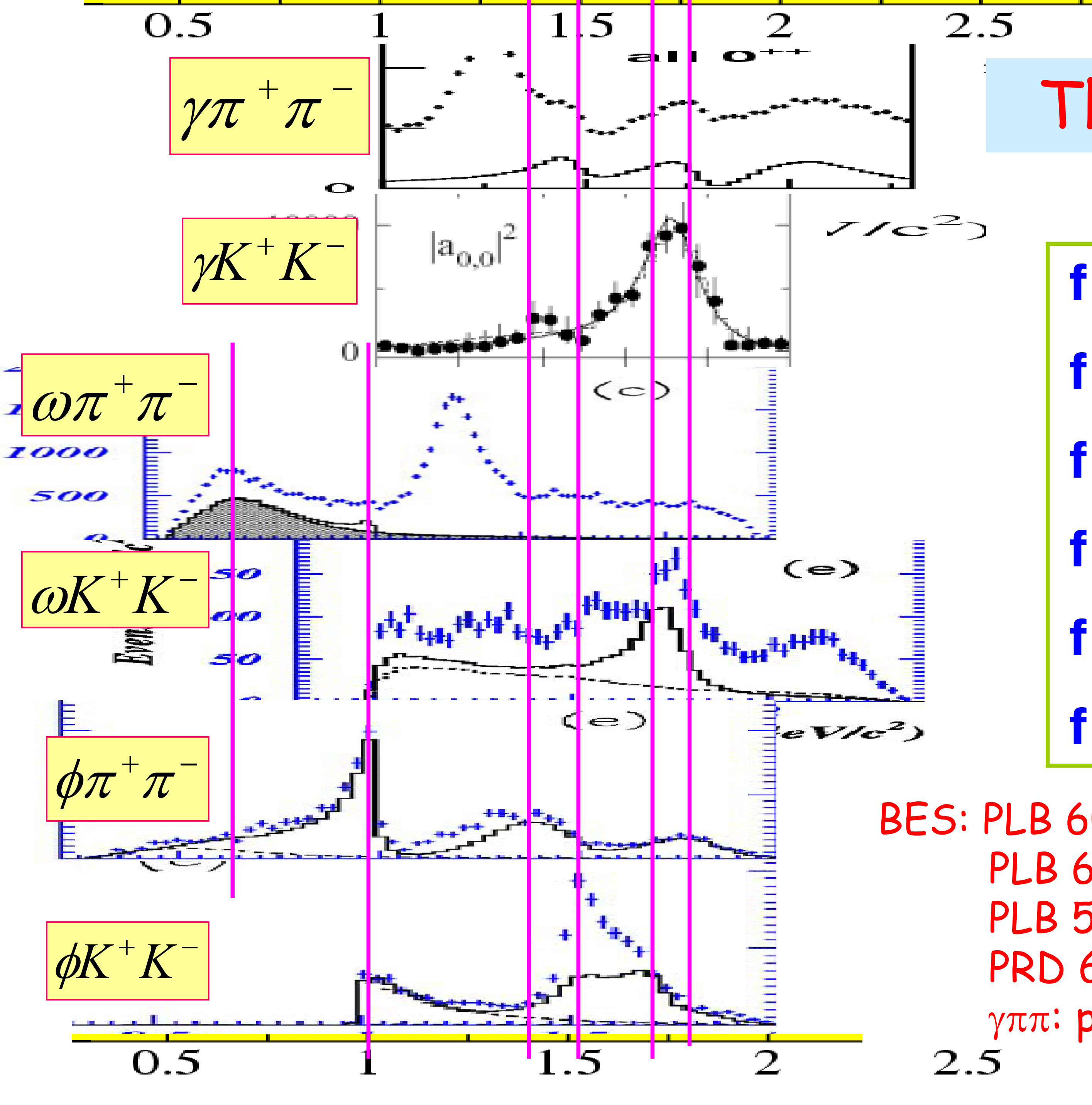
$f_0(1790)$

The mass spectra of meson pairs



Copious structures --- need partial wave analysis to extract physics information: Covariant tensor/helicity amplitudes.

The scalars



$f_0(600)$ or σ:

$f_0(980)$:

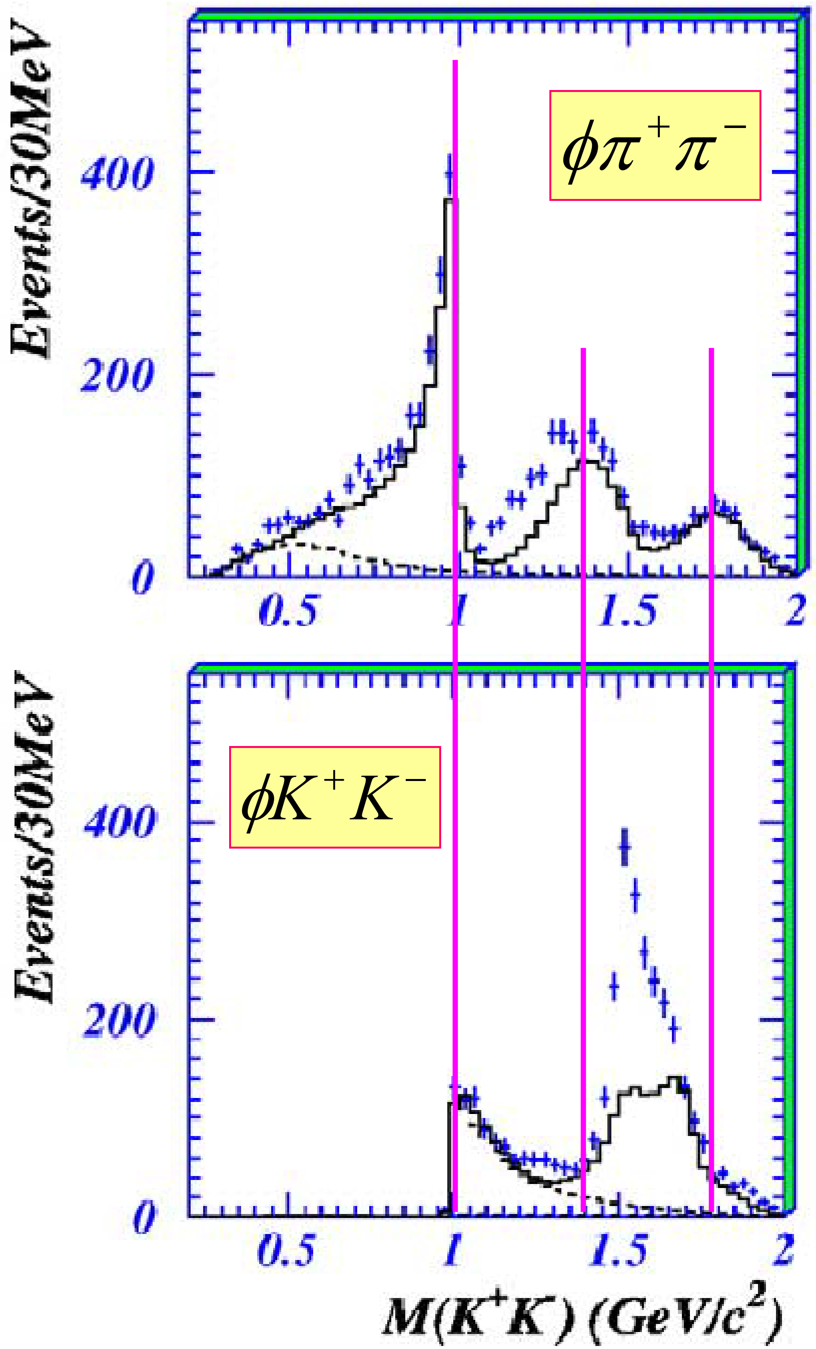
$f_0(1370)$:

$f_0(1500)$:

$f_0(1710)$:

$f_0(1790)$:

BES: PLB 607 (2005) 243
PLB 603 (2004) 138
PLB 598 (2004) 149
PRD 68 (2003) 52003
$\gamma\pi\pi$: preliminary



BES: PLB 607 (2005) 243

$f_0(980)$ parameters:

$$M = 965 \pm 8 \pm 6\ \mathrm{MeV}$$

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

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

$f_0(1370)$ peak seen!

$$M = 1350 \pm 50\ \mathrm{MeV}$$

$$\Gamma = 265 \pm 40\ \mathrm{MeV}$$

Observation of $f_0(1790)$?

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

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

Couplings to γ, ω, and ϕ in J/ψ decays, and decays to $\pi^+\pi^-$ and K^+K^- reveal its nature!

Scalar	B(ϕS, S→$\pi\pi$)(10^{-4})	B(ϕS, S→KK)(10^{-4})
$f_0(600)/\sigma$	1.6±0.6	0.2±0.1
$f_0(980)$	5.4±0.9	4.5±0.8
$f_0(1370)$	4.3±1.1	0.3±0.3
$f_0(1500)$	1.7±0.8	0.8±0.5
$f_0(1710)$	--	2.0±0.7
$f_0(1790)$	6.2±1.4	1.6±0.8

$$B(J/\psi \to \gamma f_0(1710) \to \gamma K\overline{K}) = (9.6^{+3.5}_{-1.9}) \times 10^{-4}$$

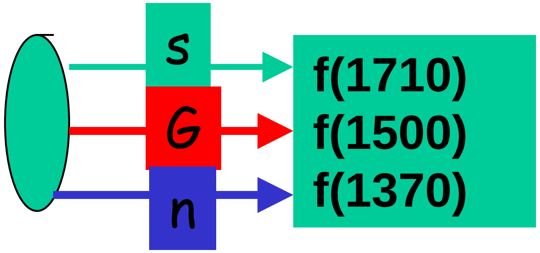
$$B(J/\psi \to \omega f_0(1710) \to \omega K^+ K^-) = (6.6 \pm 1.3) \times 10^{-4}$$

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

Use of these information can be found in hep-ph/0504043 hep-ph/0508088 …

The mixing of the scalars

Idea available long time ago,
most recent analysis in
hep-ph/0504043
By Frank Close and Qiang Zhao



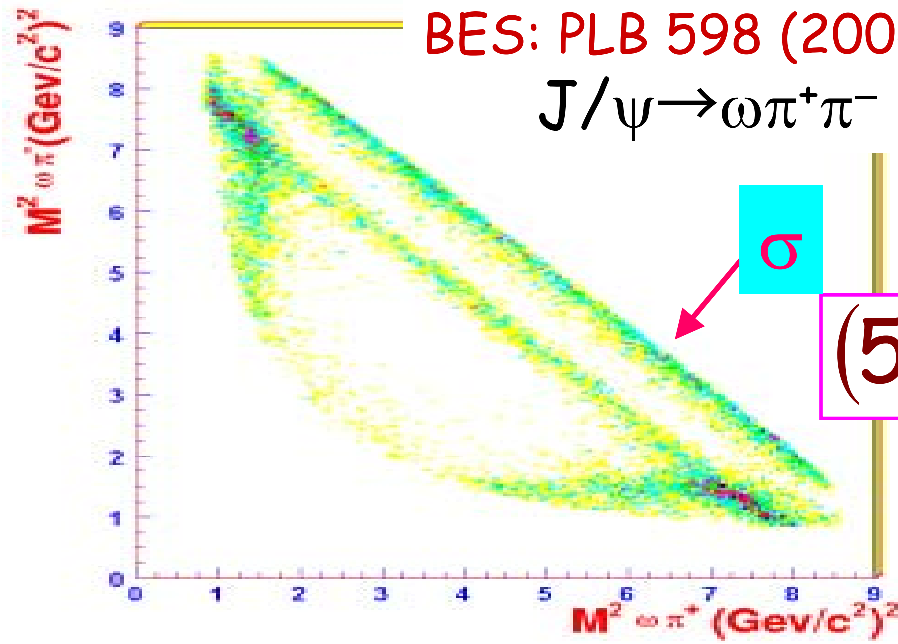
$$
\begin{aligned}
|f_0(1710)\rangle &= 0.39|G\rangle + 0.91|s\bar{s}\rangle + 0.13|n\bar{n}\rangle \\
|f_0(1500)\rangle &= -0.73|G\rangle + 0.37|s\bar{s}\rangle - 0.57|n\bar{n}\rangle \\
|f_0(1370)\rangle &= 0.56|G\rangle - 0.12|s\bar{s}\rangle - 0.82|n\bar{n}\rangle \ ,
\end{aligned}
$$

The mass of the scalar glueball is about
1.46-1.52 GeV in the same scheme.

More on σ particle

BES: PLB 598 (2004) 149

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

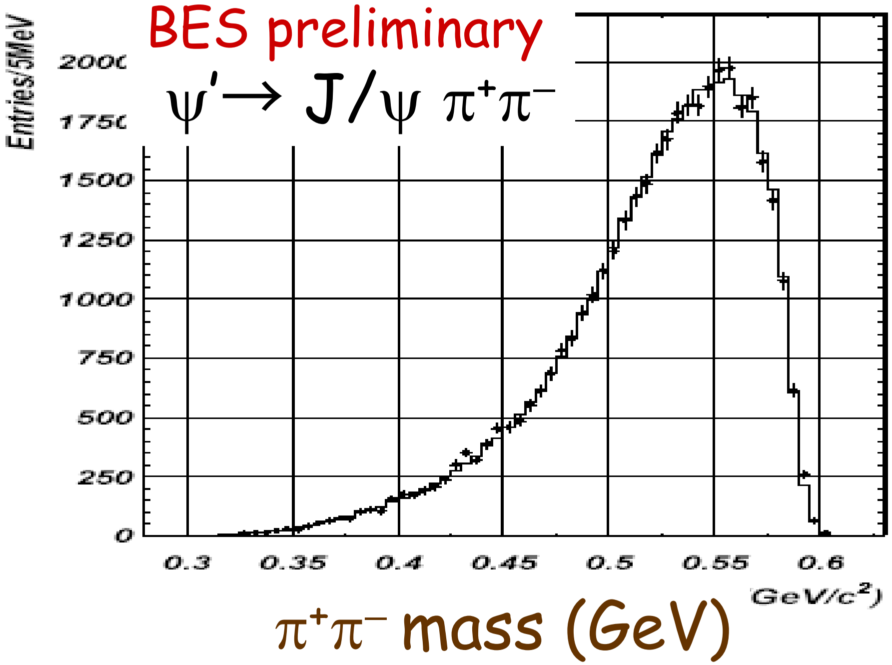


Pole position:

$$(541 \pm 39) - i(252 \pm 42)\ \text{MeV}$$

BES preliminary

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

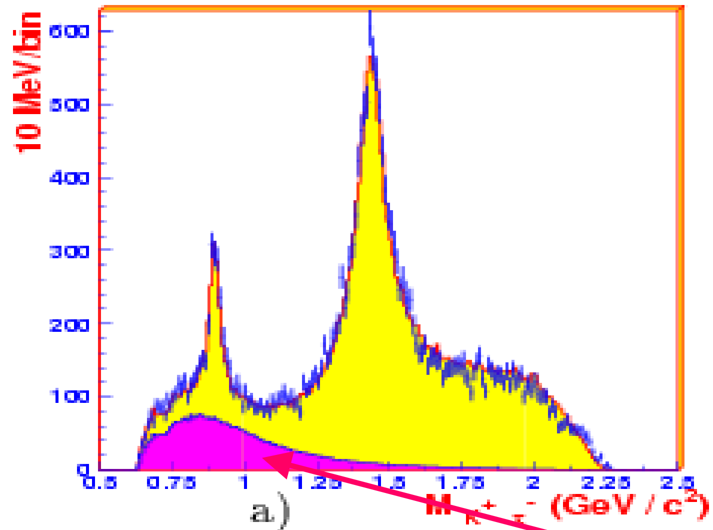


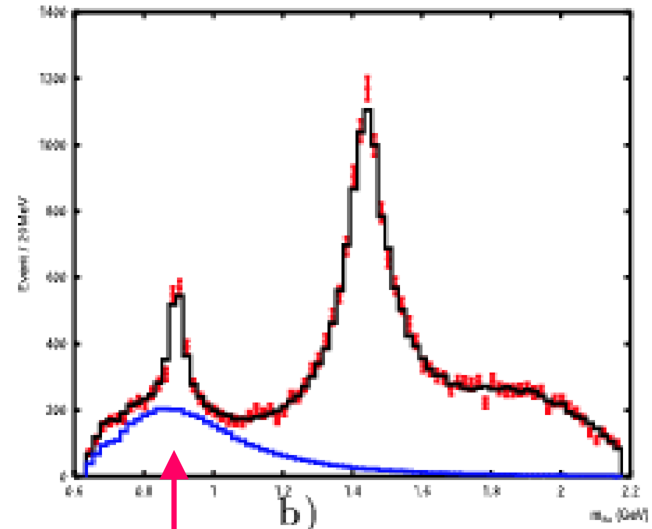
Strong destructive interference between sigma and phase space, pole position similar to J/ψ result.

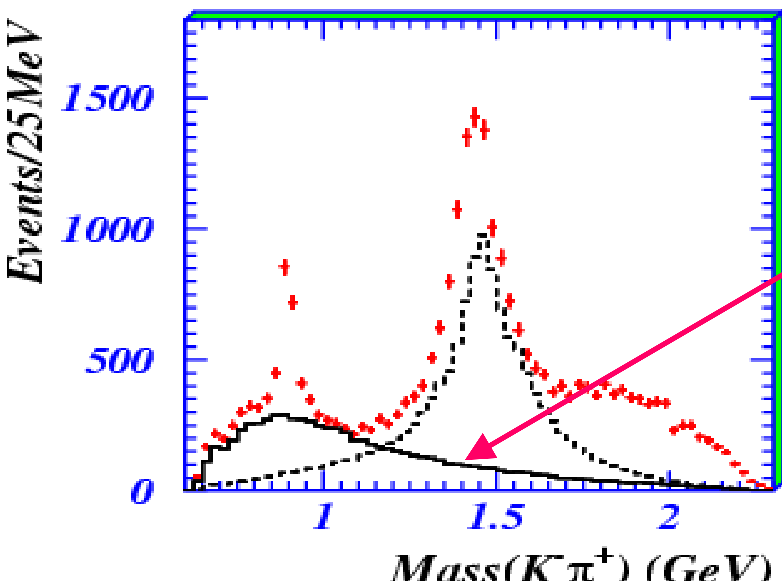
Kappa: K π S-wave resonance

BES preliminary

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







kappa

Same data sample, 3 different analysis methods, similar results.

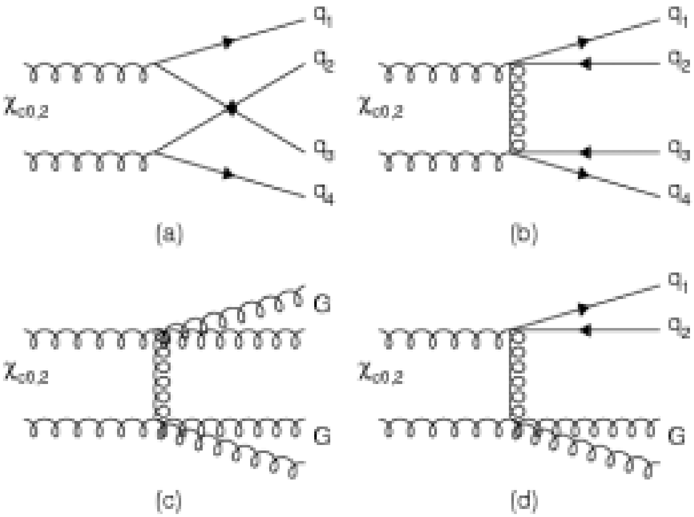
$$(841 \pm 30^{+81}_{-73}) - i(309 \pm 45^{+48}_{-72})\ \text{MeV}$$

$$(760 \pm 20 \pm 40) - i(420 \pm 45 \pm 60)\ \text{MeV}$$

Pair production of scalars

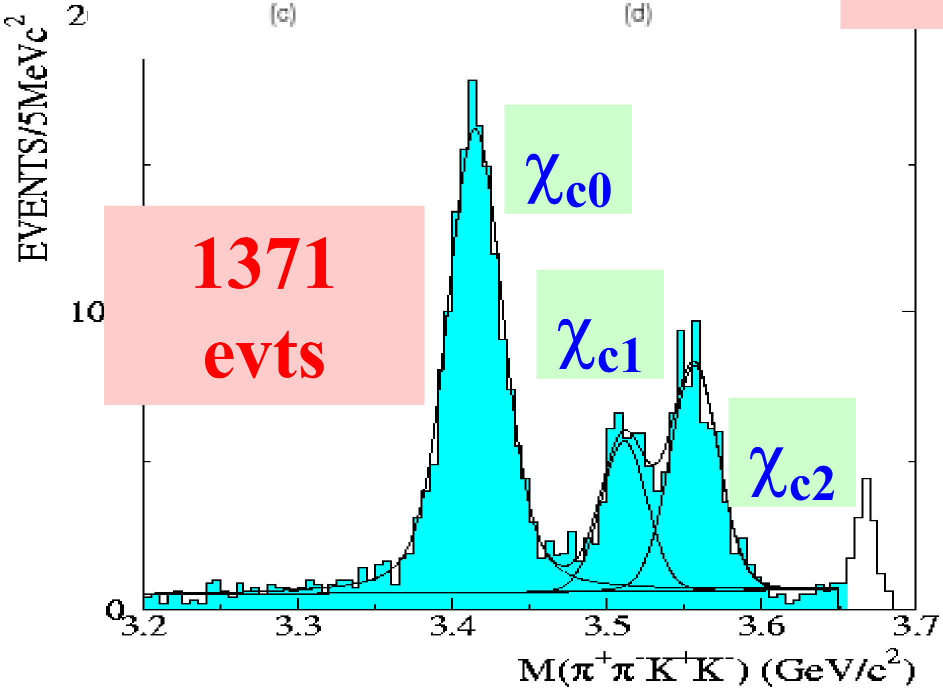
BES preliminary

$\chi_{c0} \to \pi^+\pi^-K^+K^-$



Different way for scalar study:

1. Start from $J^{PC}=0^{++}, 1^{++}, 2^{++}$
2. Start from gluon+gluon
3. Pair production of scalars, very different information than in J/ψ decays

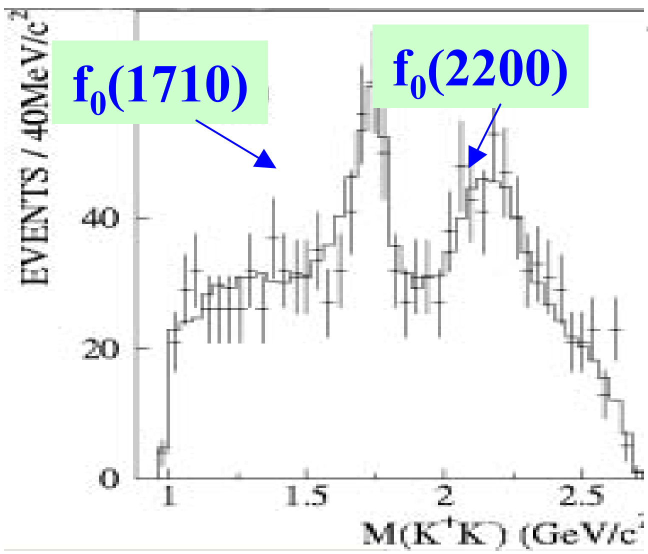


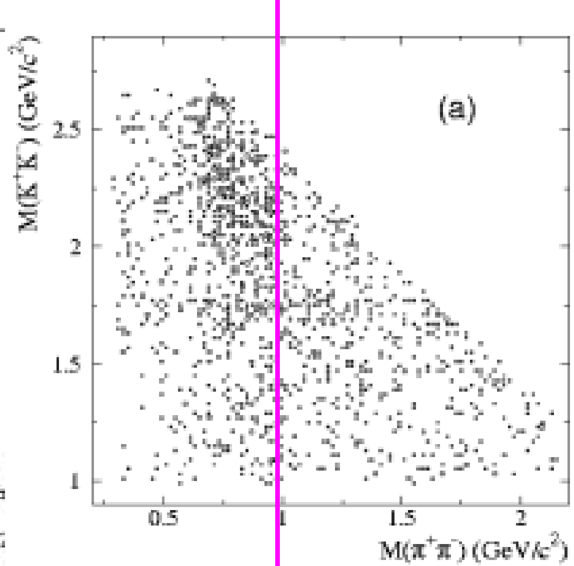
Can study different kinds of resonances:

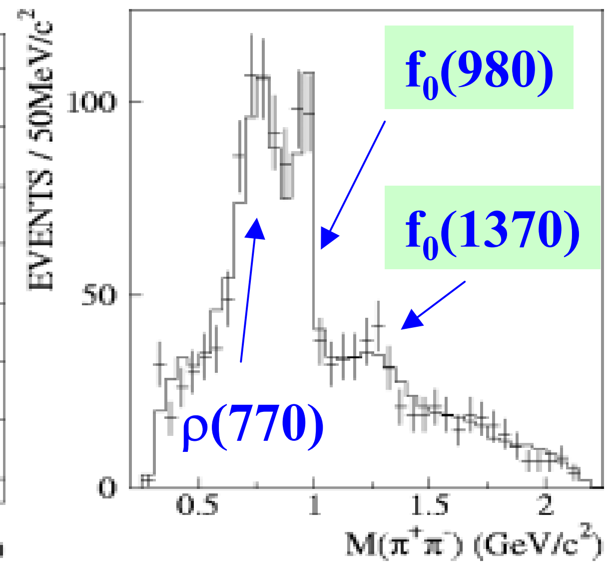
- $(\pi^+\pi^-)(K^+K^-)$
- $(K^+\pi^-)(K^-\pi^+)$
- $(K\pi\pi)K$

$(\pi^+\pi^-)(K^+K^-)$

BES preliminary, $\chi_{c0}\to\pi^+\pi^-K^+K^-$





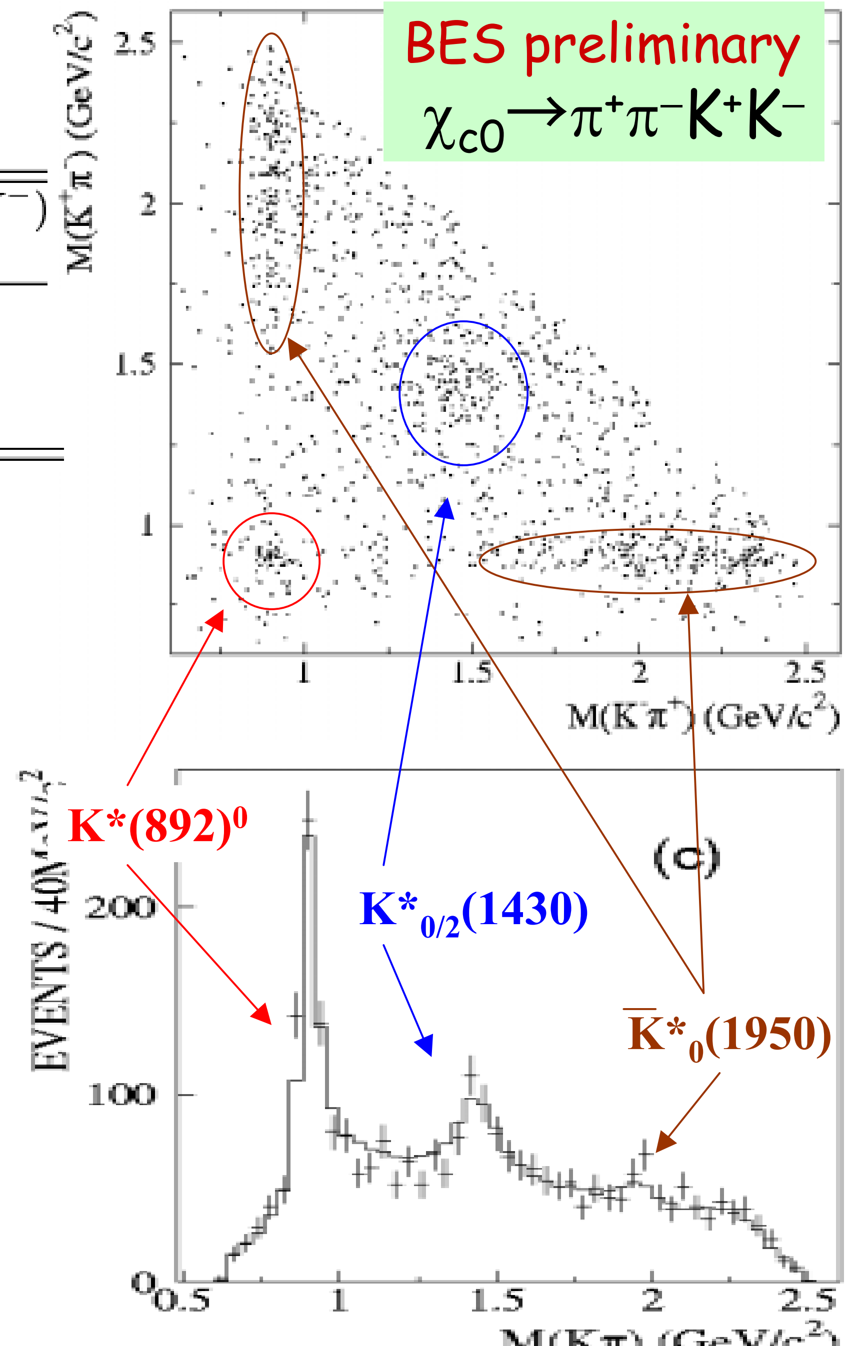


$$\mathcal{B}[\chi_{c0}\to f_0(980)f_0(980)]\mathcal{B}[f(980)\to\pi^+\pi^-]\mathcal{B}[f(980)\to K^+K^-]=(1.73\pm0.42^{+0.96}_{-0.78})\times10^{-4}$$
$$\mathcal{B}[\chi_{c0}\to f_0(980)f_0(2200)]\mathcal{B}[f_0(980)\to\pi^+\pi^-]\mathcal{B}[f_0(2200)\to K^+K^-]=(8.42\pm1.16^{+1.65}_{-2.29})\times10^{-4}$$
$$\mathcal{B}[\chi_{c0}\to f_0(1370)f_0(1710)]\mathcal{B}[f_0(1370)\to\pi^+\pi^-]\mathcal{B}[f_0(1710)\to K^+K^-]=(7.12\pm1.46^{+3.28}_{-1.68})\times10^{-4}$$
$$\mathcal{B}[\chi_{c0}\to f_0(1370)f_0(1370)]\mathcal{B}[f_0(1370)\to\pi^+\pi^-]\mathcal{B}[f_0 1370)\to K^+K^-]<2.9\times10^{-4},$$
$$\mathcal{B}[\chi_{c0}\to f_0(1370)f_0(1500)]\mathcal{B}[f_0(1370)\to\pi^+\pi]\mathcal{B}[f_0(1500)\to K^+K^-]<1.8\times10^{-4},$$
$$\mathcal{B}[\chi_{c0}\to f_0(1500)f_0(1370)]\mathcal{B}[f_0(1500)\to\pi^+\pi^-]\mathcal{B}[f_0 1370)\to K^+K^-]<1.4\times10^{-4},$$
$$\mathcal{B}[\chi_{c0}\to f_0(1500)f_0(1500)]\mathcal{B}[f_0(1500)\to\pi^+\pi^-]\mathcal{B}[f_0(1500)\to K^+K^-]<0.55\times10^{-4},$$
$$\mathcal{B}[\chi_{c0}\to f_0(1500)f_0(1710)]\mathcal{B}[f_0(1500)\to\pi^+\pi^-]\mathcal{B}[f_0(1710)\to K^+K^-]<0.73\times10^{-4}.$$

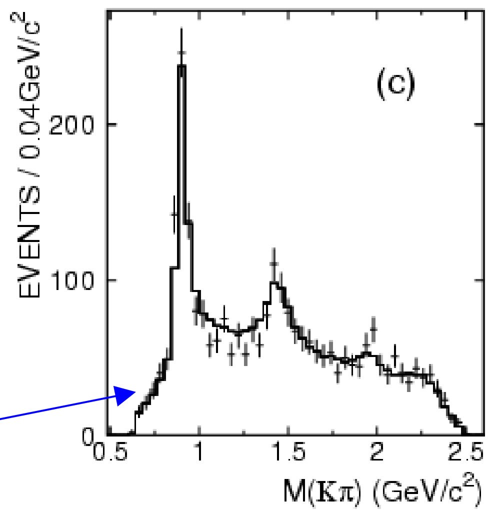
Q. Zhao, hep-ph/0508086, try to understand these data and the scalars …

$(K^+\pi^-)(K^-\pi^+)$

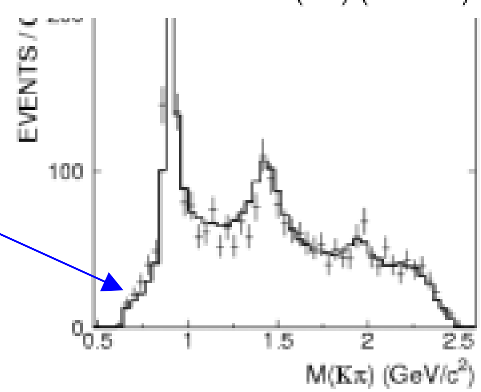
Decay mode	$\mathcal{B}(\chi_{c0} \to X \to \pi^+\pi^-K^+K^-)$ $(\times 10^{-4})$
$K^*(892)^0\bar{K}^*(892)^0$	$8.09 \pm 1.24^{+2.29}_{-1.99}$
$K_0^*(1430)\bar{K}_0^*(1430)$	$10.44 \pm 1.57^{+3.05}_{-1.90}$
$K_0^*(1430)\bar{K}_2^*(1430) + c.c.$	$8.49 \pm 1.47^{+1.32}_{-1.99}$



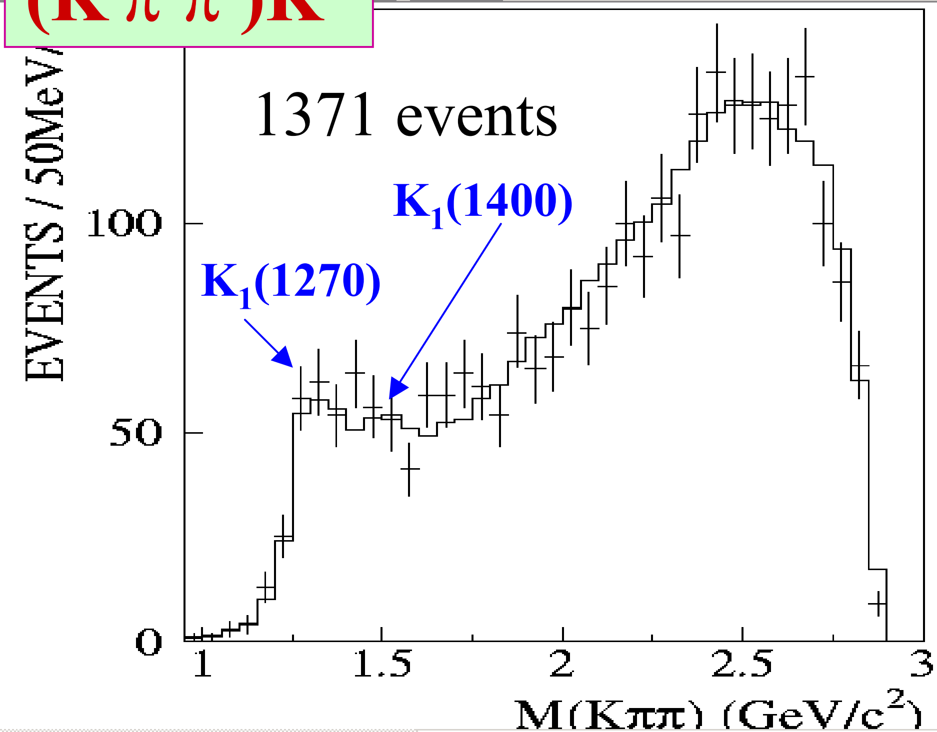
With Kappa-kappa



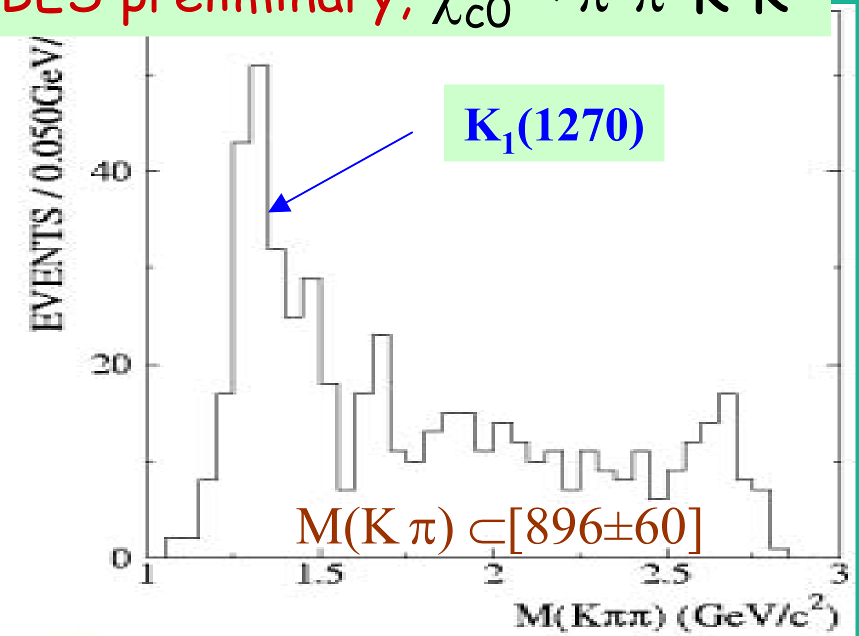
Without Kappa-kappa ΔS=39.

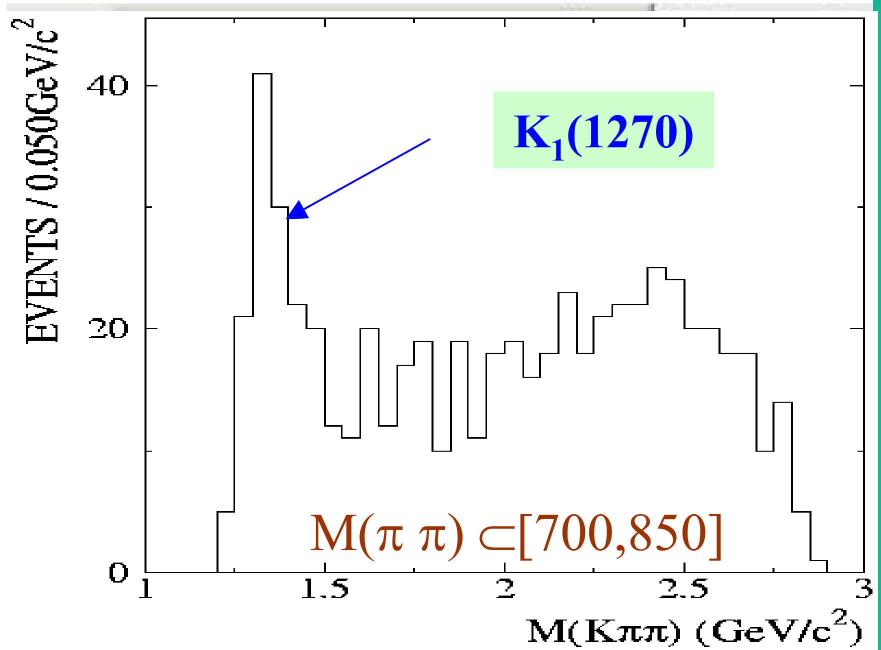


$(K\pi\pi)K$



BES preliminary, $\chi_{c0}\to\pi^+\pi^-K^+K^-$





$$\mathcal{B}(\chi_{c0}\to K_1(1270)^{\pm}K^{\mp}) = (6.66\pm1.07^{+1.60}_{-1.51})\times10^{-3}$$

$$\mathcal{B}(\chi_{c0}\to K_1(1400)^{\pm}K^{\mp}) < 2.85\times10^{-3}$$

The mixing angle between K_{1A} and K_{1B} θ>57 degrees, while in ψ' decays to K_1K, the angle is θ<29 degrees. Why?

Vector charminia decay puzzle

- "12% rule" and "$\rho\pi$ puzzle"
- Experimental progress
- ψ'' non-DDbar decays

The "12% rule"

M. Appelquist and H. D. Politzer, PRL34, 43 (1975)

$$\Gamma_h = |M_h|^2 |\Psi(0)|^2$$

$$= (2/9\pi)(\pi^2 - 9)\tfrac{5}{18}\alpha_s{}^3(\tfrac{4}{3}\alpha_s)^3 m_{\psi'}. \qquad (3)$$

The leptonic width via one photon into $\bar{l}l$ is

$$\Gamma_l = |M_l|^2 |\Psi(0)|^2 = \tfrac{1}{2}(\tfrac{2}{3}\alpha)^2(\tfrac{4}{3}\alpha_s)^3 m_{\psi'}, \qquad (4)$$

where $\alpha \approx \frac{1}{137}$. Although separately these calculations are not trustworthy, the ratio

$$\frac{\Gamma_l}{\Gamma_h} = \frac{\frac{2}{9}\alpha^2}{(2/9\pi)(\pi^2 - 9)5/\alpha_s{}^3} \qquad (5)$$

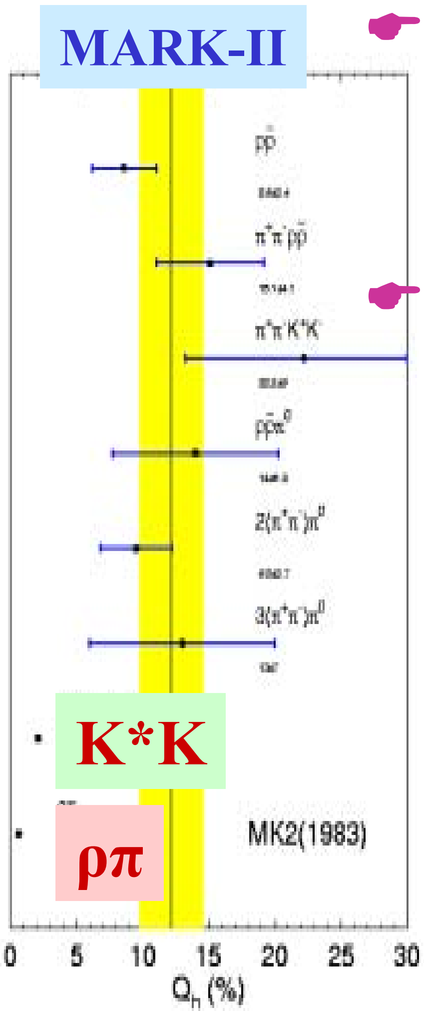
is independent of wave-function effects.

This is the famous (or notorious)

"12% rule".

$$Q_h = \frac{B_{\psi' \to X}}{B_{J/\psi \to X}} = \frac{B_{\psi' \to e^+e^-}}{B_{J/\psi \to e^+e^-}} = 12\%$$

"12% rule" and "ρπ puzzle"



- Violation found by Mark-II , confirmed by BESI at higher sensitivity.
- Extensively studied by BESII/CLEOc
  - VP mode: $\rho\ \pi$, $K^{*+}K^{-}$+c.c., $K^{*0}K^{0}$+c.c., $\omega\pi^{0}$,...
  - PP mode: $K_S K_L$
  - $B\bar{B}$ mode: $p\bar{p}$, $\Lambda\bar{\Lambda}$, ...
  - VT mode: $K^*K^*_2$, $\phi f_2'$, $\rho a2$, ωf_2
  - 3-body: $p\bar{p}\pi^0$, $p\bar{p}\eta$, $\pi^+\pi^-\pi^0$, ...
  - Multi-body: $K_S K_S hh$, $\pi^+\pi^-\pi^0 K^+K^-$, $3(\pi^+\pi^-)$, ...

Extension of the "12% rule"

- In Potential model, if J/ψ, ψ', and ψ'' are pure 1S, 2S, and 1D states, one expects

$$Q_h = \frac{B_{\psi' \to X}}{B_{J/\psi \to X}} = \frac{B_{\psi' \to e^+e^-}}{B_{J/\psi \to e^+e^-}} = (12.7 \pm 0.6)\%$$

$$Q'_h = \frac{B_{\psi'' \to X}}{B_{J/\psi \to X}} = \frac{B_{\psi'' \to e^+e^-}}{B_{J/\psi \to e^+e^-}} = (1.9 \pm 0.3) \times 10^{-4}$$

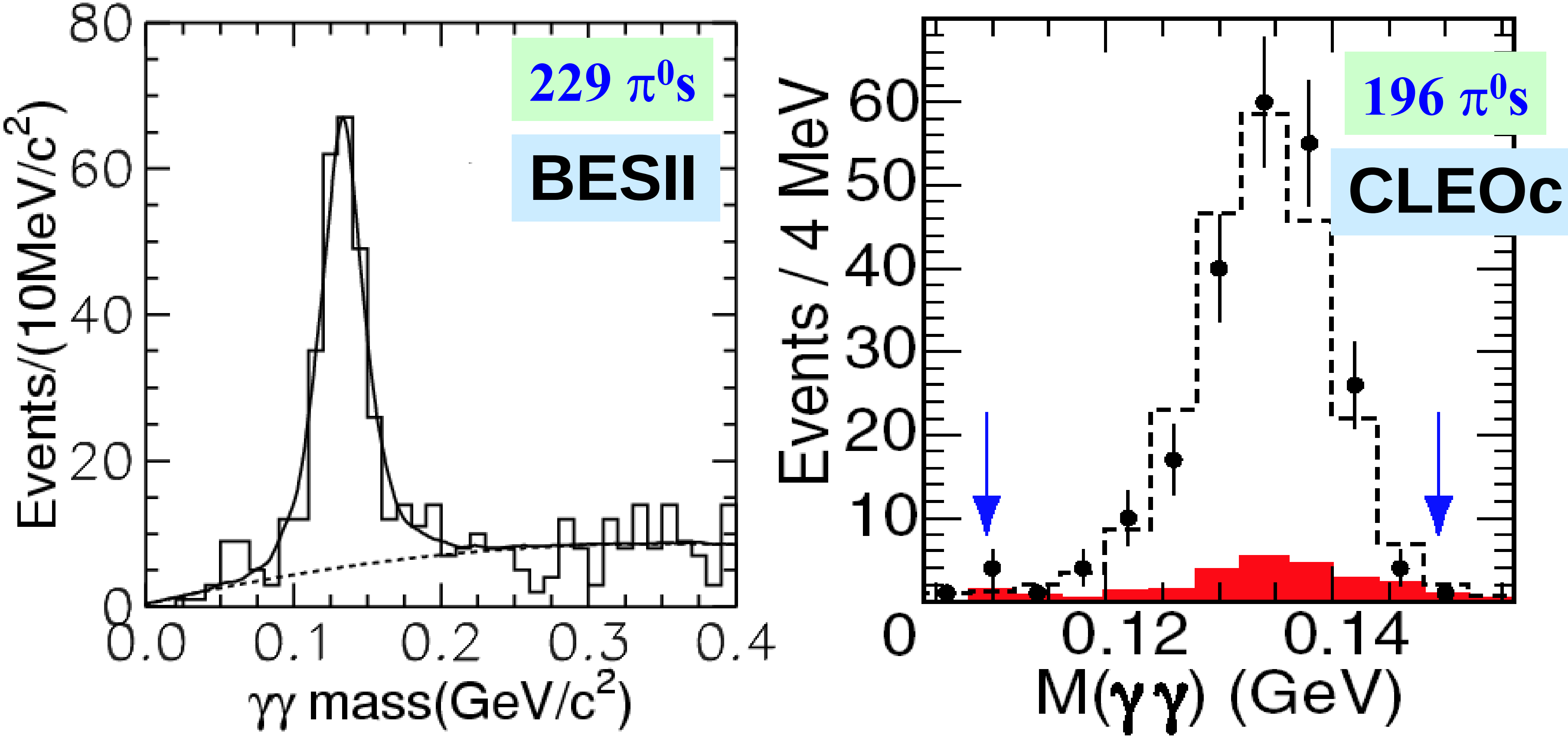
- but ψ' and ψ'' are known not pure 2S and 1D states

  PRD17, 3090 (1978); 21, 203 (1980); 41, 155 (1990); …

- Let's look at data … (and first, the story of $\rho\pi$)

$\psi' \to \pi^+ \pi^- \pi^0$

BESII: PLB619, 247 (2005)
CLEOc: PRL94, 012005 (2005)



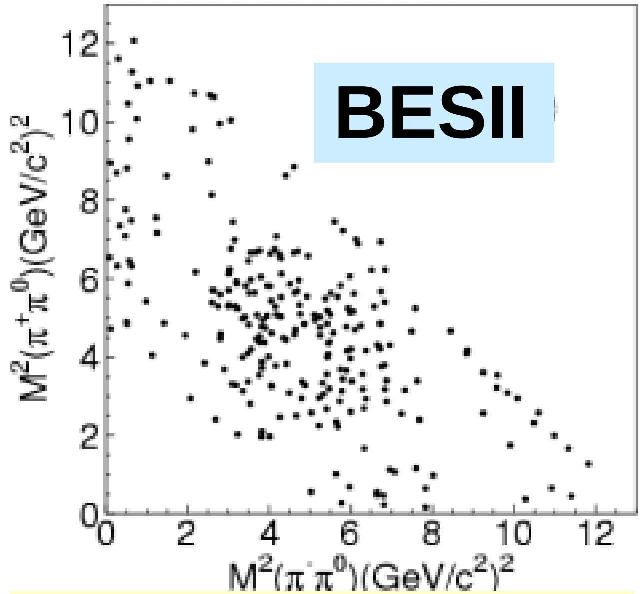
$$BESII: B(\psi' \to \pi^+\pi^-\pi^0) = (18.1 \pm 1.8 \pm 1.9) \times 10^{-5}$$

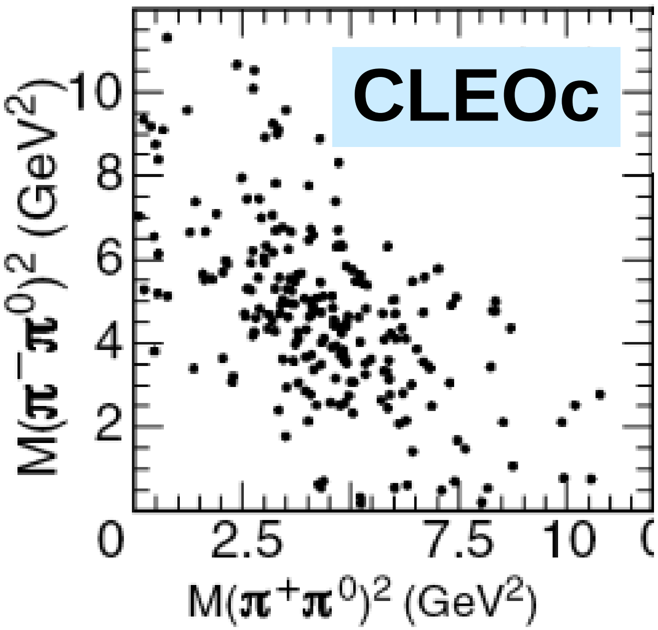
$$CLEOc: B(\psi' \to \pi^+\pi^-\pi^0) = (18.8^{+1.6}_{-1.5} \pm 2.8) \times 10^{-5}$$

BES and CLEOc in good agreement!

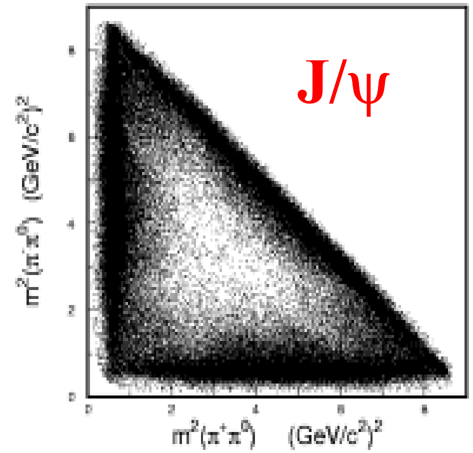
$\psi' \rightarrow \pi^+ \pi^- \pi^0$

Dalitz plots after applying π^0 mass cut!





Very different from $J/\psi \rightarrow 3\pi$!



Similar Dalitz plots, different data handling techniques:

PWA vs counting!

$$BESII : B(\psi' \rightarrow \rho\pi) = (5.1 \pm 0.7 \pm 1.1) \times 10^{-5}$$

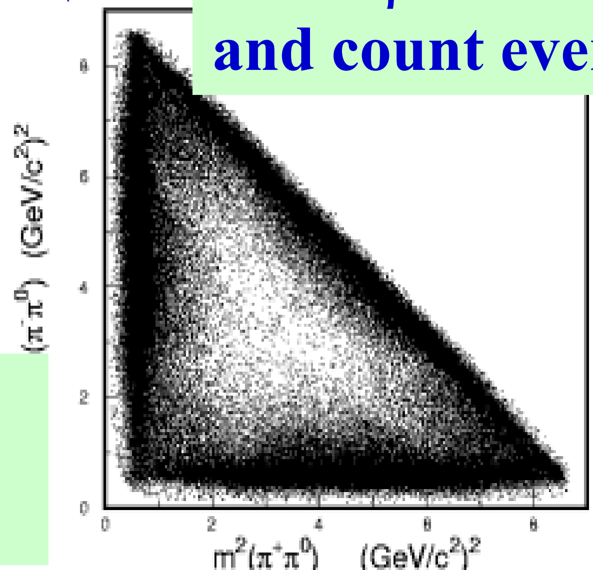
$$CLEOc : B(\psi' \rightarrow \rho\pi) = (2.4^{+0.8}_{-0.7} \pm 0.2) \times 10^{-5}$$

$\psi' \rightarrow \rho\pi$ is observed, it is not completely missing, BR is at 10^{-5} level!

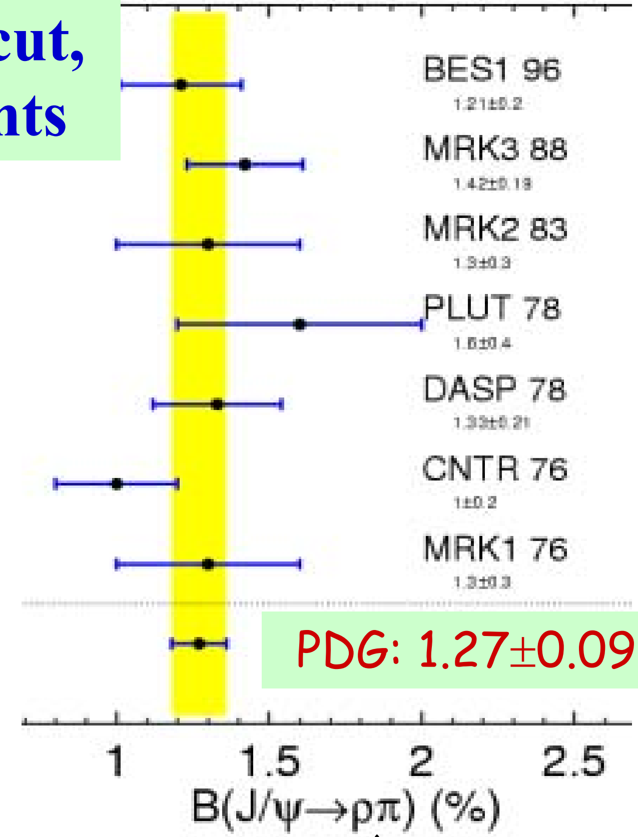
$J/\psi \to \pi^+ \pi^- \pi^0$

PWA analysis assuming ρ interferes with excited ρ states

L. P. Chen and W. Dunwoodie, Hadron'91, MRK3 data

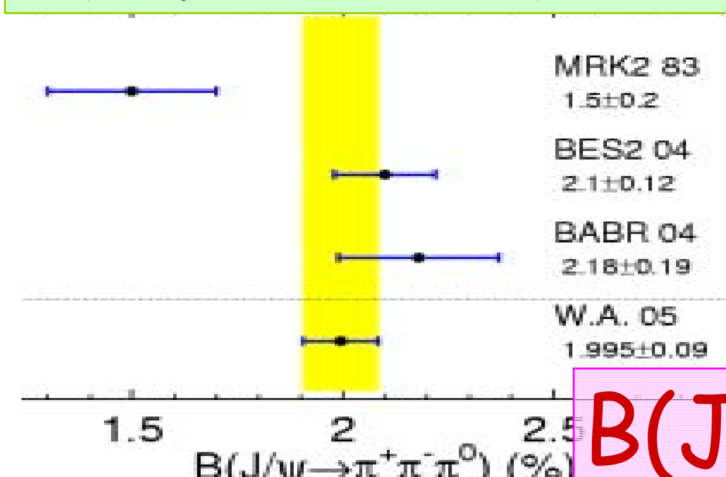


Make ρ mass cut, and count events



PDG: 1.27±0.09%

$$\frac{B(J/\psi \to \rho\pi)}{B(J/\psi \to \pi^+\pi^-\pi^0)} = 1.17(1 \pm 10\%?)$$

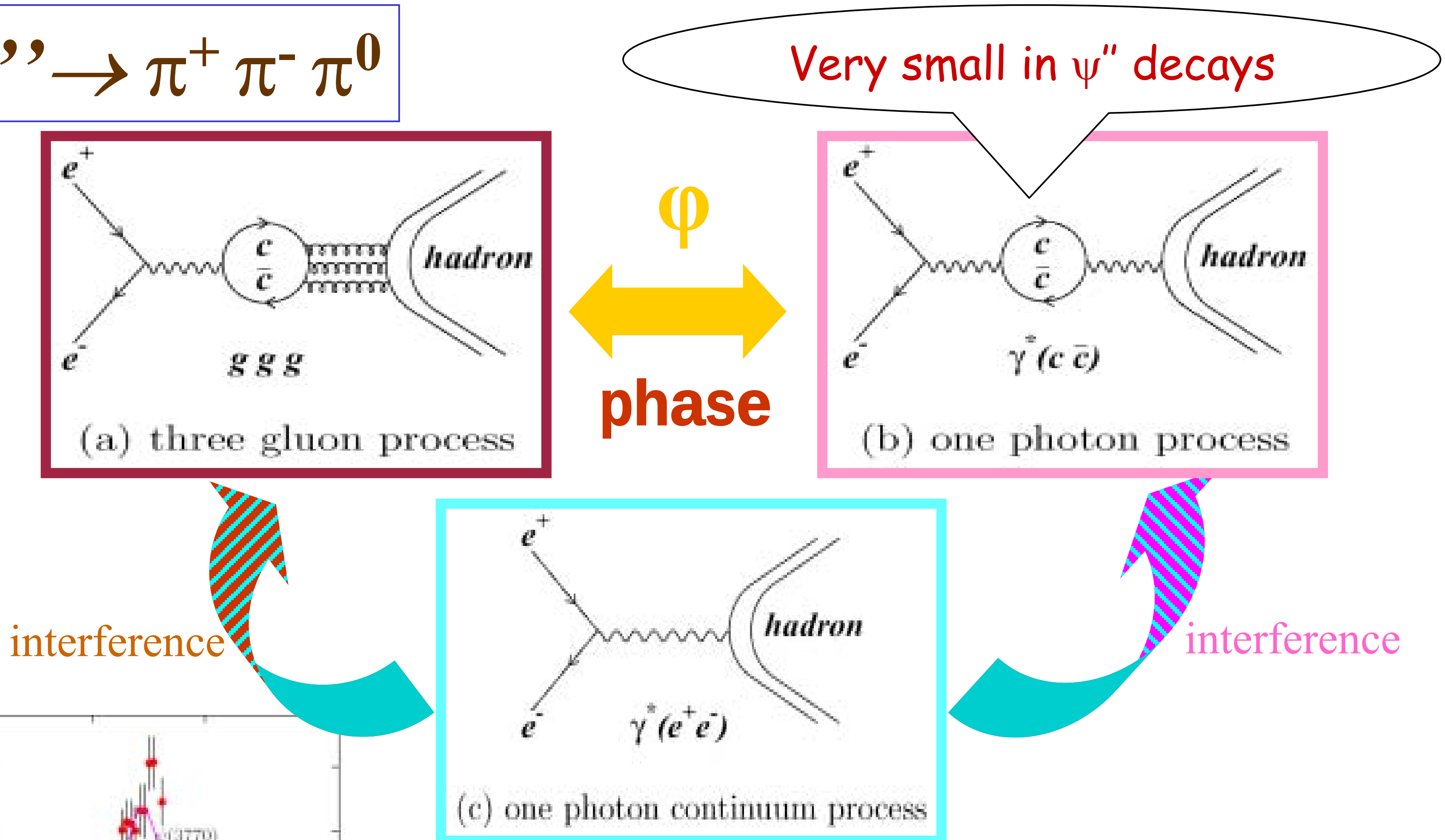


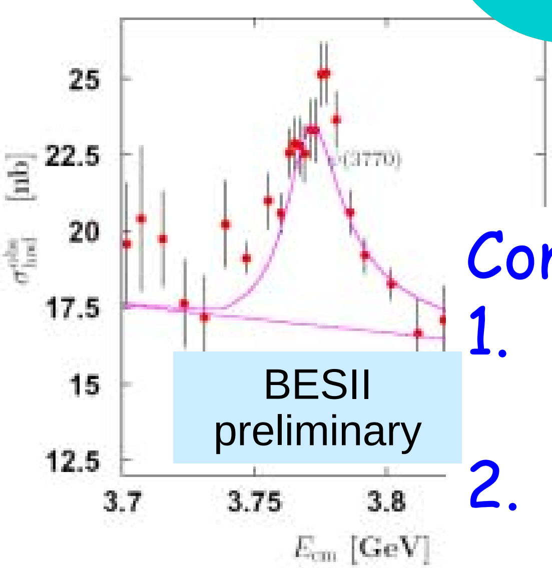
$$B(J/\psi \to \pi^+\pi^-\pi^0) = (2.00 \pm 0.09)\%$$

Very different!

$$B(J/\psi \to \rho\pi) = (2.34 \pm 0.26)\%$$

$\psi'' \to \pi^+ \pi^- \pi^0$





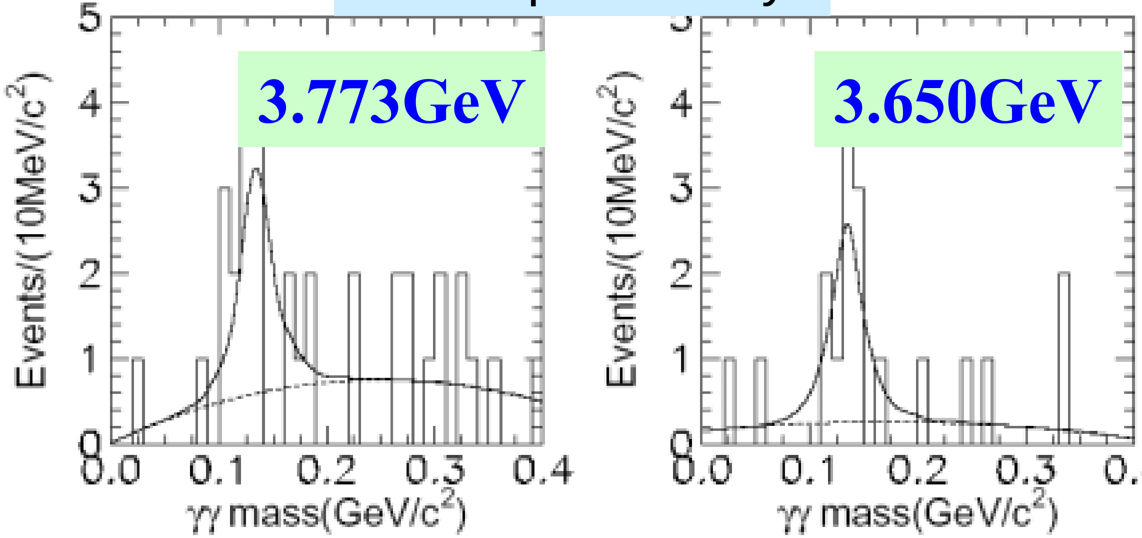
Continuum contribution is crucial in ψ'' analysis:

1. Total ψ'' charmless decays (<2nb) is much less than total continuum process (~16nb),
2. Inteference between amplitudes

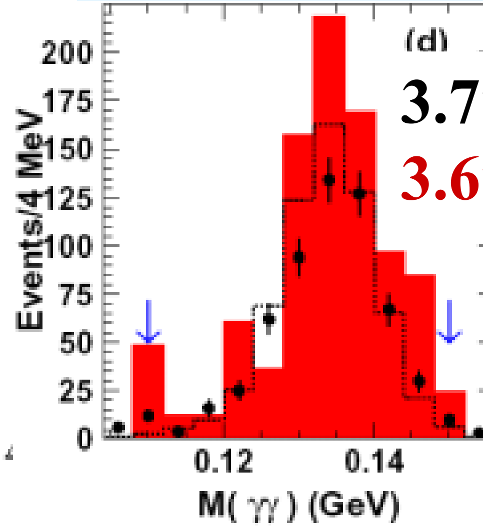
$\psi'' \to \pi^+ \pi^- \pi^0$

BESII: hep-ex/0507092
CLEOc: CLEO-CONF 05-01

BESII preliminary



CLEOc preliminary



$\sigma^B(e^+e^- \to \pi^+\pi^-\pi^0)@3.773\,GeV:$	$@continuum:$
$BESII:(8.6 \pm 3.3 \pm 2.1)\,pb$	$(19.3 \pm 7.3 \pm 3.7)\,pb$
$CLEOc:(7.4 \pm 0.4 \pm 1.2)\,pb$	$(13.1^{+1.8}_{-1.7} \pm 2.1)\,pb$

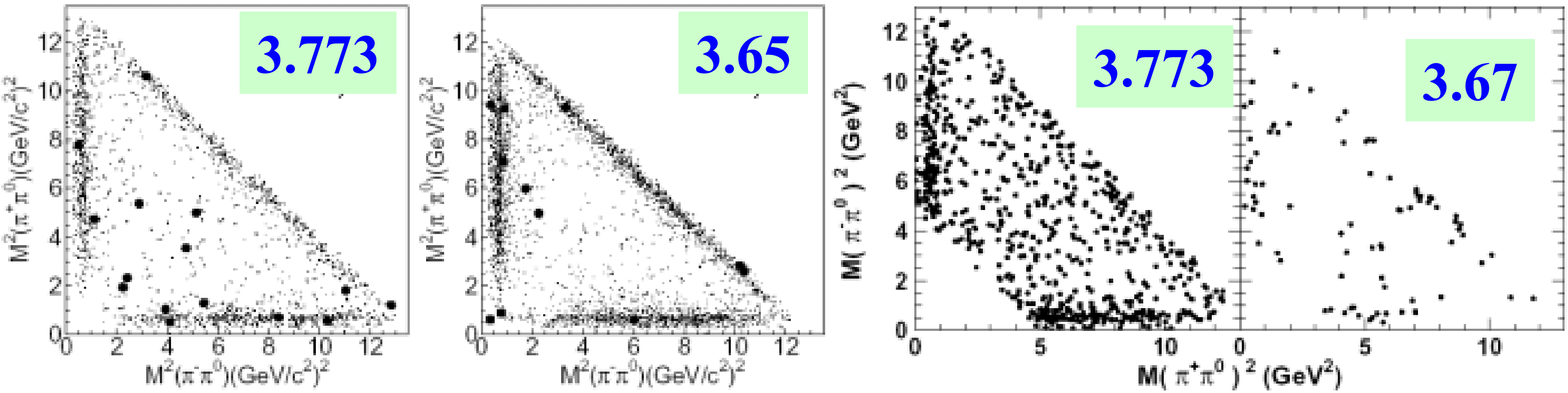
BES and CLEOc are in good agreement!
X-section at ψ'' peak is smaller than at continuum!

$\psi'' \to \pi^+ \pi^- \pi^0$

BESII: hep-ex/0507092
CLEOc: CLEO-CONF 05-01

BESII preliminary

CLEOc preliminary



$$\sigma^B(e^+e^- \to \rho\pi)@3.773GeV:$$
$$BESII :< 6.0\,pb$$
$$CLEOc : (4.4 \pm 0.3 \pm 0.5)\,pb$$

$$@continuum:$$
$$< 25\,pb$$
$$(8.0^{+1.7}_{-1.4} \pm 0.9)\,pb$$

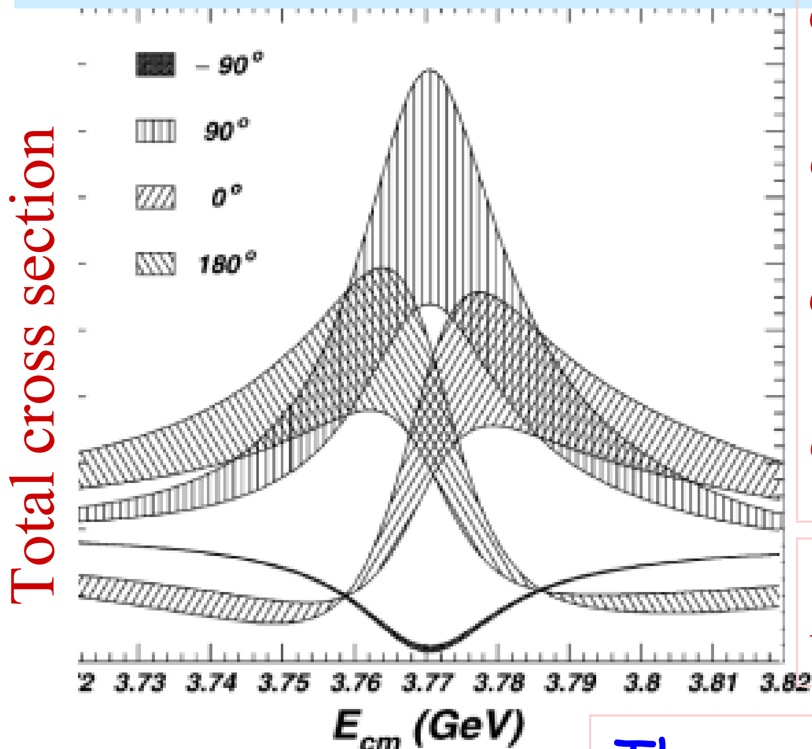
Subtle difference in handling efficiency and ISR correction.

BES and CLEOc are in good agreement!
X-section at ψ″ peak is smaller than at continuum!
➔non-zero ψ″➔ρπ amplitude.

$\psi'' \rightarrow \rho\,\pi$

BESII: hep-ex/0507092
CLEOc: CLEO-CONF 05-01

Wang, Yuan and Mo:PLB574,41(2003)



$$on-resoance-peak:$$

$$\sigma_{on}^{B} \propto \left| a_{\psi''\rightarrow ggg} + a_{\psi''\rightarrow \gamma *} + a_{e^+e^-\rightarrow\gamma *} \right|^2$$

$$off-resonance-peak:$$

$$\sigma_{off}^{B} \propto \left| a_{e^+e^-\rightarrow\gamma *} \right|^2$$

$$B(\psi''\rightarrow \rho\pi) \propto \left| a_{\psi''\rightarrow ggg} + a_{\psi''\rightarrow \gamma *} \right|^2$$

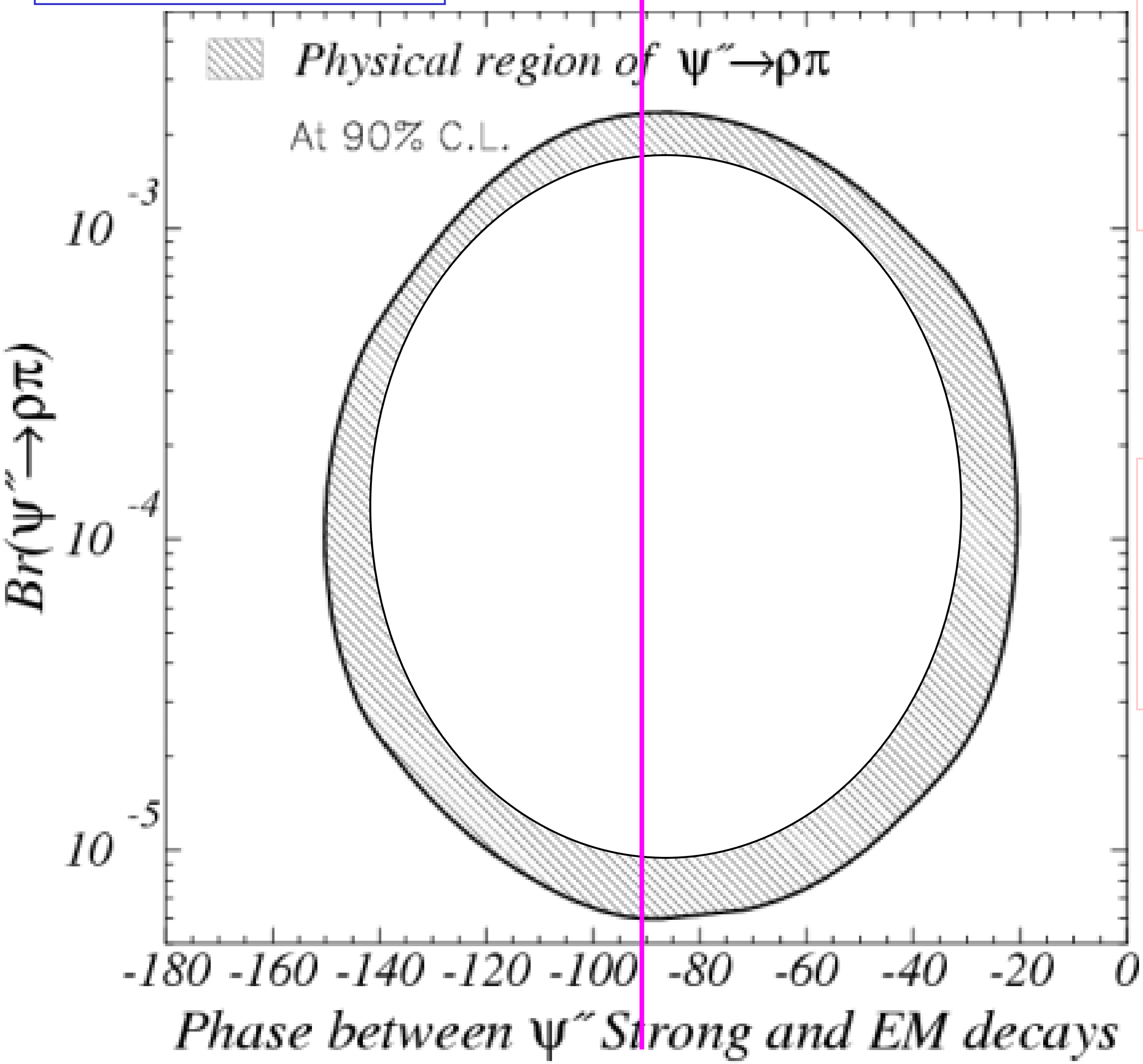
Three unknowns with two equations ---
One can plot the BR versus phase ϕ.

$$\sigma^{B} = \frac{n^{obs}}{L\varepsilon(1+\delta)}$$

σ^B depends on efficiency and ISR correction,
efficiency and ISR correction depends on $\sigma^B(s)$!
Iteration is necessary!

$\psi'' \to \rho\pi$

BESII: hep-ex/0507092
CLEOc: CLEO-CONF 05-01



BES data restrict BR and phase in a wide range (@90% C.L.):

$$BR \in \left(6\times10^{-6}, 2.4\times10^{-3}\right)$$

$$\phi \in \left(-150^\circ, -20^\circ\right)$$

CLEOc data further restrict BR and phase in a ring*. At ϕ=-90°:

$$BR = (2.1\pm0.3)\times10^{-3}$$

or

$$BR = \left(2.4^{+3.4}_{-2.0}\right)\times10^{-5}$$

*Toy MC is used to get BR from CLEOc data (not CLEO official results)!

$J/\psi,\ \psi',\ \psi'' \to \rho\pi$

- Partial width of ψ″→ρπ is larger than that of ψ′→ρπ!
- hard to understand if ψ″ is pure 1D state, also hard if ψ″ is 2S and 1D mixture.

$$\Gamma(J/\psi \to \rho\pi) \approx 2.1\, keV$$

$$\Gamma(\psi' \to \rho\pi) \approx 0.014\, keV$$

$$\Gamma(\psi'' \to \rho\pi) \approx 50\, keV$$

or

$$\Gamma(\psi'' \to \rho\pi) \approx 0.6\, keV$$

$$\frac{B(\psi' \to \rho\pi)}{B(J/\psi \to \rho\pi)} = (0.20 \pm 0.06)\%$$

$$Q_e = 12.7\%$$

$$\frac{B(\psi'' \to \rho\pi)}{B(J/\psi \to \rho\pi)} = (9.0 \pm 1.6)\%$$

or

$$\frac{B(\psi'' \to \rho\pi)}{B(J/\psi \to \rho\pi)} = (0.10^{+0.15}_{-0.09})\%$$

$$Q_e' = 0.019\%$$

In S-D mixing model, using mixing angle θ=12°, using Rosner's assumption (12% rule for 1S and 2S), one predicts $Q'_{\rho\pi}$ =(2.7-5.3)% !

φ≠-90° or imperfect model?

Other ψ' decay modes

- $\psi' \to \rho\,\pi$ is suppressed by a factor of 60!
- $\psi'' \to \rho\,\pi$ is enhanced!
- Other modes may supply more information!

We list a few new measurements
using BESII/CLEOc data ...

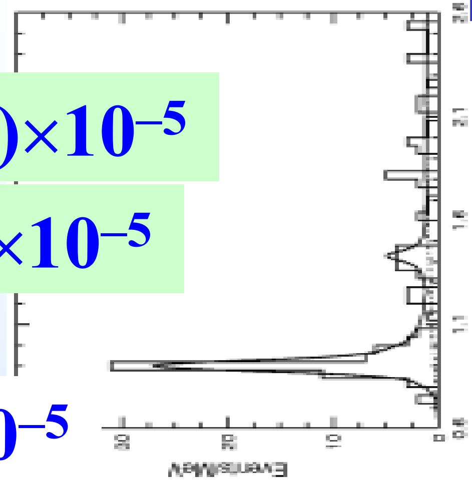
$\psi' \to VP$

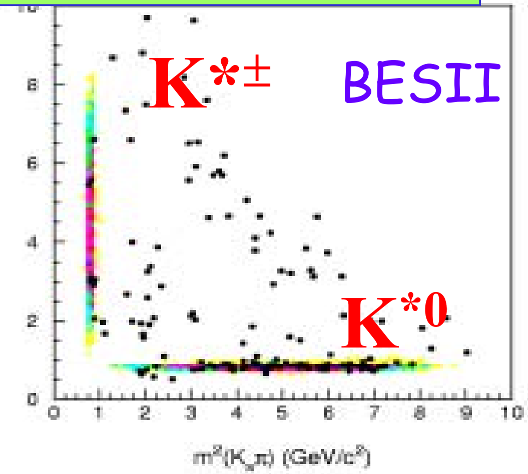
BESII : PLB614, 37 (2005)

$K^*(892)K$+c.c.

$Br_0=(13.3\pm2.7\pm1.7)\times10^{-5}$

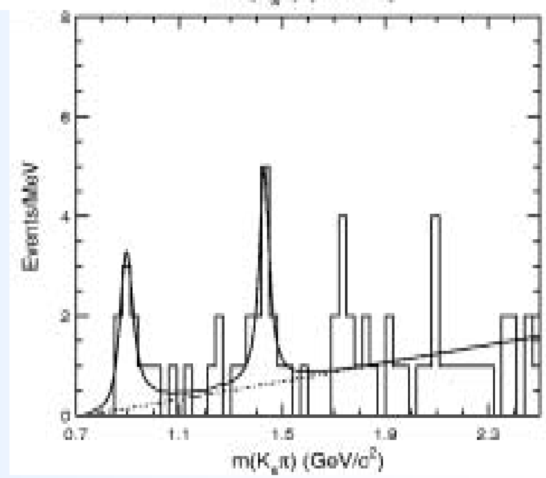
$Br_\pm=(2.9\pm1.7\pm0.4)\times10^{-5}$

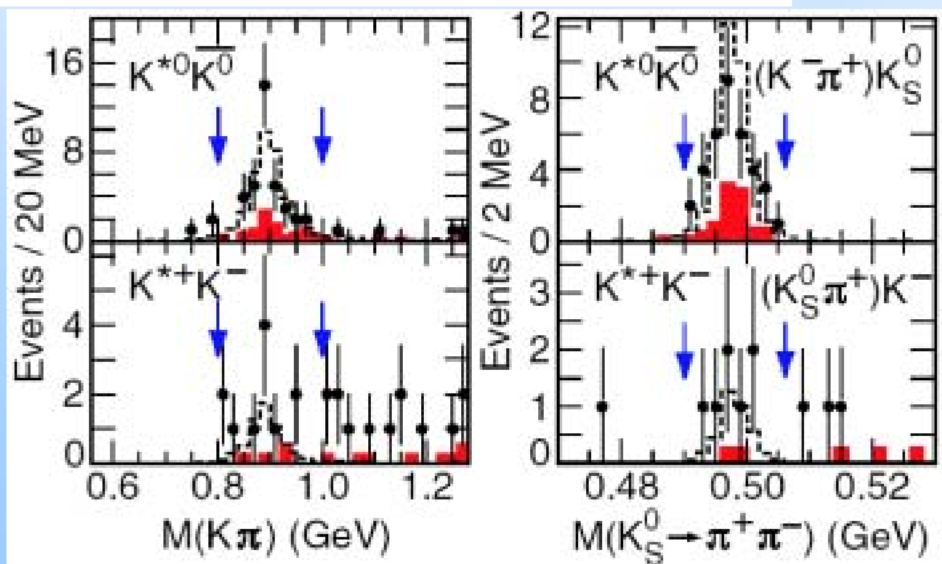




$Br_0=(9.2\pm2.7\pm0.9)\times10^{-5}$

$Br_\pm=(1.3\pm1.0\pm0.3)\times10^{-5}$





CLEOc: PRL94, 012005 (2005)

Good agreement!

Large Isospin violation!

Both modes suppressed!

ψ'→ VP

Mode	$\mathcal{B}$ (10^{-6})
$\pi^+\pi^-\pi^0$	$188^{+16}_{-15} \pm 28$
$\rho\pi$	$24^{+8}_{-7} \pm 2$
$\rho^0\pi^0$	$9^{+5}_{-4} \pm 1$
$\rho^+\pi^-$	$15^{+7}_{-6} \pm 2$
$\omega\pi$	$25^{+12}_{-10} \pm 2$
$\phi\pi$	–
$\rho\eta$	$30^{+11}_{-9} \pm 2$
$\omega\eta$	–
$\phi\eta$	$20^{+15}_{-11} \pm 4$
$K^{*0}\bar{K}^0$	$92^{+27}_{-22} \pm 9$
$K^{*+}K^-$	$13^{+10}_{-7} \pm 3$
$b_1\pi$	$642^{+58}_{-56} \pm 135$
$b_1^0\pi^0$	$235^{+47}_{-42} \pm 40$
$b_1^+\pi^-$	$418^{+43}_{-42} \pm 92$

h	$N^{\rm obs}$	ϵ (%)	$B(\psi(2S) \to\ ) \times 10^{-5}$
$\phi\pi^0$	<4.4	16.1	<0.40
$\phi\eta$	16.7 ± 5.6	18.9	$3.3 \pm 1.1 \pm 0.5$
$\phi\eta'(\eta' \to \gamma\pi^+\pi^-)$	5.8 ± 3.2	11.1	...
$\phi\eta'(\eta' \to \eta\pi^+\pi^-)$	2.6 ± 1.8	3.8	...
$\phi\eta'$ (combined)	8.4 ± 3.7	8.4	$3.1 \pm 1.4 \pm 0.7$
$\omega\eta$	<9.7	6.3	<3.1
$\omega\eta'(\eta' \to \gamma\pi^+\pi^-)$	4.2 ± 2.7	2.6	...
$\omega\eta'(\eta' \to \eta\pi^+\pi^-)$	$0.0^{+1.7}_{-0.0}$	1.8	...
$\omega\eta'$ (combined)	$4.2^{+3.2}_{-2.7}$	2.3	$3.2^{+2.4}_{-2.0} \pm 0.7$

State	$B_{\psi(2S)\to VP}(\times 10^{-5})$
$\omega\pi^0$	$1.87^{+0.68}_{-0.62} \pm 0.28$
$\rho\eta$	$1.78^{+0.67}_{-0.62} \pm 0.17$
$\rho\eta'$	$1.87^{+1.64}_{-1.11} \pm 0.33$

Some modes are suppressed, while some others obey the 12% rule!

CLEOc: PRL94, 012005 (2005)

BESII : PRD70, 112007 (2004)
PRD70, 112003 (2004)

Multi-body ψ′ decays

Mode h	$\mathcal{B}(\psi(2S)\to h)$ (units of 10^{-4})	$\mathcal{B}$ (PDG) (units of 10^{-4})	Q_h (%)
$2(\pi^+\pi^-)$	$2.2 \pm 0.2 \pm 0.2$	4.50 ± 1.00	5.55 ± 1.5
$\rho\pi^+\pi^-$	$2.0 \pm 0.2 \pm 0.4$	4.20 ± 1.50	—
$2(\pi^+\pi^-)\pi^0$	$26.1 \pm 0.7 \pm 3.0$	30.00 ± 8.00	7.76 ± 1.10
$\eta\pi^+\pi^-$	<1.6	—	—
$\omega\pi^+\pi^-$	$8.2 \pm 0.5 \pm 0.7$	4.80 ± 0.90	11.35 ± 1.94
$\eta 3\pi(\eta\to\gamma\gamma)$	$10.3 \pm 0.8 \pm 1.4$	—	—
$\eta 3\pi(\eta\to 3\pi)$	$8.1 \pm 1.4 \pm 1.6$	—	—
$\eta 3\pi$	$9.5 \pm 0.7 \pm 1.5$	—	—
$\eta' 3\pi$	$4.5 \pm 1.6 \pm 1.3$	—	—
$K^+K^-\pi^+\pi^-$	$7.1 \pm 0.3 \pm 0.4$	16.00 ± 4.00	9.85 ± 3.23
ρK^+K^-	$2.2 \pm 0.2 \pm 0.4$	—	—
$\phi\pi^+\pi^-$	$0.9 \pm 0.2 \pm 0.1$	1.50 ± 0.28	11.07 ± 3.30
$K^+K^-\pi^+\pi^-\pi^0$	$12.7 \pm 0.5 \pm 1.0$	—	10.59 ± 2.81
ηK^+K^-	<1.3	—	—
ωK^+K^-	$1.9 \pm 0.3 \pm 0.3$	1.50 ± 0.40	10.19 ± 2.96
$2(K^+K^-)$	$0.6 \pm 0.1 \pm 0.1$	—	6.71 ± 2.74
ϕK^+K^-	$0.8 \pm 0.2 \pm 0.1$	0.60 ± 0.22	5.14 ± 1.53
$2(K^+K^-)\pi^0$	$1.1 \pm 0.2 \pm 0.2$	—	—
$p\bar{p}\pi^+\pi^-$	$5.9 \pm 0.2 \pm 0.4$	8.00 ± 2.00	9.90 ± 1.16
$\rho p\bar{p}$	$0.5 \pm 0.1 \pm 0.2$	—	—
$p\bar{p}\pi^+\pi^-\pi^0$	$7.3 \pm 0.4 \pm 0.6$	—	18.70 ± 5.80
$\eta p\bar{p}$	$0.8 \pm 0.3 \pm 0.3$	—	3.80 ± 2.09
$\omega p\bar{p}$	$0.6 \pm 0.2 \pm 0.2$	0.80 ± 0.32	4.69 ± 2.22
$p\bar{p}K^+K^-$	$0.3 \pm 0.1 \pm 0.0$	—	—
$\phi p\bar{p}$	<0.24	<0.26	—
$\Lambda\bar{\Lambda}\pi^+\pi^-$	$2.8 \pm 0.4 \pm 0.5$	—	—
$\Lambda\bar{p}K^+$	$1.0 \pm 0.1 \pm 0.1$	—	10.92 ± 2.93
$\Lambda\bar{p}K^+\pi$			

CLEOc: PRL95, 062001 (2005)

BESII: PRD71, 072006 (2005)

$$Q_{p\bar{p}\pi^0} = \frac{B(\psi'\to p\bar{p}\pi^0)}{B(J/\psi\to p\bar{p}\pi^0)} = \frac{(13.2\pm1.0\pm1.5)\times10^{-5}}{(1.09\pm0.09)\times10^{-3}} = (12.1\pm1.9)\%,$$

$$Q_{p\bar{p}\eta} = \frac{B(\psi'\to p\bar{p}\eta)}{B(J/\psi\to p\bar{p}\eta)} = \frac{(5.8\pm1.1\pm0.7)\times10^{-5}}{(2.09\pm0.18)\times10^{-3}} = (2.8\pm0.7)\%.$$

BESII, preliminary

Channel	$B_{\psi(2S)\to h}(10^{-4})$	$B_{J/\psi\to h}(10^{-4})$	$Q_h(\%)$
$K^+K^-\pi^+\pi^-\pi^0$	12.4 ± 1.8	120 ± 28 [10]	10.3 ± 2.9
ωK^+K^-	2.38 ± 0.47	16.8 ± 2.1 [17]	14.2 ± 3.4
$f_0(1710)\to\omega K^+K^-$	0.59 ± 0.22	6.6 ± 1.3 [17]	8.9 ± 3.8

CLEOc preliminary: hep-ex/0505057

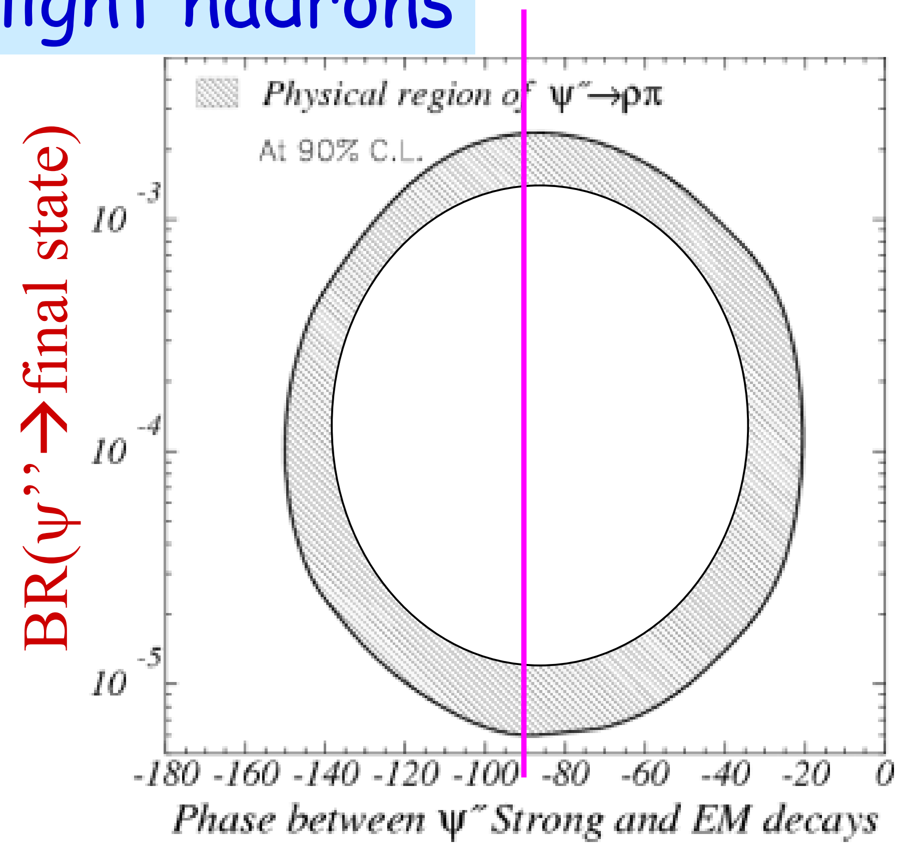
Modes	$B(10^{-4})$	Q(%)
$p\bar{p}$	$2.87\pm0.12\pm0.15$	13.6 ± 1.1
$\Lambda\bar{\Lambda}$	$3.28\pm0.23\pm0.25$	25.2 ± 3.5
$\Sigma^+\overline{\Sigma^+}$	$2.57\pm0.44\pm0.68$	-
$\Sigma^0\overline{\Sigma^0}$	$2.63\pm0.35\pm0.21$	20.7 ± 4.2
$\Xi^-\overline{\Xi^-}$	$2.38\pm0.30\pm0.21$	13.2 ± 2.2
$\Xi^0\overline{\Xi^0}$	$2.75\pm0.64\pm0.61$	
$\Xi^{*0}\overline{\Xi^{*0}}$	$0.72^{+1.48}_{-0.62}\pm0.10$ (<3.2 @90 CL)	-
$\Omega^-\overline{\Omega^-}$	$0.70^{+0.55}_{-0.33}\pm0.10$ (<1.6 @90 CL)	-

Some modes are suppressed, some are enhanced, while some others obey the 12% rule!

Search for ψ'' decays to light hadrons

CLEOc preliminary: LP2005-439

Channel	$\sigma^{3.67\text{GeV}}$ [pb]	$\sigma^{3.77\text{GeV}}$ [pb]
$\pi^+\pi^-\pi^0$	$13.1^{+1.9}_{-1.7} \pm 2.1$	$7.4 \pm 0.4 \pm 1.2$
$\rho^0\pi^0$	$3.1^{+1.0}_{-0.8} \pm 0.4$	$1.3 \pm 0.2 \pm 0.2$
$\rho^+\pi^-$	$4.8^{+1.5}_{-1.2} \pm 0.5$	$3.2 \pm 0.3 \pm 0.3$
$\rho\pi$	$8.0^{+1.7}_{-1.4} \pm 0.9$	$4.4 \pm 0.3 \pm 0.5$
$\omega\pi^0$	$14.5^{+2.6}_{-2.3} \pm 1.5$	$14.8 \pm 0.6 \pm 1.5$
$\phi\pi^0$	< 2.2	< 0.2
$\rho\eta$	$9.6^{+2.1}_{-1.8} \pm 1.0$	$10.4 \pm 0.5 \pm 1.0$
$\omega\eta$	$2.3^{+1.8}_{-1.1} \pm 0.5$	< 0.8
$\phi\eta$	< 5.0	$4.5 \pm 0.5 \pm 0.5$
$\rho\eta'$	$2.0^{+4.5}_{-1.6} \pm 0.2$	$3.8^{+0.9}_{-0.8} \pm 0.5$
$\omega\eta'$	< 17.1	$0.6^{+0.7}_{-0.3} \pm 0.6$
$\phi\eta'$	< 12.6	< 5.2
$K^{*0}\overline{K^0}$	$23.5^{+4.6}_{-3.8} \pm 3.1$	$23.5 \pm 1.1 \pm 3.1$
$K^{*+}K^-$	< 3.5	< 0.6
$b_1^0\pi^0$	< 17.1	< 2.6
$b_1^+\pi^-$	$4.2^{+1.6}_{-1.3} \pm 0.6$	$4.7 \pm 0.4 \pm 0.6$
$b_1\pi$	$7.9^{+3.1}_{[illegible]} \pm 1.8$	$7.6 \pm 0.[illegible]$



Same operation as for ψ''→ρπ should done for all the modes to extract the BRs of ψ'' decays.

Some x-sections agree, some very different.

- ϕ=-90 degrees as in J/ψ and ψ' decays?
- Any way to choose one solution?

"12%" rule and "0.02%" rule

- $\psi' \to VP$ suppressed
- $\psi' \to PP$ enhanced
- $\psi' \to VT$ suppressed
- $\psi' \to B\underline{B}$ obey/enh
- Multi-body –obey/sup

Seems no obvious rule to categorize the suppressed, the enhanced, and the normal decay modes of J/ψ and ψ'.

The models developed for interpreting specific mode may hard to find solution for other (all) modes.

The ψ" decays into light hadrons may be large --- more data and more sophisticated analysis are needed to extract the branching fractions from the observed cross sections. Why D-wave decay width so large?

Model to explain J/ψ, ψ' and ψ'' decays naturally and simultaneously?

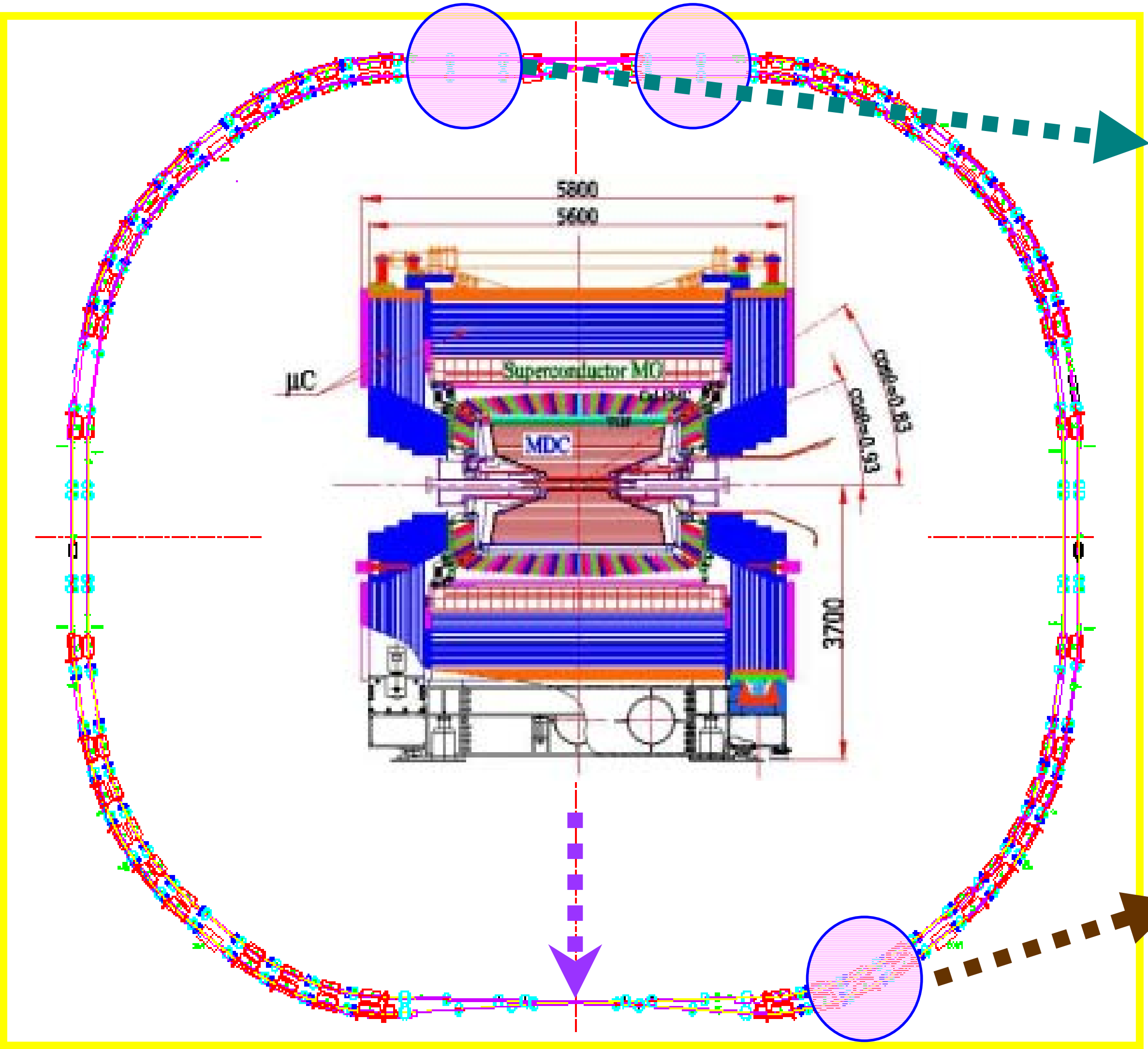
- S-D mixing in ψ' and ψ'' [J. L. Rosner, PRD64, 094002 (2001)]
- DD-bar reannihilation in ψ'' (J. L. Rosner, hep-ph/0405196)
- Four-quark component in ψ'' [M. Voloshin, PRD71, 114003 (2005)]
- Survival cc-bar in ψ' (P. Artoisenet et al., hep-ph/0506325)
- Other model(s)?

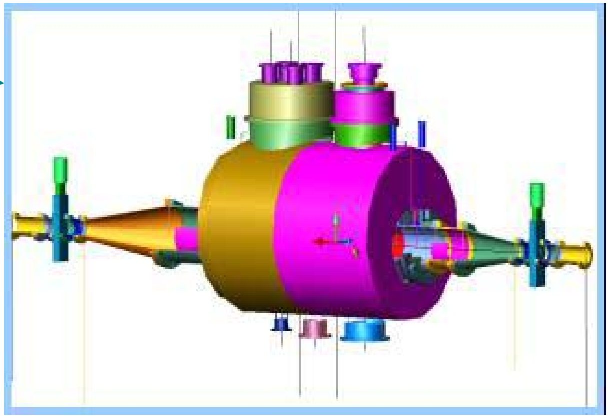
I did not cover D physics at BES, since the data sample is small and the detector is poorer than CLEOc --- we are working to have a modern detector (as well as a modern accelerator) for D physics, as well as for the physics I have just talked about, that is BESIII.

BESIII status

- BEPCII design
- BESIII detector status
- Schedule

BEPCII: a high luminosity double-ring collider





BEPCII luminosity

DR: multi-bunch k_{bmax}~400, k_b=1 ➔ 93

Choose large ε_x & optimum param.: I_b=9.8mA, ξ_y=0.04

$$L(\mathrm{cm}^{-2}\mathrm{s}^{-1}) = 2.17 \times 10^{34}(1+R)\xi_y \frac{E(GeV)k_b I_b(A)}{\beta_y^*(cm)}$$

Micro-β: β_y^* =5cm ➔ 1.5 cm
SC insertion quads

Reduce impedance +SC RF
σ_z =5cm ➔ <1.5cm

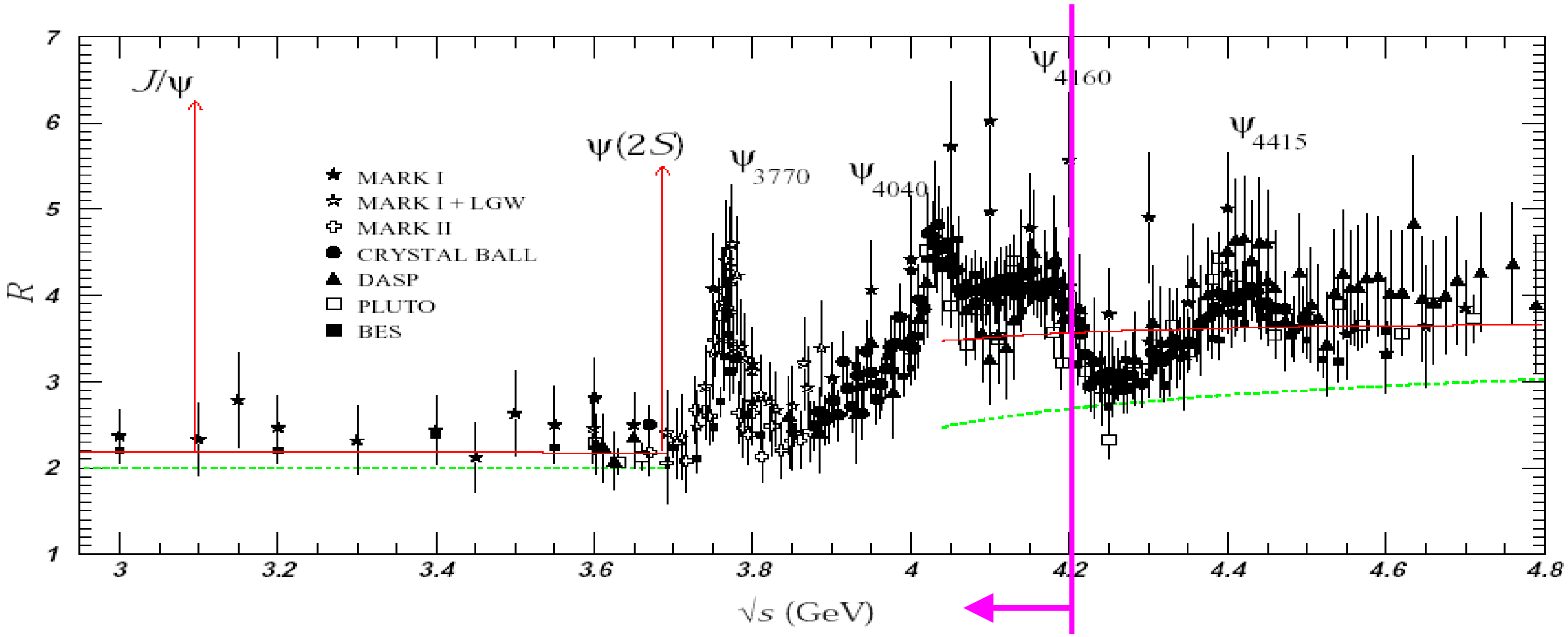
$(L_{BEPCII}/ L_{BEPC})_{D.R.}$=(5.5/1.5) ×93 × 9.8/35=96

$L_{BEPC}=1.0\times10^{31}$ cm^{-2}s^{-1} ➔ L_{BEPCII} =1×10^{33} cm^{-2}s^{-1}

Main Parameters of BEPCII

Parameters	Unit	Collision	SR
Operation energy (E)	GeV	1.0–2.1	2.5
Injection energy (E_{inj})	GeV	1.55–1.89	1.89
Circumference (C)	m	237.53	241.13
β^*-function at IP (β_x^*/β_y^*)	cm	100/1.5	-
Tunes ($\nu_x/\nu_y/\nu_s$)		6.53/7.58/0.034	8.28/5.18/0.035
Hor. natural emittance (ε_{x0})	mm·mr	0.14 @1.89 GeV	~0.10
Damping time ($\tau_x/\tau_y/\tau_e$)		25/25/12.5 @1.89 GeV	12/12/6
RF frequency (f_{rf})	MHz	499.8	499.8
RF voltage per ring (V_{rf})	MV	1.5	3.0
Bunch number (N_b)		93	multi
Bunch spacing	m	2.4	0.6
Beam current	mA	910 @1.89 GeV	250
Bunch length (cm) σ_l	cm	~1.5	-
Crossing angle	mrad	11×2	-
beam-beam param. ξ_y		0.04	-
Beam lifetime	hrs.	2.7	>10
luminosity@1.89 GeV	$10^{31}cm^{-2}s^{-1}$	100	-

Charmonia Productions at BESIII



Limited by existing tunnel

Ecm energy spread:

$$\Delta = 2.73\sqrt{2}E_b^2 \times 10^{-4}$$

Ecm=3.097 GeV

Δ=0.93 MeV

Ecm=3.686 GeV

Δ=1.3 MeV

Important for narrow resonance like J/ψ or ψ'.

Events Productions at BESIII

Physics	Ecm	Peak Lum. ($10^{33}cm^{-2}s^{-1}$)	Cross Sec.(nb)	Events / year
J/ψ	3.097	0.6	3400	10×10^9
$\psi(2S)$	3.686	1.0	640	3.2×10^9
$\psi(3770)$	3.770	1.0	7.4	37×10^6
$\psi(4040)$	4.040	0.6	9.2	28×10^6
$\psi(4160)$	4.160	0.6	6.2	19×10^6
τ	3.670	1.0	2.4	12×10^6
DDbar	3.770	1.0	6	30×10^6
D_s	4.030	0.6	0.3	0.9×10^6
D_s	4.140	0.6	0.6	1.8×10^6

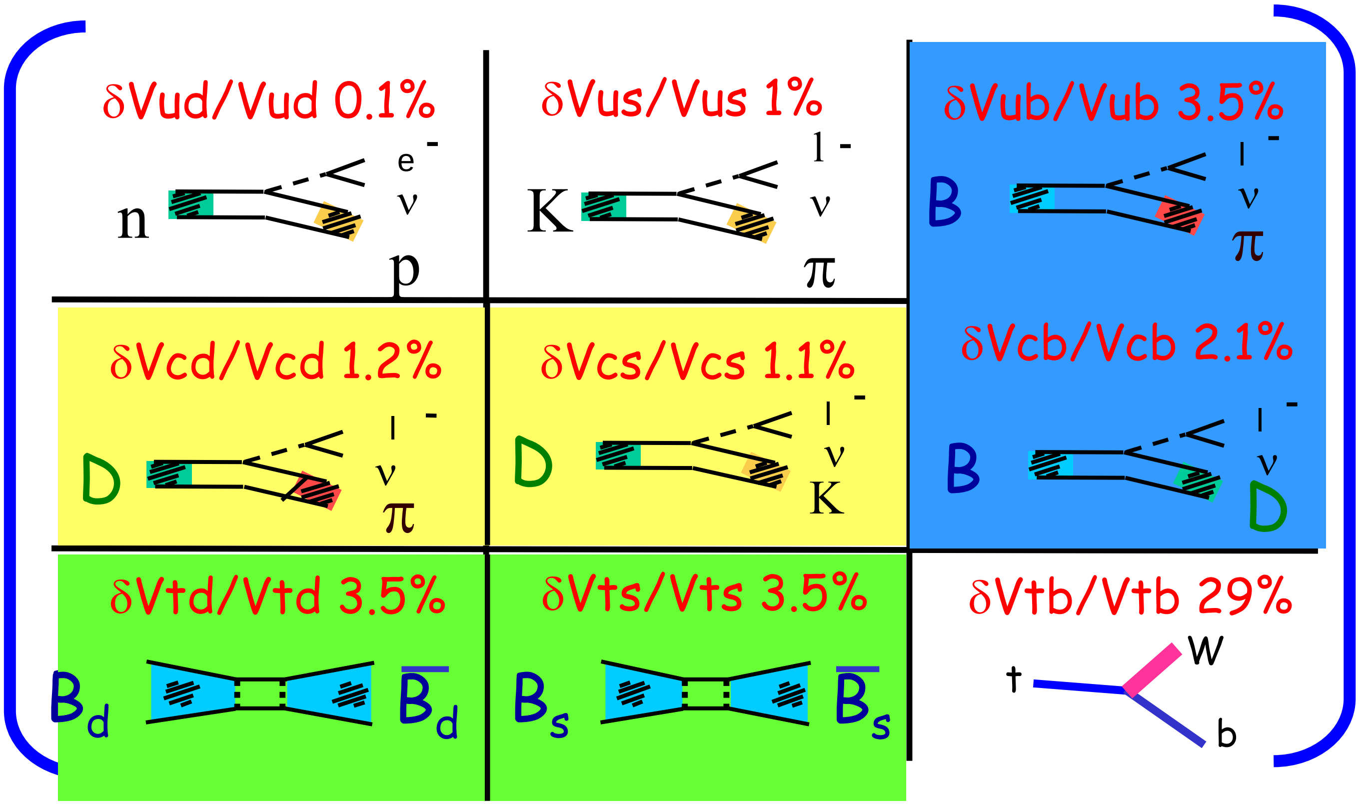
Average Lum. = 0.5 × Peak Lum; and 1 year = 10^7s data taking time

Huge numbers of J/ψ or ψ' in one year's running ---
So the accelerator and detector optimized for D physics!

BESIII physics goals

Systematic study of hadron spectroscopy (qqbar, glueball, hybrids, baryons), charmonium physics (ψ's and χ_c's, h_c, η_c, …), tau, R …

BESIII
One year
Lumi. $5fb^{-1}$
At $\psi(3770)$
peak



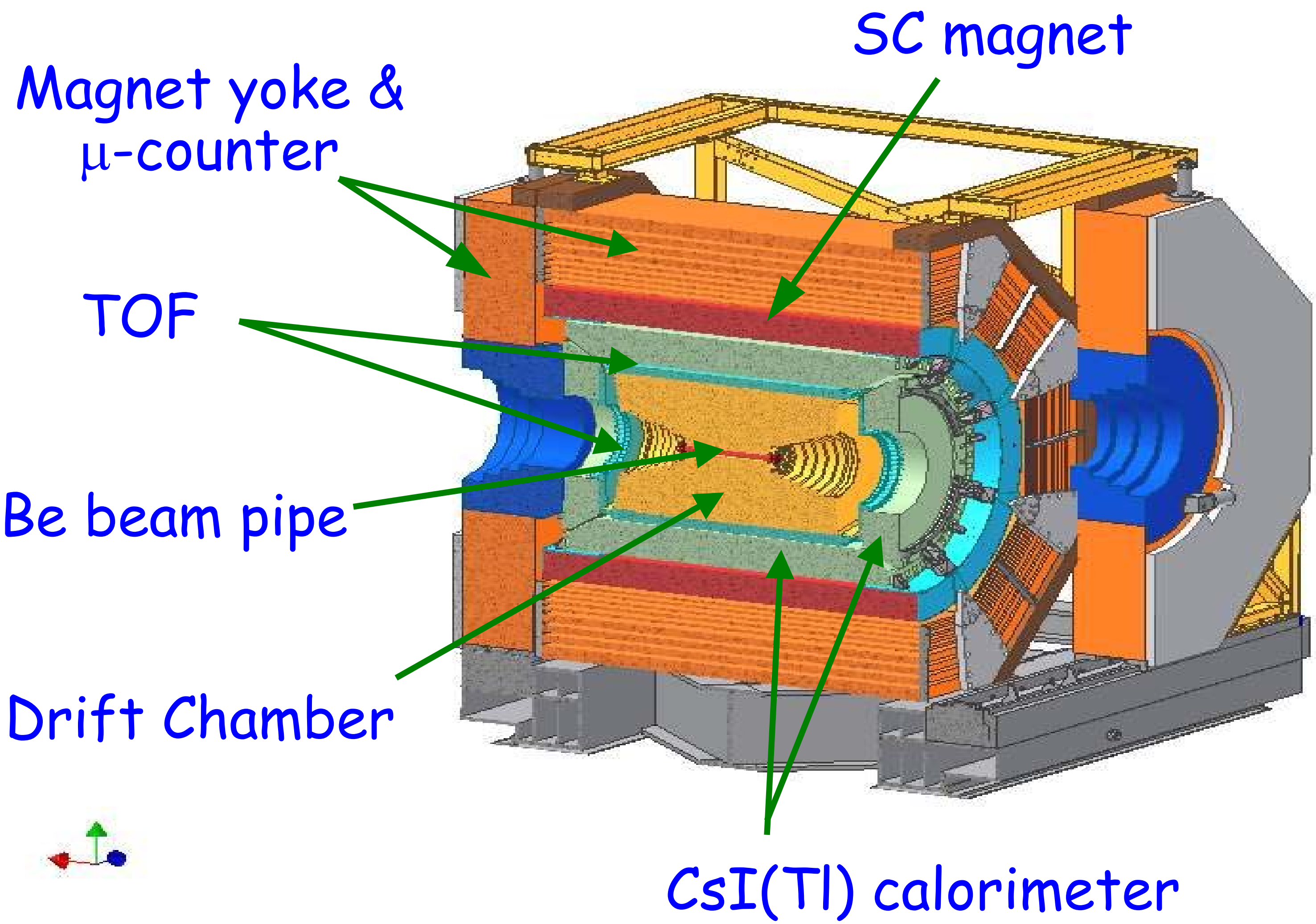
BESIII (yellow)

BESIII + Lattice QCD +B factories (blue)

BESIII + Lattice QCD +B factories + $p\bar{p}$ (green)

The Goal: Measure all CKM matrix elements and associated phases in order to over-constrain the unitary triangles.

The BESIII Detector



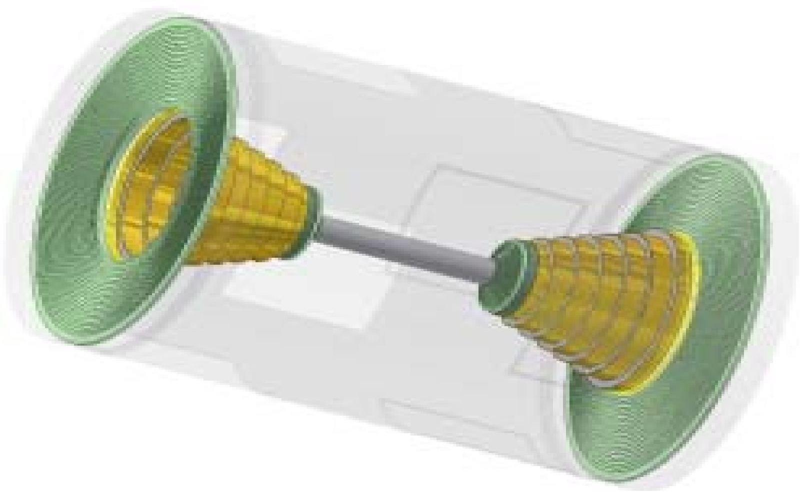
Main drift chamber

- Inner diameter: 63mm; Outer diameter: 810mm; length: 2400 mm, 40 layers
- End flange: 18 mm thick Al (6 steps)
- 7000 Signal wires: 25mm gold-plated tungsten (3% rhenium)
- 22000 Field wires: 110 mm gold-plated Aluminum
- Small cell: inner---6*6 mm^2, outer---8.2*8.2 mm^2
- Gas: He + C_3H_8 (60%/40%)

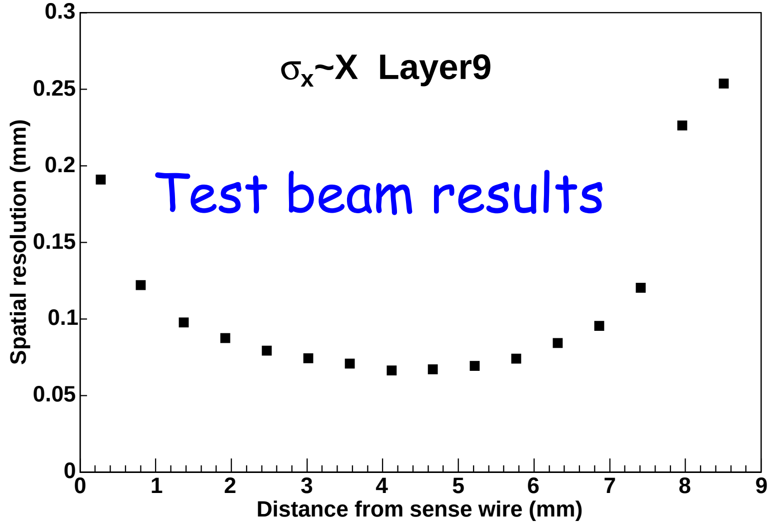
- Momentum resolution :

$$\frac{\sigma_{P_t}}{P_t} = 0.32\% \oplus 0.37\%$$

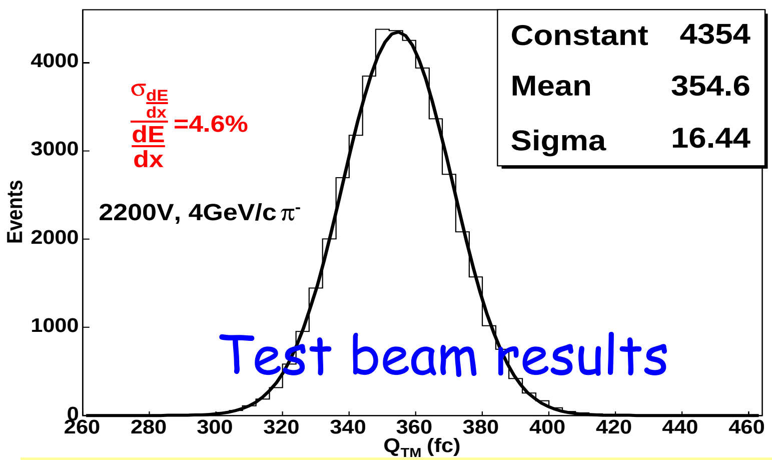
- dE/dx resolution : 6 ~ 7%



Main drift chamber



	Single wire reso.	dE/dx
BESIII	~120μm	6%
CLEOc:	~100μm	5.7%
Babar:	~110μm	6.2%
Belle:	~130μm	5.7%



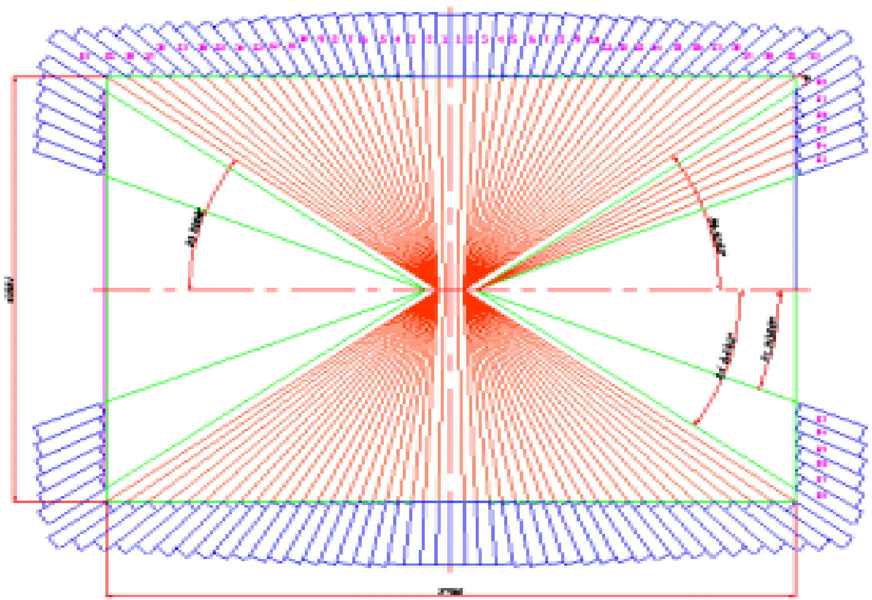
Whole mechanical structure of MDC have been assembled and delivered to IHEP, wiring started since Aug. 5, 2005, expect to be finished in Feb. 2006. Cosmic ray test Jun.-Jul. 2006.

CsI(Tl) crystal carlorimeter

- 6300 crystals, (5.2x5.2 – 6.4x6.4) x $28cm^3$
- PD readout, noise ~1100 ENC
- Energy resolution: 2.5%@1GeV
- Position resolution: 6mm@1GeV
- Tiled angle: θ~1-3°, ϕ~1.5°
- Minimum materials between crystals

Other detectors：

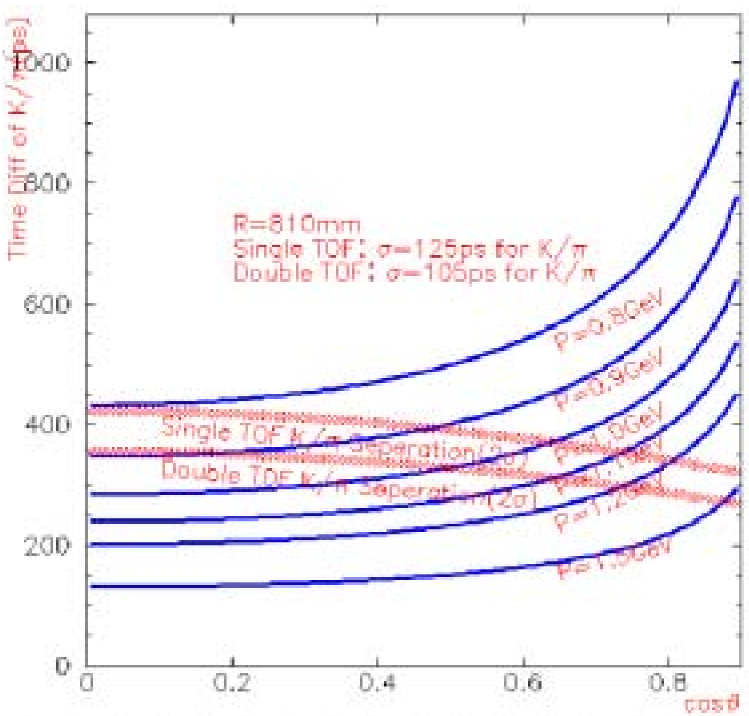
- –Babar: 2.67%@1GeV
- –BELLE: 2.2% @1GeV
- –CLEOc: 2.2%@1GeV

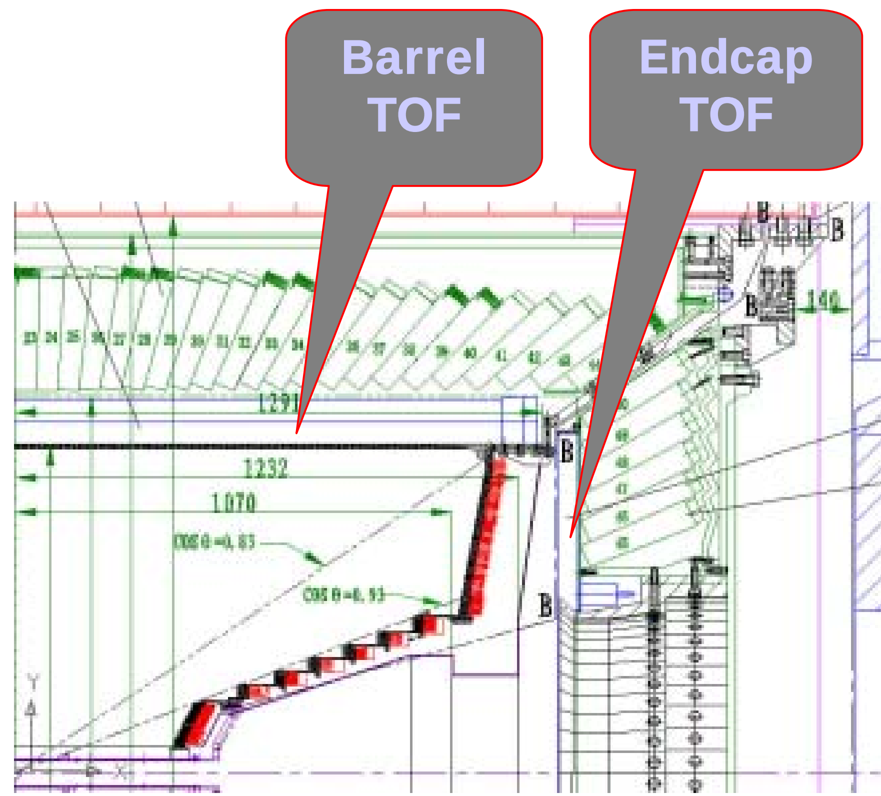


~60% crystals successfully delivered, 1/3 crystals tested and assembly underway.

PartID: double-layer TOF

- R=81-92.5cm, coverage: 82%
- 88/layer pieces scintillator, 2.320m long, 5cm thick
- Intrinsic time resolution 90ps/layer
- Time resolution 100-110ps/layer, 80-90ps double-layer





Super-conducting magnet

- Al stabilized NbTi/Cu conductor from Hitachi
- 1.0T, <5% non-uniformity
- 921 turns, 3150A @4.5K
- R = 1.475m, L=3.52m, cold mass 3.6t
- Thickness: 1.92X_0
- Inner-winding method

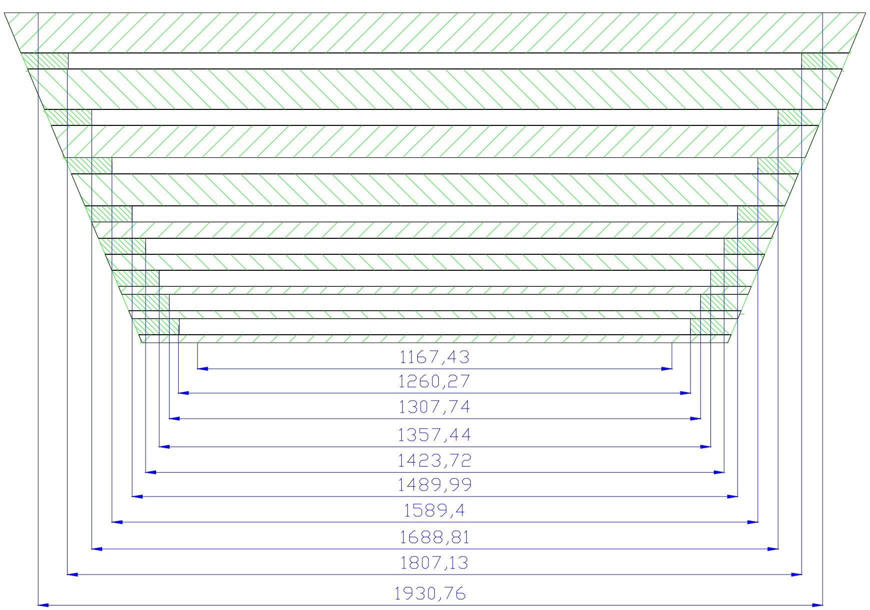
Coil wiring completed in June 2005, assembly finished. B-field measurement with iron yoke in one month.

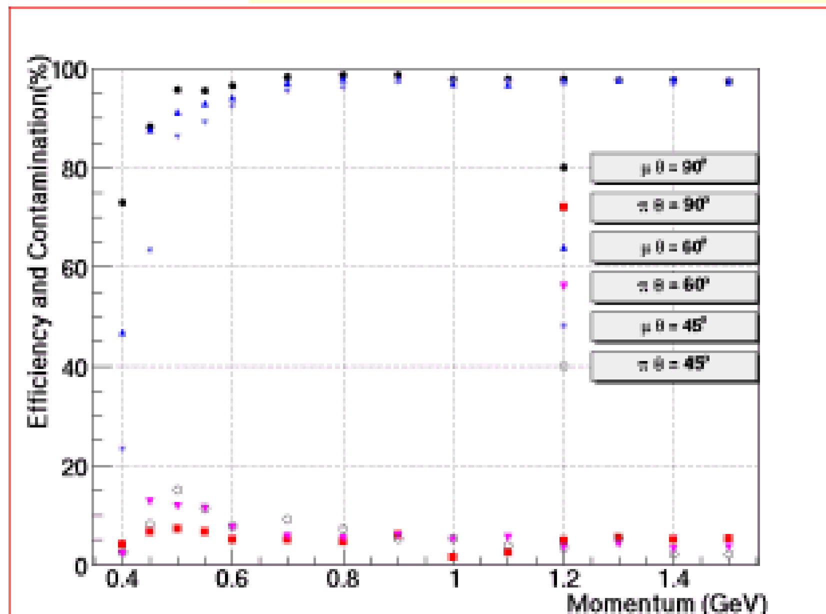
μ system: RPC

- 9 layers, 2000m², 7500-8000V
- Bakelite and glass, no linseed oil
- 4cm strips, 10000 channels
- Tens of prototypes (up to 1*0.6m²)
- Noise less than 0.2 Hz/cm²

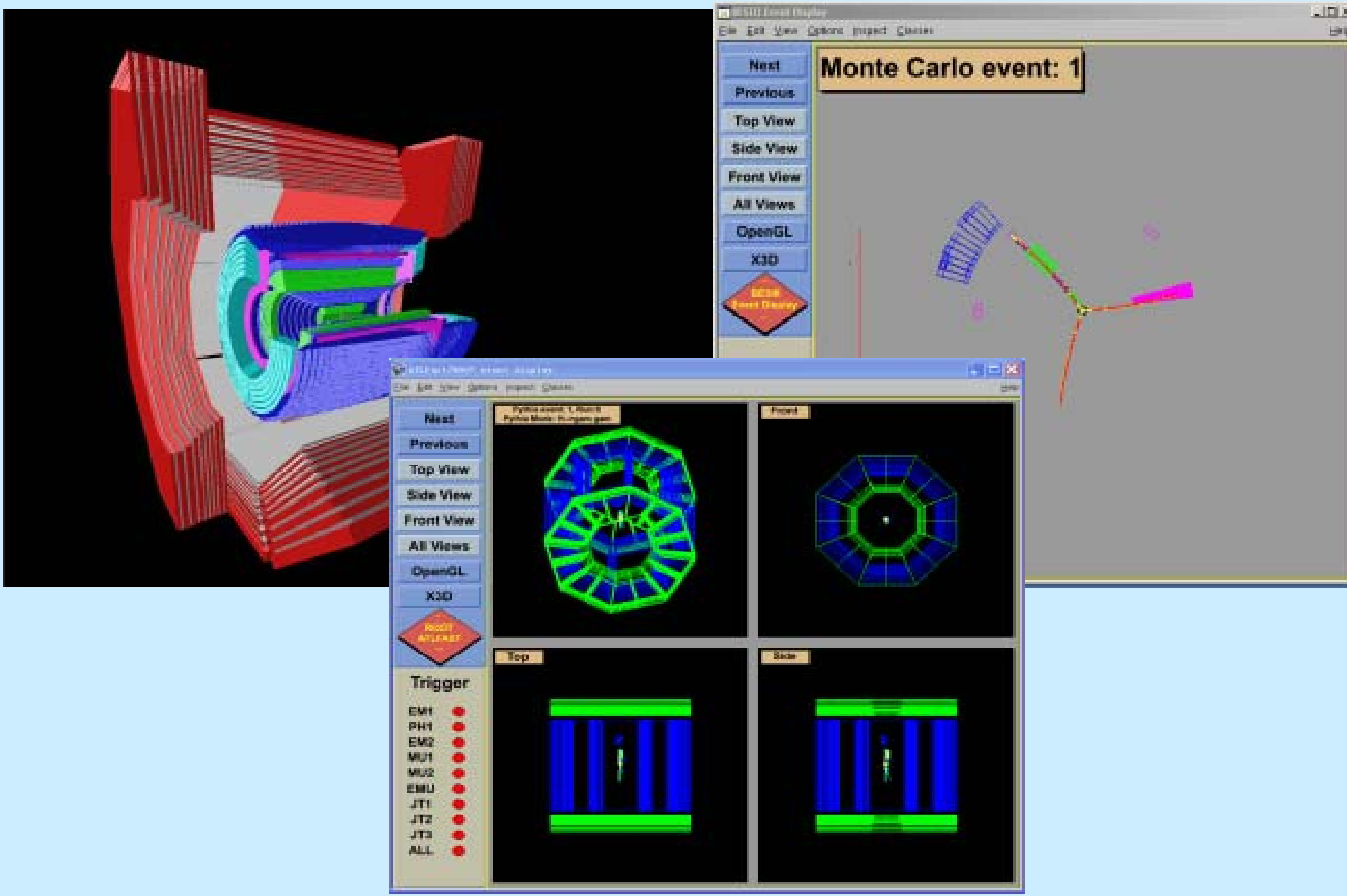
Known RPC quality and aging problems mainly related to the linseed oil

- Endcap completed
- Barrel in progress





Event Display



Project Schedule

- → June 2003 — R&D and prototype
- → May 2004 — BEPC run
- Jan. 2004 → Jun. 2006 — Construction
- May 2004 → Nov. 2004 — BESII dismounting/Linac upgrade
- Nov. 2004 → Jan. 2005 — Linac commissioning
- Jan. 2005 → Jun. 2005 — SR run
- Jul. 2005 → Apr. 2006 — Storage ring assembling
- Jan. 2006 → June 2006 — Commissioning of storage ring
- Dec. 15, 2006 — Move BESIII to beam-line
- Jan. 2007 → — Commissioning machine & detector
- Feb. 2007 → — Test run→physics run

<u>Very tight schedule</u>

Summary

- Lots of progress in hadron spectroscopy and charmonium physics study from BES.
- X(1835) observed in $J/\psi \to \gamma + (\eta' \pi\pi)$ decays, could be the same state observed in $J/\psi \to \gamma$ppbar, could be a baryonium. Need more information (J^{PC} etc.).
- Scalars are studied in J/ψ, ψ' and χ_{c0} decay. Parameters of σ and κ are given, other states are also measured in hadronic and radiative decays.
- Vector charmonia (J/ψ, ψ', and ψ'') hadronic decays are studied extensively and simultaneously to understand charmonium decay dynamics.
- "$\rho\pi$ puzzle" remains a puzzle, ψ'' charmless decays is observed and could be large.
- More data are needed (and expected) for further studies from BESIII.

谢谢！

Merci!

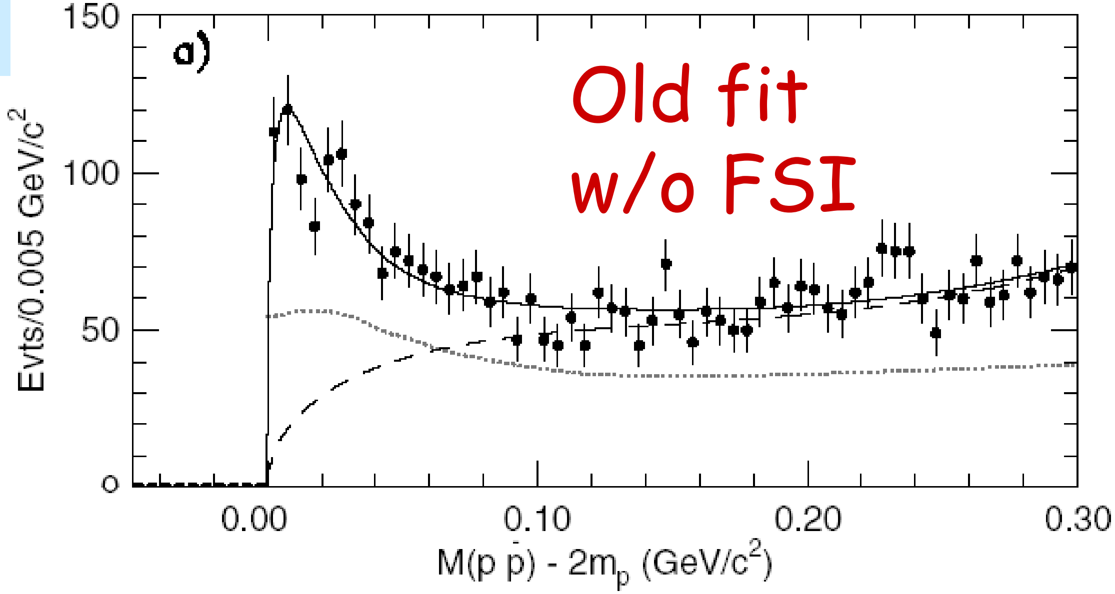
Thanks!

BES, PRL91, 022001(2003)

$$J/\psi \rightarrow \gamma p\bar{p}$$

$$M = 1859^{+3+5}_{-10-25}\ \mathrm{MeV/c^2}$$

$$\Gamma < 30\ \mathrm{MeV/c^2}$$



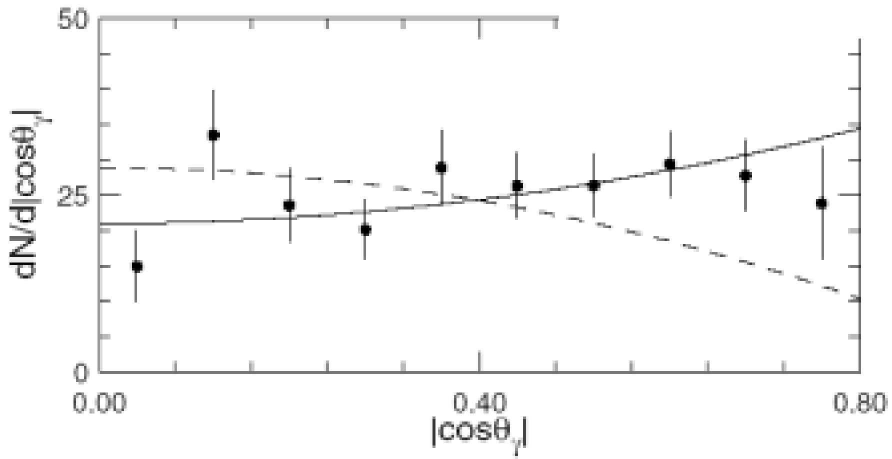
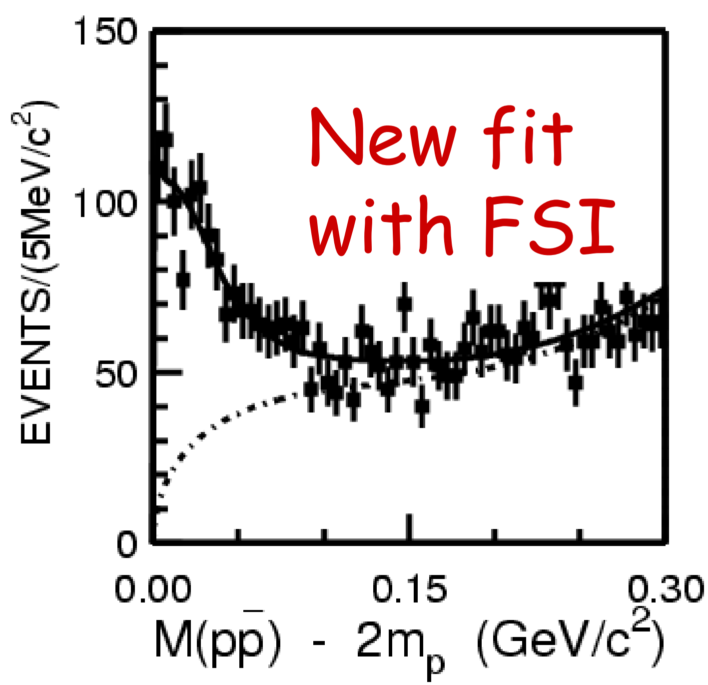


FIG. 4. The background-subtracted, acceptance-correct $|\cos\theta_\gamma|$ distribution for $J/\psi \rightarrow \gamma p\bar{p}$-enriched events w $M_{p\bar{p}} \leq 1.9\ \mathrm{GeV}/c^2$. The solid curve is a fit to a $1 + \cos^2$ shape for the region $|\cos\theta_\gamma| \leq 0.8$; the dashed curve is t result of a fit to $\sin^2\theta_\gamma$.



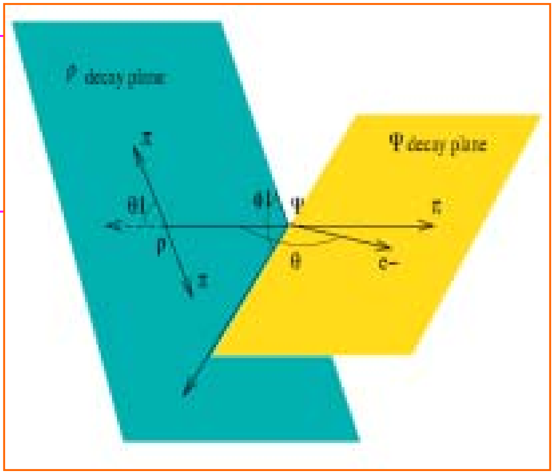
Comments on PWA

- Something may affect the results:
  - Resolution correction (finite momentum resolution)
  - Parametrization of the resonance (theoretical efforts)

    (When statistics increases, significant fake signals may be produced)
- A PWA fit should supply also
  - Goodness-of-fit (indicate how reliable is the fit)
    - Likelihood method (Toy MC simulation)
    - χ^2 method (1-dimension or multi-dimension DT/MC comparison)
  - Correlation between components
    - Mass/width/fraction are all correlated, only quoting diagonal error is not enough
    - Significance of the signal also depends on correlation

$\psi' \to \pi^+ \pi^- \pi^0$
PWA

$$\psi'(1^-) \to \rho(1^-) + \pi(0^-)$$
$$\hookrightarrow \pi(0^-) + \pi(0^-)$$



$$dI = \sum_{i=\pm 1} (|A_i|^2 + |C_i|^2) d(LIPS)$$

$$A_i = A_i^0(\pi^-, \pi^+) + A_i^+(\pi^+, \pi^0) + A_i^-(\pi^0, \pi^-)$$

$$A^c_{\pm 1} = B(m^2) \sin\theta_\pi (\cos\phi_\pi \pm i \cos\theta \sin\phi_\pi) e^{\pm i\phi}$$

$$B(m^2) = \frac{BW_{\rho(770)}(m^2) + \sum_j c_j e^{i\beta_j} BW_j(m^2)}{1 + \sum_j c_j}$$

C is incoherent background term

$$BW^{GS}_{\rho(M_\rho)}(m^2) = \frac{p_\rho \left(\frac{p_\pi(m^2)}{p_\pi(M_\rho^2)}\right) M_\rho^2 (1 + d \cdot \Gamma_\rho / M_\rho)}{M_\rho^2 - m^2 + f(m^2) - i m \Gamma_\rho(m^2)}$$

Gounaris-Sakurai's parametrization

S- and D-wave mixing

A prediction of ψ'' charmless decays
Wang, Mo and Yuan, PRD70, 114014(2004)

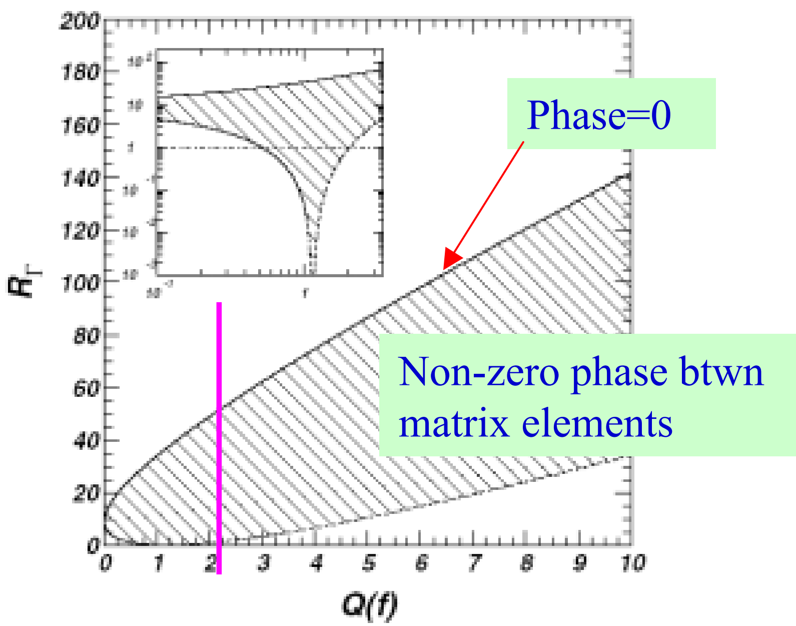
- $Q(f) < 1$ means the final state f is suppressed in ψ' decays relative to J/ψ;
- $Q(f) > 1$ means it is enhanced;
- $Q(f) = 1$ means it observes the 12% rule.

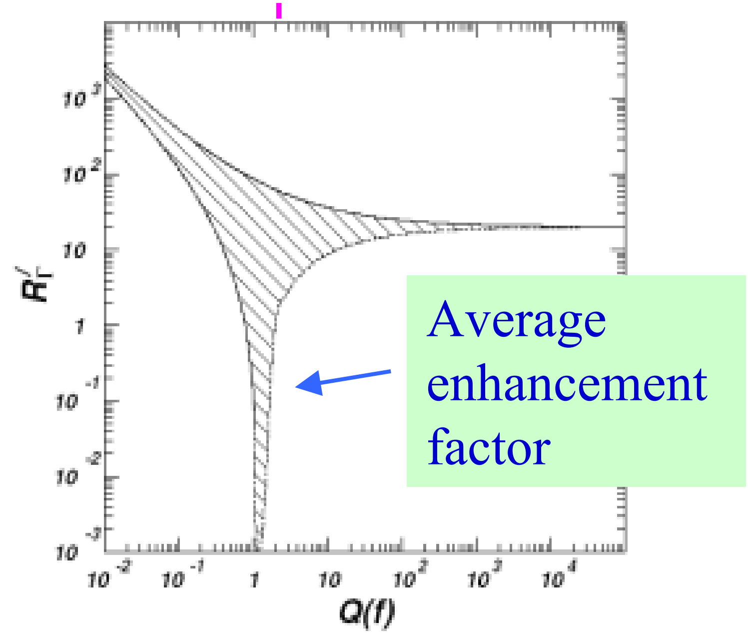
$B(\psi(2S) \to ggg)/B(J/\psi \to ggg) = 0.26 \pm 0.04$

$$Q(f) \equiv \frac{\Gamma(\psi' \to f)}{\Gamma(J/\psi \to f)} \frac{\Gamma(J/\psi \to e^+e^-)}{\Gamma(\psi' \to e^+e^-)}$$

$$R_\Gamma = \frac{\Gamma(\psi'' \to f)}{\Gamma(J/\psi \to f)}$$

$$R'_\Gamma = \frac{\Gamma(\psi' \to f)}{\Gamma(J/\psi \to f)}$$





Prediction on ψ(3770) charmless decay branching fraction: **≤16%** (or 3.8MeV)