Recent BES Results on $\Psi(2S)$ Decay

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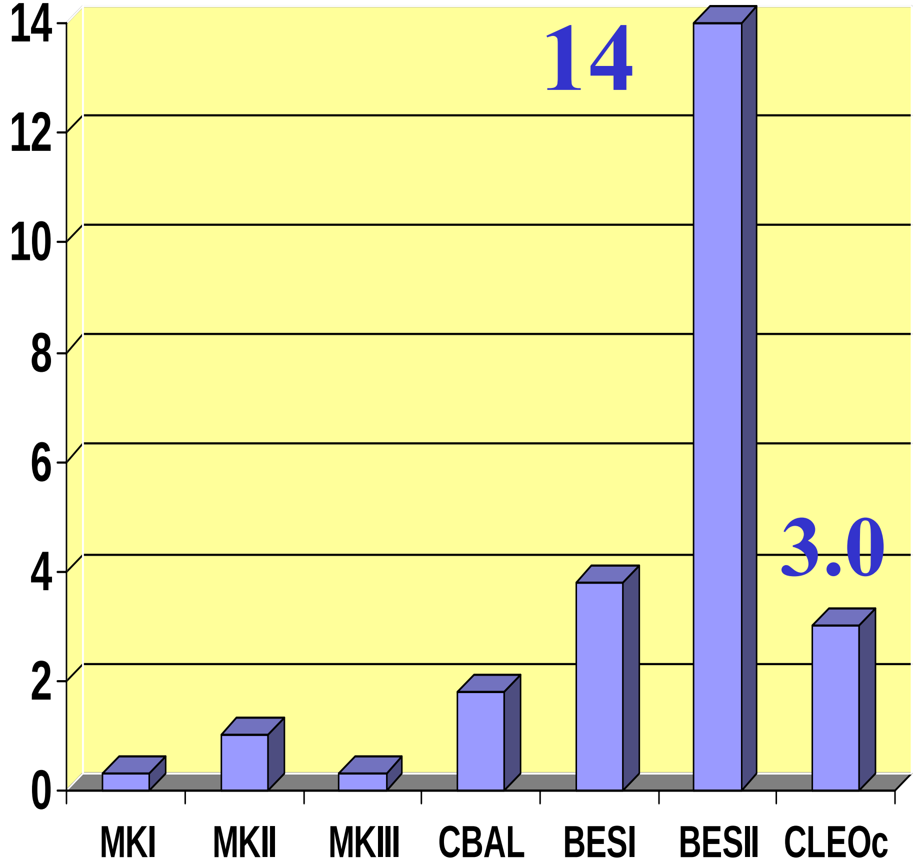
for the BES Collaboration

DAΦNE 2004: Physics at meson factories

7-11 June 2004 - Laboratori Nazionali di Frascati - Italy

14 M ψ' events



01.11-02.3

- **6.4pb^{-1}** *ψ' con. data @ 3.65 GeV*
- **58M** *J/ψ events @ 3.10 GeV*
- **27pb^{-1}** *ψ'' data @ 3.773 GeV*

- $\psi' \to$ V P
- $\psi' \to$ V T
- $\psi' \to$ P P

(ψ', J/ $\psi \to K^0_S K^0_L$)

- $\psi' \to J/\psi$-contained

12% rule and "ρπ puzzle"

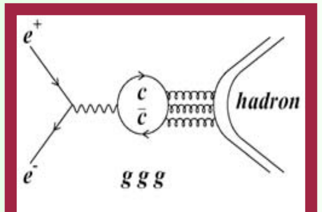
- 12% rule

[the relation between J/ ψ and ψ']

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

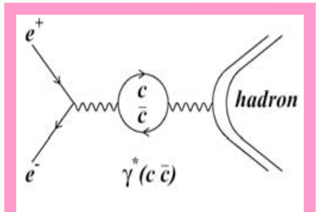
- Violation was revealed by MARK-II , confirmed by BES at higher sensitivity;
- Provide new clues concerning the dynamics of charmonium decay .

The Relative Phase



(a) three gluon process

φ ↔



(b) one photon process

J/ψ Decays:

1. AP : 90 ° — M. Suzuki, PRD63, 054021 (2001)
2. VP : (106 ±10) ° — J. Jousset et al., PRD41, 1389 (1990); D. Coffman et al., PRD38, 2695 (1988); N. N. Achasov, talk at Hadron2001
3. PP : (90 ±10) ° — M. Suzuki, PRD60, 051501 (1999)
4. VV : (138 ±37) ° — L. Köpke and N. Wermes, Phys. Rep. 74, 67 (1989)
5. $N\bar{N}$: (89 ±15) ° — R. Baldini et al., PLB444, 111 (1998)

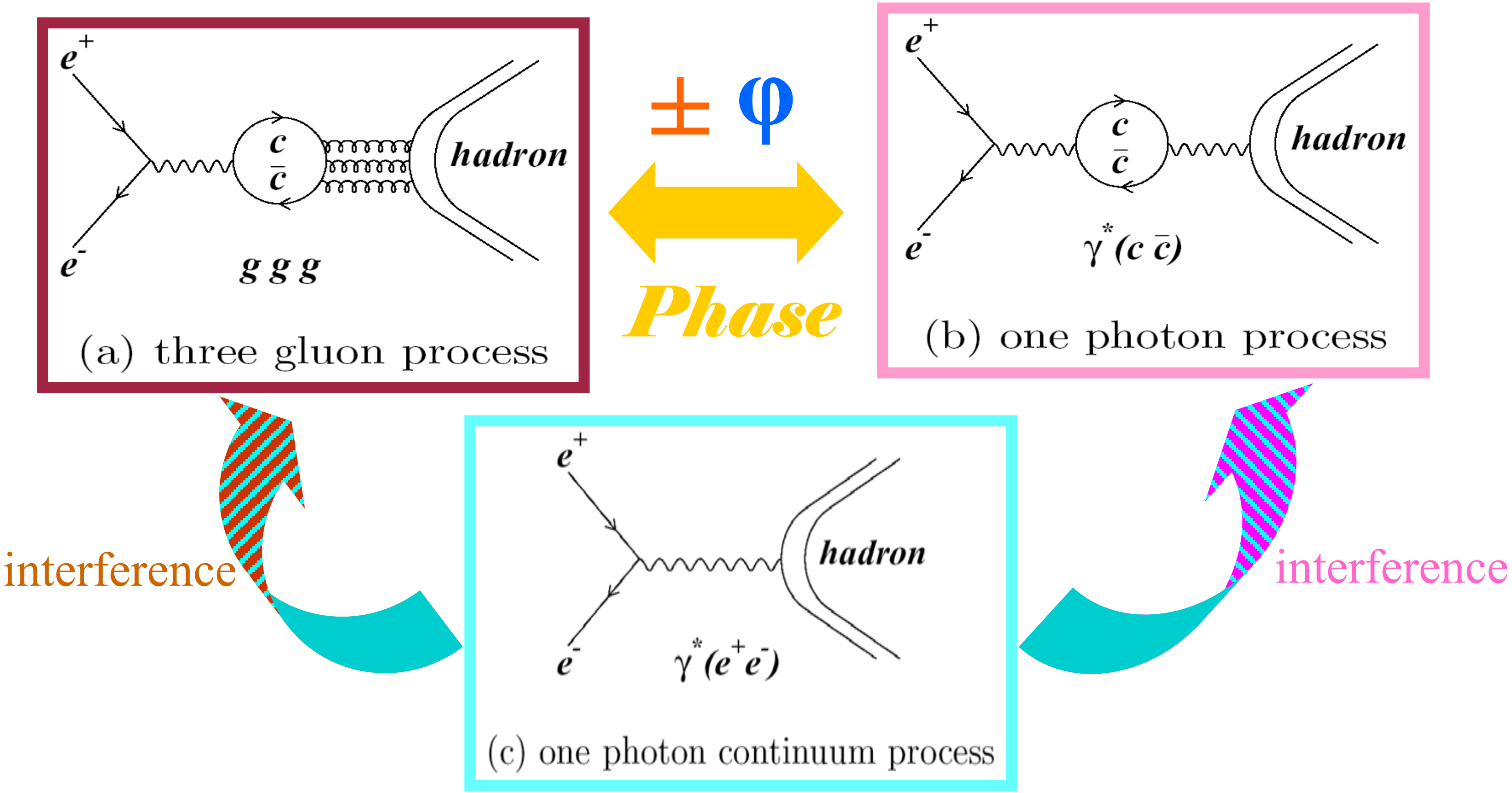
} Large | phase | ~ 90°

ψ' Decays:

1. VP : φ = - 90 ° or 180 ° — P. Wang et al. , PRD69, 057502 (2004)
2. PP : φ = (- 82 ±29)° or (+121 ±27)° — J. Z. Bai et al. , PRL92, 052001 (2004)

} Large phase ~ – 90°

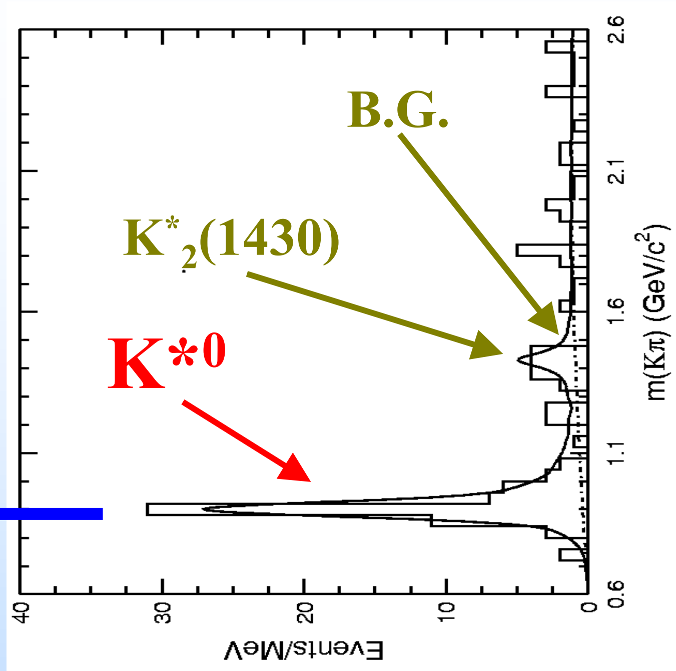
The phase study in e^+e^- experiment

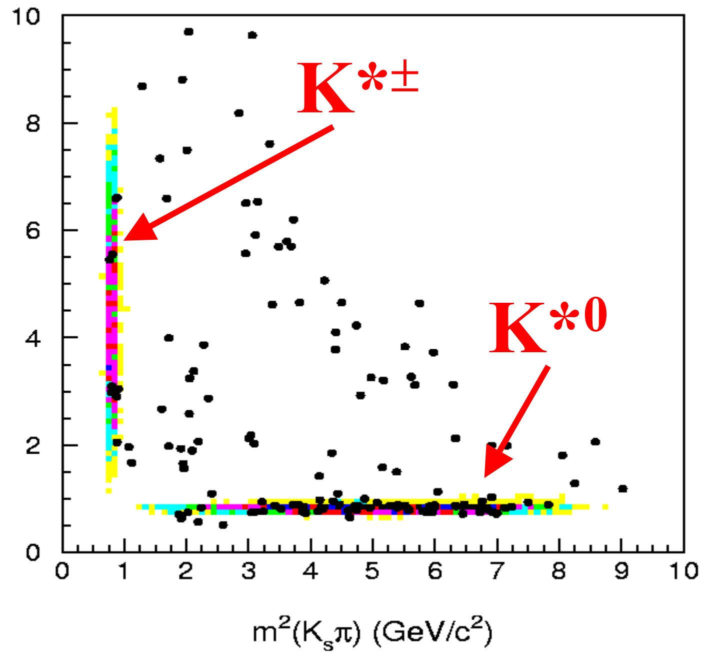


Take the continuum contribution and its interference effect into consideration , we could determine not only the ***magnitude*** but also the ***sign*** of the phase. Furthermore, the cont. contr. and its int. effect will exert obvious influence on BR. measurement.

$\psi' \rightarrow VP$

$K^*(892)\bar{K}$ + *c.c.*



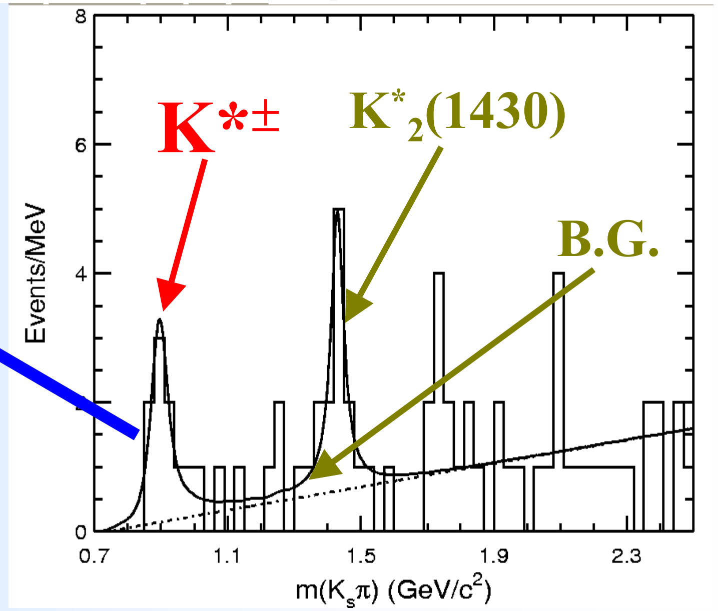


65.6±9.0
Evt. 11σ

$Br_0(15.0 \pm 2.1 \pm 1.7) \times 10^{-5}$

$Br_\pm(2.9 \pm 1.3 \pm 0.4) \times 10^{-5}$

9.6±4.2
Evt. 3.5σ



WITHOUT CONSIERATION OF CONTINUUM CONTRIBUTION !

$\psi' \to VP$

$K^*(892)\mathbb{K}$ +*c.c.*

$K^{*0}\,\mathbb{K}^0$: $g(1-s_g)$ +e

$K^{*\pm}K^{\mp}$: $g(1-s_g)$ −2 e

Phys. Rep. 174(1989) 67

$\sigma(K^{*+}K^{-}$+c.c.) : (20.9 ±9.1 ±2.3) pb

$\sigma(K^{*0}\mathbb{K}^0$ +c.c.) : (107 ±15 ±12) pb

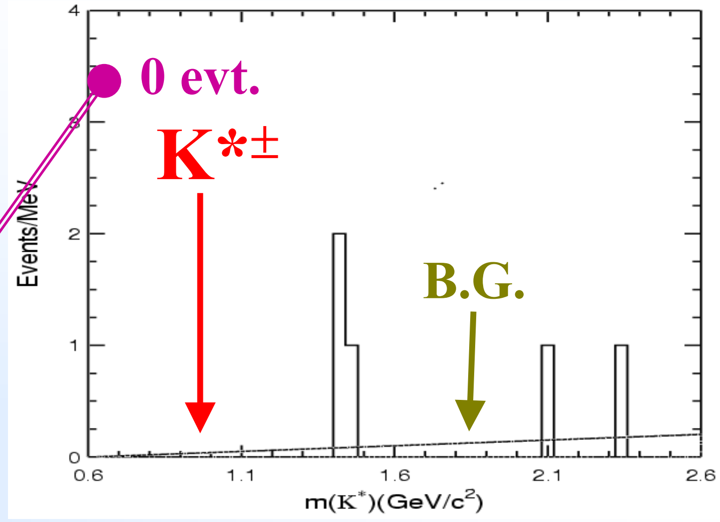
@3.686GeV& $\mathcal{L}$=(19.72 ±0.86) pb $^{-1}$

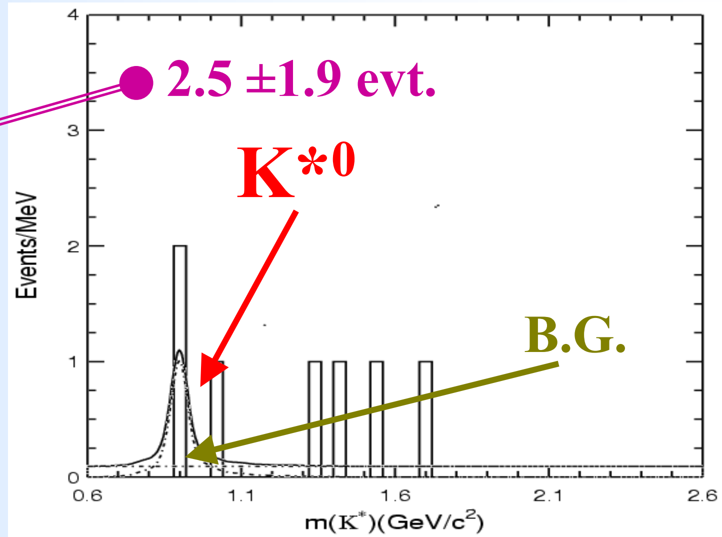
$\sigma(K^{*+}K^{-}$+c.c.) : < 19 (90% C.L.)

$\sigma(K^{*0}\mathbb{K}^0$ +c.c.) : < 30 (90% C.L.)

or : (16 ±12 ±2) pb

@3.650GeV& $\mathcal{L}$=(6.42 ±0.24) pb $^{-1}$



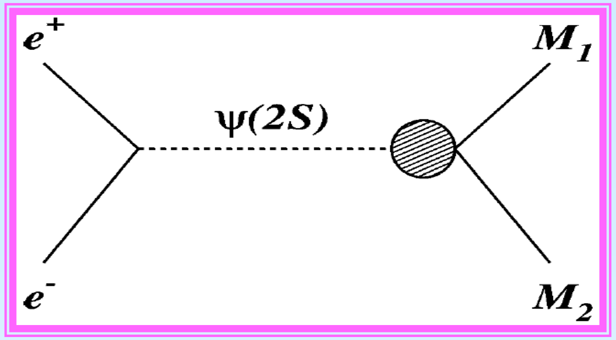


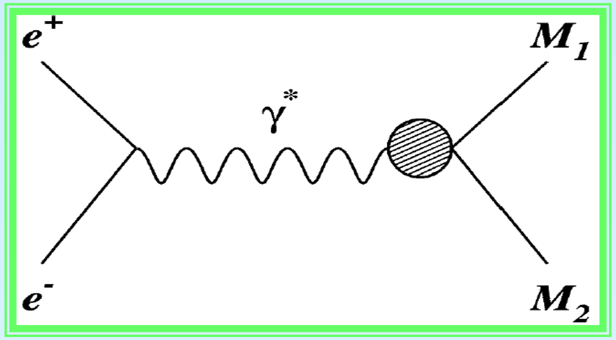
From simple estimation, we can see the continuum contribution can be more 10 %

6.4pb^{-1} *ψ' con. Data @ 3.65* GeV

$\psi' \to VP$

$\omega\pi^0$





Wang, Mo, Yuan
PLB557, 192(2003)

$$\sigma_{Born}^{Res}(s) = \frac{12\pi\Gamma_e\Gamma_f}{(s-M^2)^2+\Gamma_t^2M^2}$$

$$\sigma_{Born}^{Con}(s) = \frac{4\pi\alpha^3}{s^{3/2}}|\mathcal{F}_f|^2\mathcal{P}_f(s)$$

$$\sigma_{Born}(s) = \frac{4\pi\alpha^3}{s^{3/2}}\left[1+2\Re B(s)+|B(s)|^2\right]|\mathcal{F}_f|^2\mathcal{P}_f(s)$$

$$B(s) \equiv \frac{3\sqrt{s}\Gamma_e/\alpha}{s-M^2+i\Gamma_t M}e^{i\phi}$$

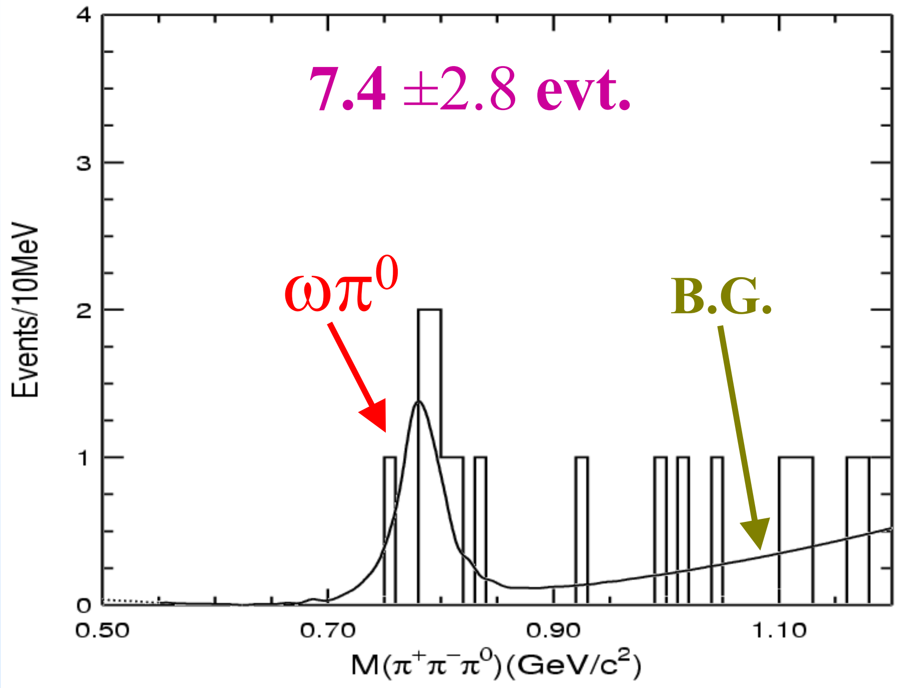
$$\sigma_{r.c.}(s) = \int_0^{x_m} dx F(x,s)\frac{\sigma_{Born}(s(1-x))}{|1-\Pi(s(1-x))|^2}$$

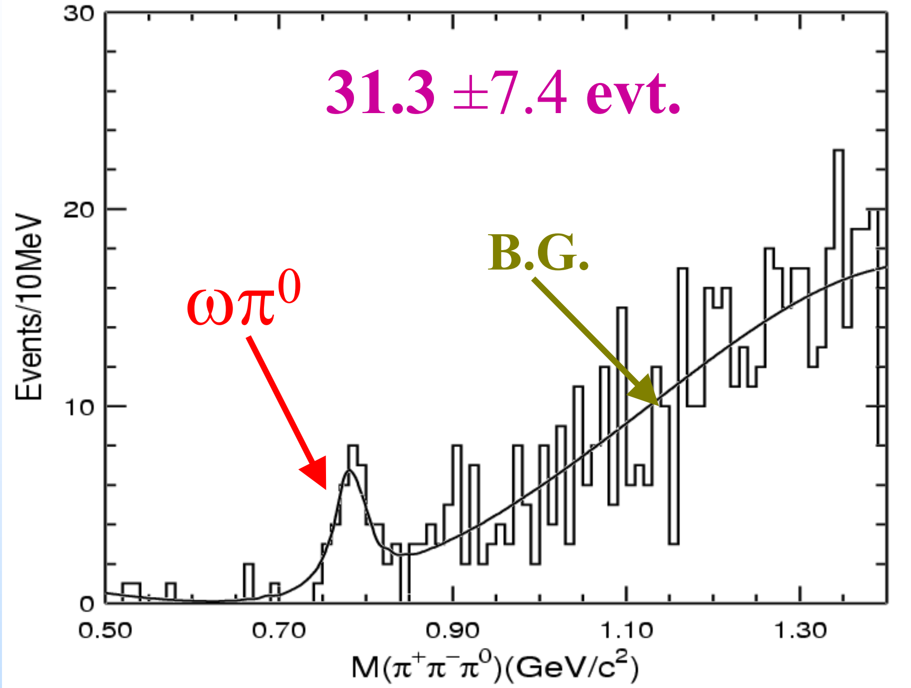
$$\sigma_{exp}(W) = \int_0^{\infty} dW'\sigma_{r.c.}(W')G(W',W).$$

Form factor evaluation shows the contribution from continuum can come up to 60% in total observed section at BES

$\psi' \to VP$

$\omega\pi^0$





@3.650GeV& $\mathcal{L}$=(6.42 ±0.24) pb $^{-1}$

@3.686GeV& $\mathcal{L}$=(19.72 ±0.86) pb $^{-1}$

7.4×(19.72/6.42) ~23, ⇒ Con. /Tot. = 23/31 ~ 70%
consistent with theoretical expectation 60%

Studies of Br($\psi' \to \omega\pi^0$) and $\mathscr{F}_{\omega\pi^0}(s)$ are in progress

$\psi' \to V P$

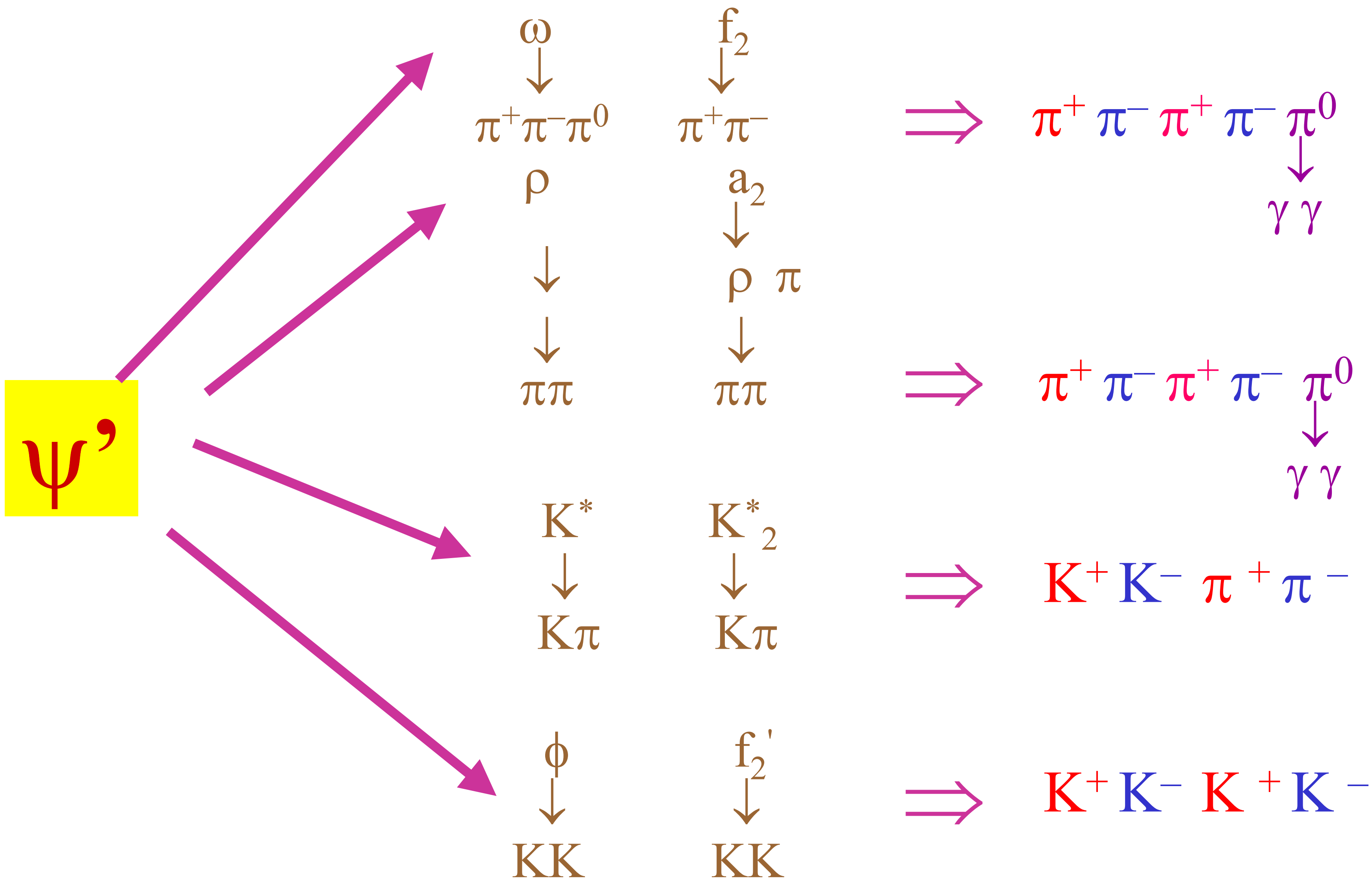
BES-II results (Preliminary)

VP Mode	Final states	N^{fit} (@3.686GeV)	N^{fit} (@3.65GeV)
$\omega\pi^0$	$\pi^+\pi^-\gamma\gamma\gamma\gamma$	31.3 ±7.4	7.4 ±2.8
$K^{*0}K^0$+c.c.	$K\pi K_S(\pi^+\pi^-)$	65.6 ±9.0	2.5 ±1.9
$K^{*+}K^-$+c.c.	$K\pi K_S(\pi^+\pi^-)$	9.6 ±4.2	0

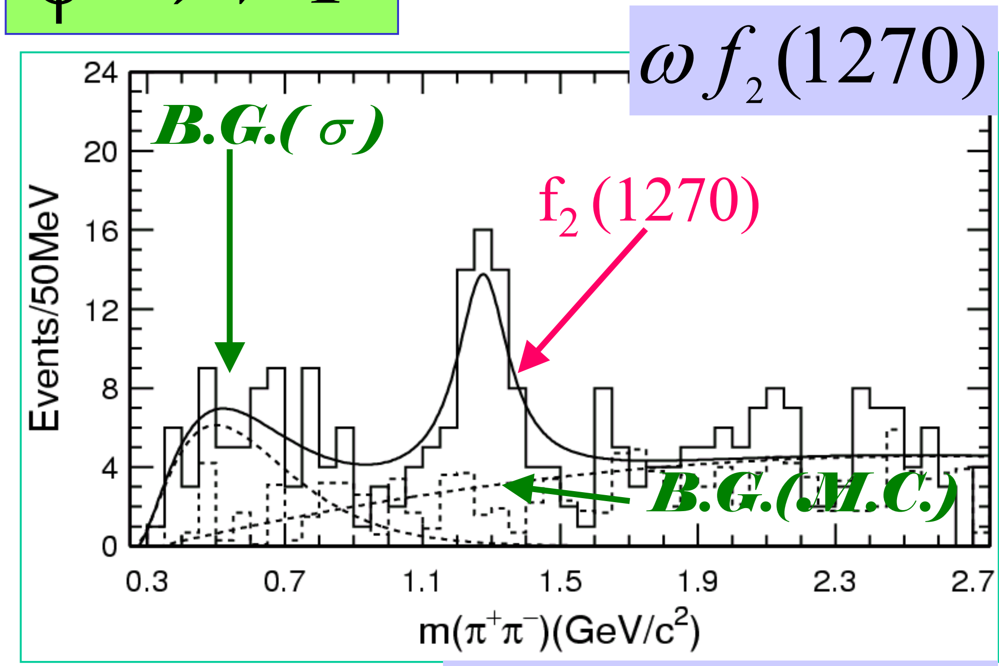
VP Mode	$B(\psi' \to X)(10^{-5})$	$B(J/\psi \to X)(10^{-4})$ (PDG2002)	Q_h (%)
$\omega\pi^0$	< 3.27	4.2 ±0.6	**< 7.8**
$K^{*0}K^0$ +c.c.	15.0 ±2.7	42 ±4	**3.6** ±0.7
$K^{*+}K^-$+c.c.	2.9 ±1.9	50 ±4	**0.58** ±0.29

Suppressed w.r.t. 12% rule !!

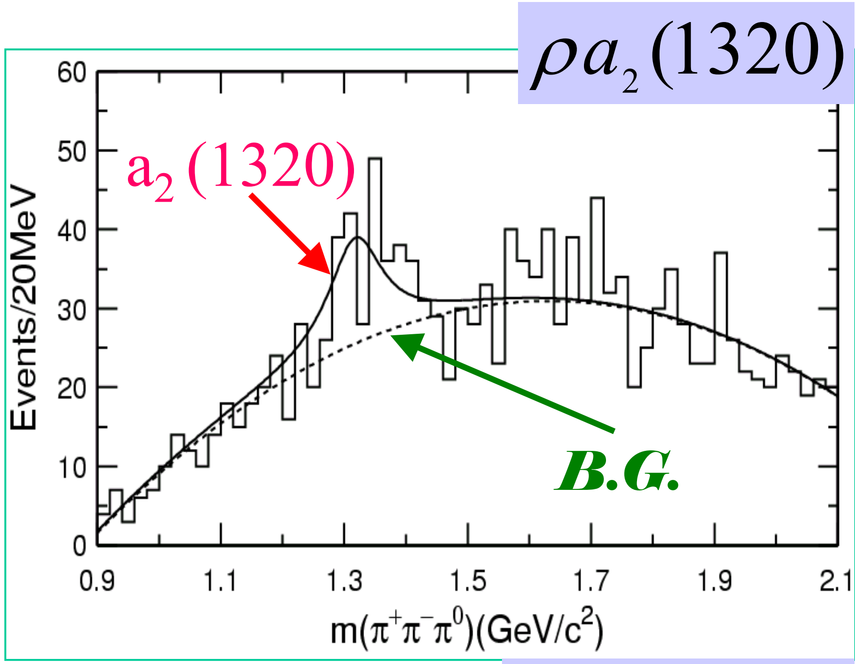
$\psi' \to V\,T$


ψ'
ω → π+π−π0
f2 → π+π−
⇒ π+ π− π+ π− π0, π0 → γ γ
ρ → ππ
a2 → ρ π → ππ
⇒ π+ π− π+ π− π0, π0 → γ γ
K* → Kπ
K*2 → Kπ
⇒ K+ K− π + π −
φ → KK
f2' → KK
⇒ K+ K− K + K −

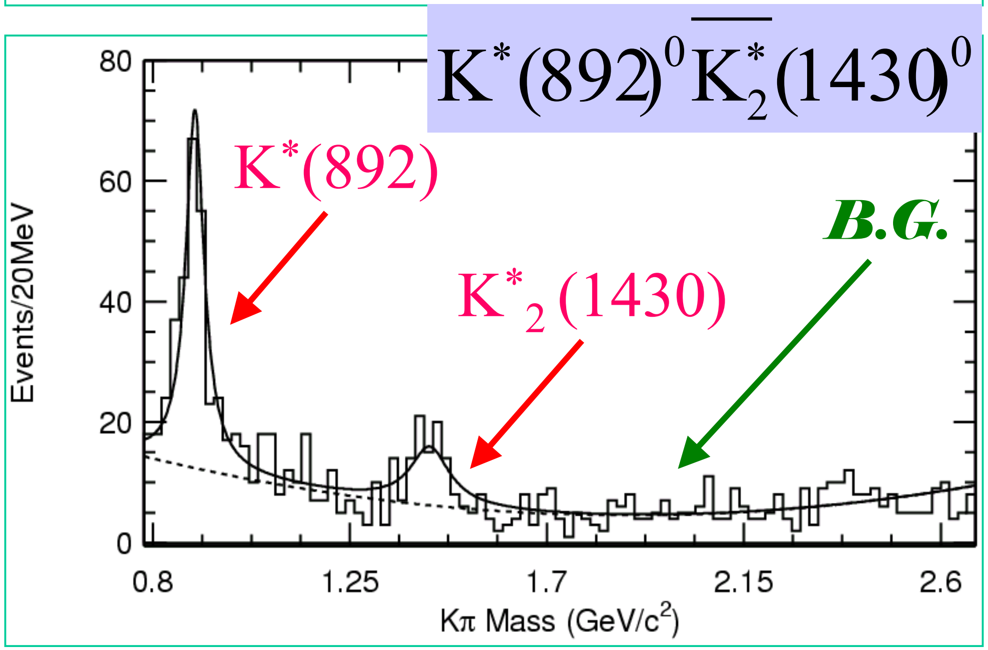
$\psi' \to V\, T$



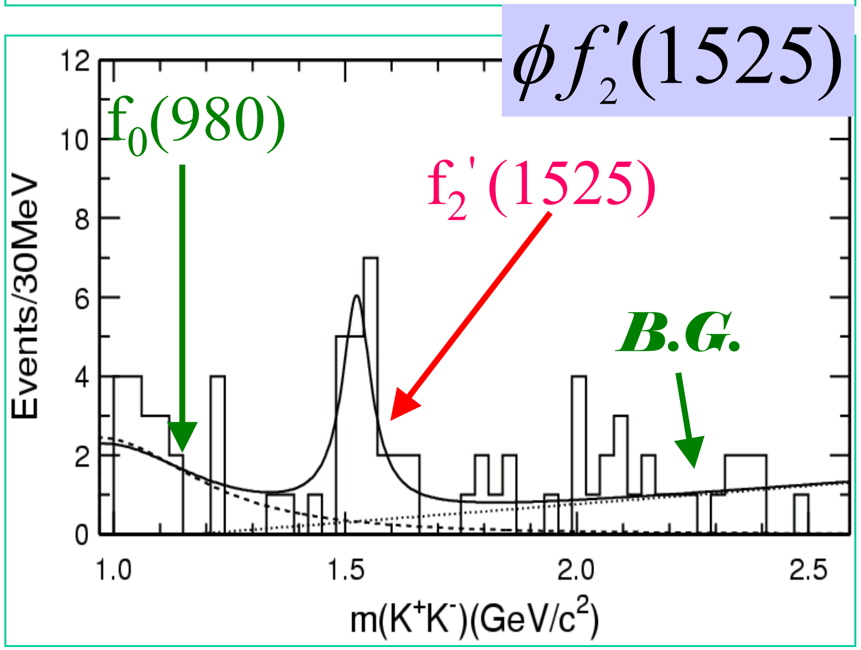
$\omega f_2(1270)$
B.G.(σ)
f_2 (1270)
B.G.(M.C.)
Events/50MeV
$m(\pi^+\pi^-)(GeV/c^2)$



$\rho a_2(1320)$
a_2 (1320)
B.G.
Events/20MeV
$m(\pi^+\pi^-\pi^0)(GeV/c^2)$



$K^*(892)^0\overline{K^*_2}(1430)^0$
$K^*(892)$
K^*_2 (1430)
B.G.
Events/20MeV
Kπ Mass (GeV/c²)



$\phi f_2'(1525)$
$f_0(980)$
f_2' (1525)
B.G.
Events/30MeV
$m(K^+K^-)(GeV/c^2)$

$\psi' \to V\,T$

$$B_{\psi' \to X} = \frac{n^{obs}_{\psi' \to X \to Y}}{N_{\psi'} \cdot B_{X \to Y} \cdot \varepsilon^{MC}}$$

VT mode	$B_{\psi' \to X}\ (10^{-4})$ (BES-II)	$B_{J/\psi \to X}\ (10^{-3})$ (PDG2002)	$Q_h(\%)$
ωf_2	2.05 ±0.41 ±0.38	4.3 ±0.6	4.8 ±1.5
ρa_2	2.55 ±0.73 ±0.47	10.9 ±2.2	2.3 ±1.1
$K^* \overline{K^*}_2$	1.86 ±0.32 ±0.43	6.7 ±2.6	2.8 ±1.3
$\phi f_2'$	0.44 ±0.12 ±0.11	1.23 ±0.21 †	3.6 ±1.5

† This value from DM2 only

Suppressed!!

12 % rule

Accepted by PRD

Parameterization and phase study

VT -Parameterization

ωf_2 : g +e

ρa_2 : g +e

$K^* \overline{K^*}_2$: g(1–s_g) – e (2–s_e)

$\phi f_2'$: g(1–2s_g) – 2 e (1–s_e)

Too many parameters;
Few channels measured;
Limited data sample .

Phase undetermined

A.Seiden,H.F.-W. Sadrozinski and E.Haber : Phys.Rev.D38, 824 (1988)

PP -Parameterization

$\pi^+\pi^-$: E

K^+K^- :($\surd$3/2) M +E

$K_S K_L$: ($\surd$3/2) M

E.Haber and J.Perrier : Phys.Rev.D32, 2961 (1985)

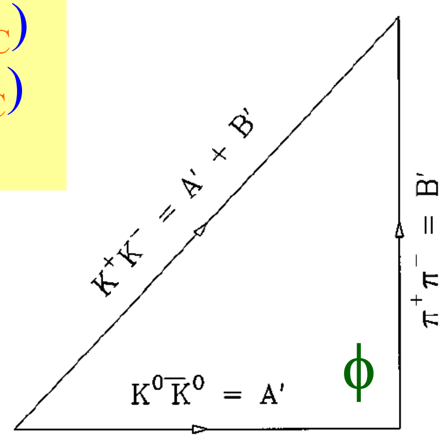
Continuum Contribution

PP -Parameterization

$\pi^+\pi^-$: (E+E_C)

K^+K^- :($\surd$3/2) M +(E+E_C)

$K_S K_L$: ($\surd$3/2) M



C.Z.Yuan, P.Wang and X.H.Mo: PLB567, 74 (2003)

Parameterization and phase study

$$\sigma^{\rm Born}_{\pi^+\pi^-}(s) = \frac{4\pi\alpha^2}{s^{3/2}}[1 + 2\Re B(s) + |B(s)|^2] \times |\mathcal{F}_\pi(s)|^2 \mathcal{P}_{\pi^+\pi^-}(s),$$

$$\sigma^{\rm Born}_{K^+K^-}(s) = \frac{4\pi\alpha^2}{s^{3/2}}[1 + 2\Re(\mathcal{C}_\phi B(s)) + |\mathcal{C}_\phi B(s)|^2] \times |\mathcal{F}_\pi(s)|^2 \mathcal{P}_{K^+K^-}(s),$$

$$\sigma^{\rm Born}_{K^0_S K^0_L}(s) = \frac{4\pi\alpha^2}{s^{3/2}}\mathcal{C}^2 |B(s)|^2 |\mathcal{F}_\pi(s)|^2 \times \mathcal{P}_{K^0_S K^0_L}(s),$$

$$B(s) = \frac{3\sqrt{s}\,\Gamma_{ee}/\alpha}{s - M^2_{\psi(2S)} + iM_{\psi(2S)}\Gamma_t}$$

$$\mathcal{C}_\phi \equiv 1 + \mathcal{C}e^{i\phi}$$

C.Z.Yuan,P.Wang and X.H.Mo:
PLB567, 74 (2003)

DASP:

$$\mathcal{B}(\psi(2S) \to \pi^+\pi^-) = (8 \pm 5) \times 10^{-5},$$

$$\mathcal{B}(\psi(2S) \to K^+K^-) = (10 \pm 7) \times 10^{-5},$$

BES-I:

$$\mathcal{B}(\psi(2S) \to \pi^+\pi^-) = (0.84 \pm 0.55^{+0.16}_{-0.35}) \times 10^{-5},$$

$$\mathcal{B}(\psi(2S) \to K^+K^-) = (6.1 \pm 1.4^{+1.5}_{-1.3}) \times 10^{-5}.$$

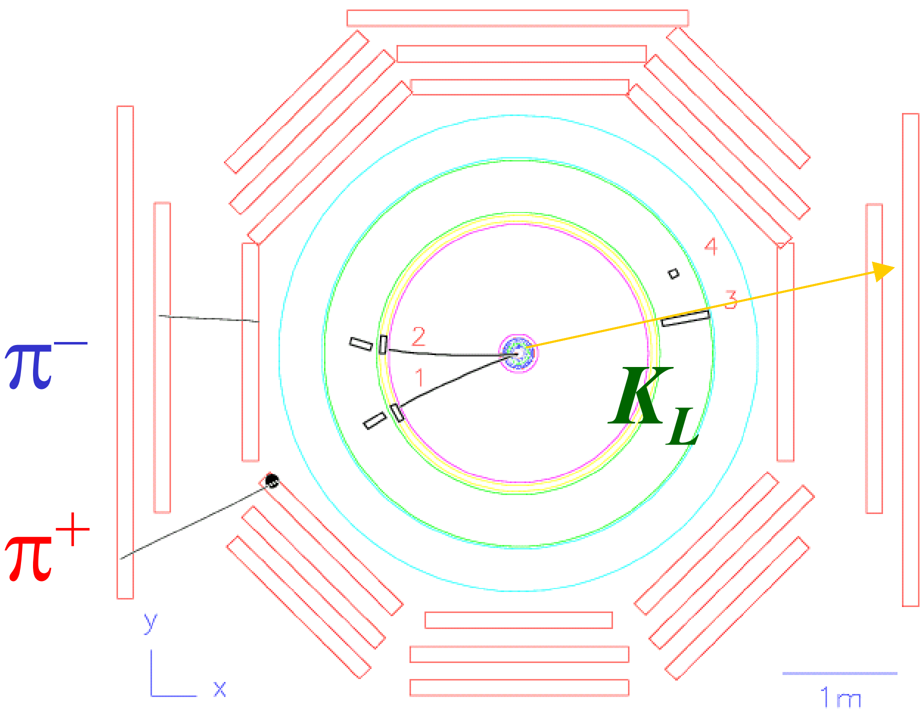
BES Collaboration:PRL 92, 052001 (2004)

$\mathcal{B}_{\psi' \to K_S K_L} = (5.24 \pm 0.47 \pm 0.48) \times 10^{-5}$

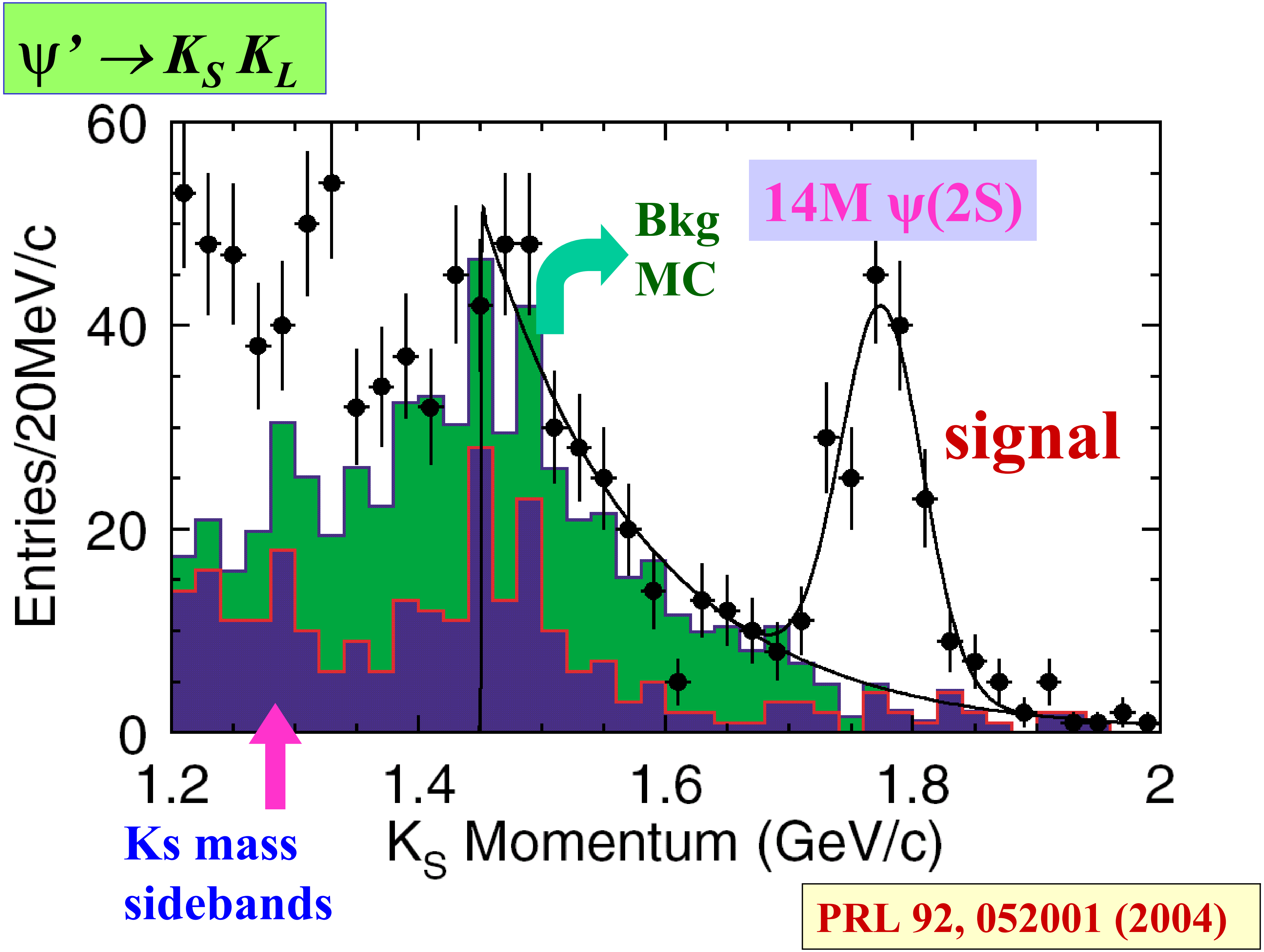
$\phi = (-82 \pm 29)°$, or $(+121 \pm 27)°$

$\psi' \to K_S K_L$

Event Selection



1. *Two Good charged tracks with net charge zero ;*
2. *Decay length in transverse plane greater than 1.0 cm for K_S ID;*
3. *Total Energy of photon candidates less than 1* GeV.


ψ' → K_S K_L
60
40
20
0
Entries/20MeV/c
14M ψ(2S)
Bkg
MC
signal
1.2
1.4
1.6
1.8
2
K_S Momentum (GeV/c)
Ks mass
sidebands
PRL 92, 052001 (2004)

$\psi' \to K_S K_L$

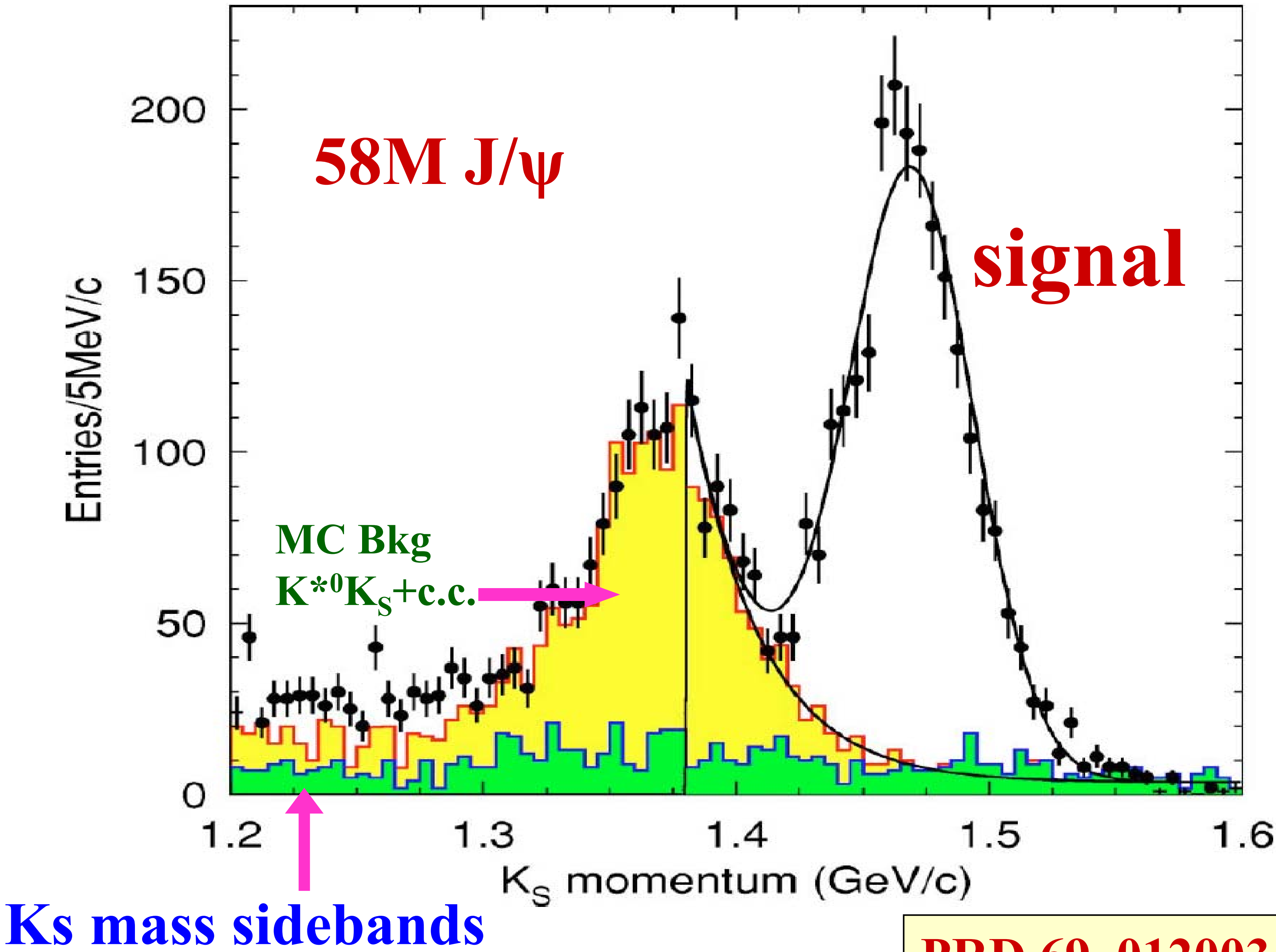
BESII: first measurement for $B(\psi' \to K_S K_L)$

$$B_{\psi' \to K_S K_L} = \frac{n^{obs}/(\varepsilon \cdot f)}{N_{\psi'} \cdot B_{K_S \to \pi^+\pi^-}}$$

Quantity	*Value*
n^{obs}	**156 ± 14**
ε_{MC} (%)	**41.59 ± 0.48**
f (%)	**74.6 ± 3.5**
$N_{\psi'}$ (10^6)	**14.0 ± 0.7**
$\mathcal{B}_{Ks \to \pi+\pi-}$	**0.6860 ± 0.0027**
$\mathcal{B}_{\psi' \to Ks\, K_L}$ (10^{-5})	**5.24 ± 0.47 ± 0.48**

PRL 92, 052001 (2004)

$J/\psi \to K_S K_L$



PRD 69, 012003 (2004)

$J/\psi \to K_S K_L$

BESII: Higher precision for B ($J/\psi \to K_S K_L$)

$$B_{J/\psi \to K_S K_L} = \frac{n^{obs}/(\varepsilon \cdot f)}{N_{J/\psi} \cdot B_{K_S \to \pi^+\pi^-}}$$

Quantity	*Value*
n^{obs}	**2155 ± 45**
ε_{MC} (%)	**38.69 ± 0.23**
f (%)	**77.2 ± 3.4**
$N_{\psi'}$ (10^6)	**57.7 ± 2.7**
$B_{Ks \to \pi+\pi-}$	**0.6860 ± 0.0027**
$B_{J/\psi \to Ks\,K\,L}$ (10^{-4})	**1.82 ± 0.04 ± 0.13**

PDG2002: $\mathscr{B}_{J/\psi \to Ks\,K\,L} = (1.08 \pm 0.14) \times 10^{-4}$

~4σ diff.

PRD 69, 012003 (2004)

$J/\psi\ ,\ \psi' \rightarrow K_S K_L$

$$B_{\psi' \rightarrow K_S K_L} = (5.24 \pm 0.47 \pm 0.48) \times 10^{-5}$$

$$B_{J/\psi \rightarrow K_S K_L} = (1.82 \pm 0.04 \pm 0.13) \times 10^{-4}$$

$$\frac{B_{\psi' \rightarrow K_S K_L}}{B_{J/\psi \rightarrow K_S K_L}} = (28.8 \pm 3.7)\%$$

$$Q_h = \frac{B_{\psi' \rightarrow X}}{B_{J/\psi \rightarrow X}} = 12\%$$

$> 4\sigma$

B(ψ') enhanced!

"12%" rule and mixing model

Wang, Yuan and Mo: PLB574,41(2004); & hep-ph/0402227;

- ψ' → **P P** **enhanced**
- ψ' → **V T** **suppressed**
- ψ' → **V P** **some**

  greatly suppressed

  (such as $\rho\,\pi$ & $K^{*0}\,\bar{K}^0$ **)**

J.L.Rosner : PRD64,094002(2001)

$J/\psi = |\,1^3S_1\rangle$,

$\psi' \,\&\, \psi'' = |\,2^3S_1\rangle \,\&\, |\,1^3D_1\rangle$:

$\langle f|\psi'\rangle = \langle f|\,2^3S_1\rangle\cos\theta - \langle f|\,1^3D_1\rangle\sin\theta$,

$\langle f|\psi''\rangle = \langle f|\,2^3S_1\rangle\sin\theta + \langle f|\,1^3D_1\rangle\cos\theta$.

$(\theta=12^o)$

Some recent studies indicate the S- and D-wave mixing model is a natural, calculable model ! It probably gives a unified explanation for all 12% rule violated decays

"12%" rule:

$|\langle f|J/\psi\rangle\,/\,\langle f|\,2^3S_1\rangle|^2 = \Gamma_{ee}(J/\psi)/\,\Gamma_{ee}(2^3S_1)$

$\Rightarrow \langle f|\,2^3S_1\rangle$

Mixing :

1. $\langle f|\psi'\rangle = \langle f|\,2^3S_1\rangle\cos\theta - \langle f|\,1^3D_1\rangle\sin\theta$

   $\langle f|\psi'\rangle$ & $\langle f|\,2^3S_1\rangle \Rightarrow \langle f|\,1^3D_1\rangle$

2. $\langle f|\psi''\rangle = \langle f|\,2^3S_1\rangle\sin\theta + \langle f|\,1^3D_1\rangle\cos\theta$

   $\Rightarrow \langle f|\psi''\rangle \Rightarrow Br(f)$

The measurement at ψ'' can be used to test the mixing model !

J/ψ , $\psi' \to K_S K_L$

A solution of ψ' enhancement
Wang, Mo and Yuan, hep-ph/0402227

$$|\psi'\rangle = |2^3S_1\rangle \cos\theta - |1^3D_1\rangle \sin\theta \ ,$$
$$|\psi''\rangle = |2^3S_1\rangle \sin\theta + |1^3D_1\rangle \cos\theta \ ,$$

$$\Gamma(\psi'' \to f) = \frac{C_f}{M^2_{\psi''}} |\sin\theta R_{2S}(0) + \eta \cos\theta|^2 ,$$
$$\Gamma(\psi' \to f) = \frac{C_f}{M^2_{\psi'}} |\cos\theta R_{2S}(0) - \eta \sin\theta|^2 ,$$
$$\Gamma(J/\psi \to f) = \frac{C_f}{M^2_{J/\psi}} |R_{1S}(0)|^2 \ ,$$

$$\frac{\Gamma(\psi' \to f)}{\Gamma(J/\psi \to f)} = \frac{\Gamma(\psi' \to e^+e^-)}{\Gamma(J/\psi \to e^+e^-)} \times \left| \frac{\cos\theta R_{2S}(0) - \eta\sin\theta}{\cos\theta R_{2S}(0) - \frac{5}{2\sqrt{2}m_c^2}\sin\theta R''_{1D}(0)} \right|^2 ,$$

$$\frac{\Gamma(\psi'' \to f)}{\Gamma(\psi' \to f)} = \frac{M^2_{\psi'}}{M^2_{\psi''}} \left| \frac{\sin\theta R_{2S}(0) + \eta\cos\theta}{\cos\theta R_{2S}(0) - \eta\sin\theta} \right|^2 .$$

Searching for
$\psi'' \to K_S K_L$
to test the model!

Prediction on ψ″ branching fraction:

$$0.12 \pm 0.07 \leq 10^5 \times \mathcal{B}(\psi'' \to K^0_S K^0_L) \leq 3.8 \pm 1.1$$

Wait for CLEOc/BESIII for the answer!

$\psi' \to J/\psi$-Contained

Motivation: Improve Exp. Precision and Test The. Calculation

$B(\psi(2S) \to \text{hadrons})/B(J/\psi \to \text{hadrons}) =$

$B(\psi(2S) \to ggg + gg\gamma)/B(J/\psi \to ggg + gg\gamma)$

$= 0.23 \pm 0.07$: Disagrees with "12 % Rule"

Important to measure $\psi' \to X\, J/\psi$ and components.

Theoretical prediction for charmonium hadronic transition amplitude can be tested by the high statistics measurements

M. Suzuki: PRD63, 054021, (2001).
Y. F. Gu & X. H. Li: PRD63, 114019 (2001).

G. A. Miller : Phys. Rep. 194,1(1990).
Y. P. Kuang : PRD24, 2874(1981);D37, 1210 (1988)

Inclusive Method [BES-I]

XJ/ψ, $J/\psi \to \mu^+\mu^-$

- *Anything* J/ψ
- $\pi^0\pi^0 J/\psi$
- $\eta J/\psi$
- $\gamma\,\chi_{c1}$, $\chi_{c1} \to \gamma\, J/\psi$
- $\gamma\,\chi_{c2}$, $\chi_{c2} \to \gamma\, J/\psi$

Both accepted by PRD; hep-ex/0403023; hep-ex/0404020.

Exclusive Method [BES-II]

$\gamma\gamma J/\psi$, $J/\psi \to l^+ l^-$

- $\pi^0 J/\psi$
- $\eta J/\psi$
- $\gamma\,\chi_{c1}$, $\chi_{c1} \to \gamma\, J/\psi$
- $\gamma\,\chi_{c2}$, $\chi_{c2} \to \gamma\, J/\psi$

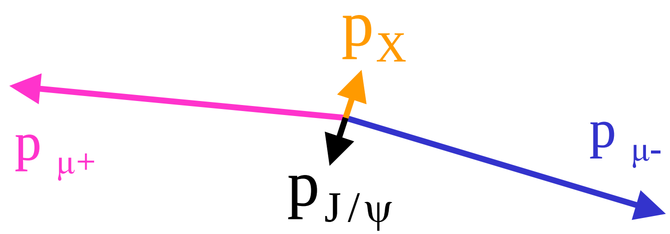
$\psi' \to X\ J/\psi$

Inclusive Method

Method – identify $J/\psi \to \mu^+\mu^-$

Select muons ; I C fit to $m_{J/\psi}$; determine m_X

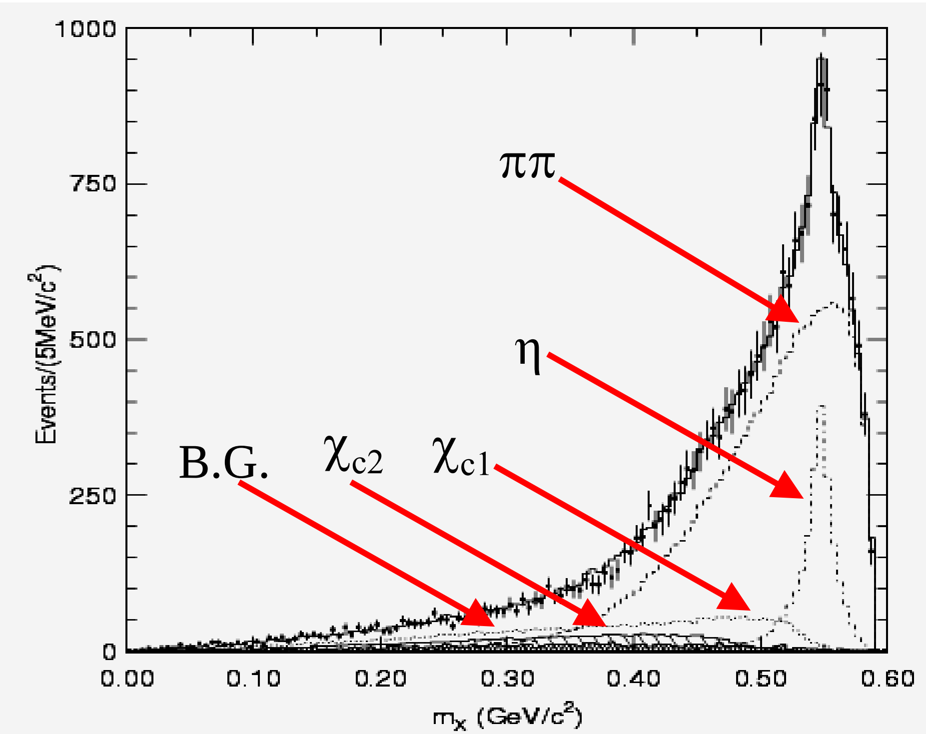
$$\vec{p}_X = -\vec{p}_{J/\psi}$$
$$E_X = m_{\psi(2S)} - E_{J/\psi}$$



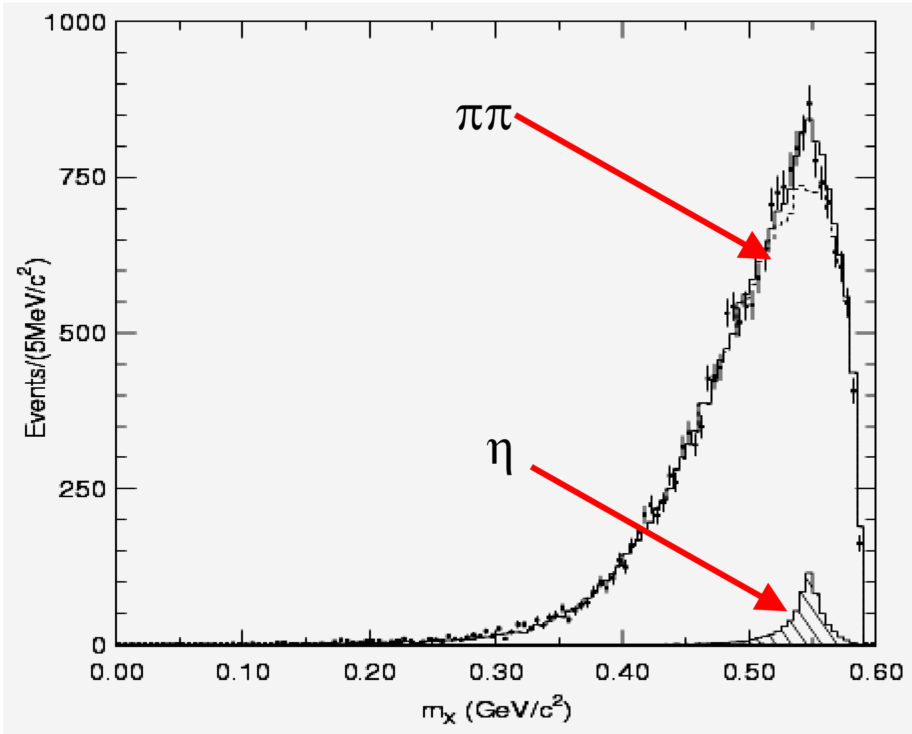
m_X is plotted for with and without extra charged-track cases. Fit two plots simultaneously with component shapes.

$\chi^2 < 7$

no extra

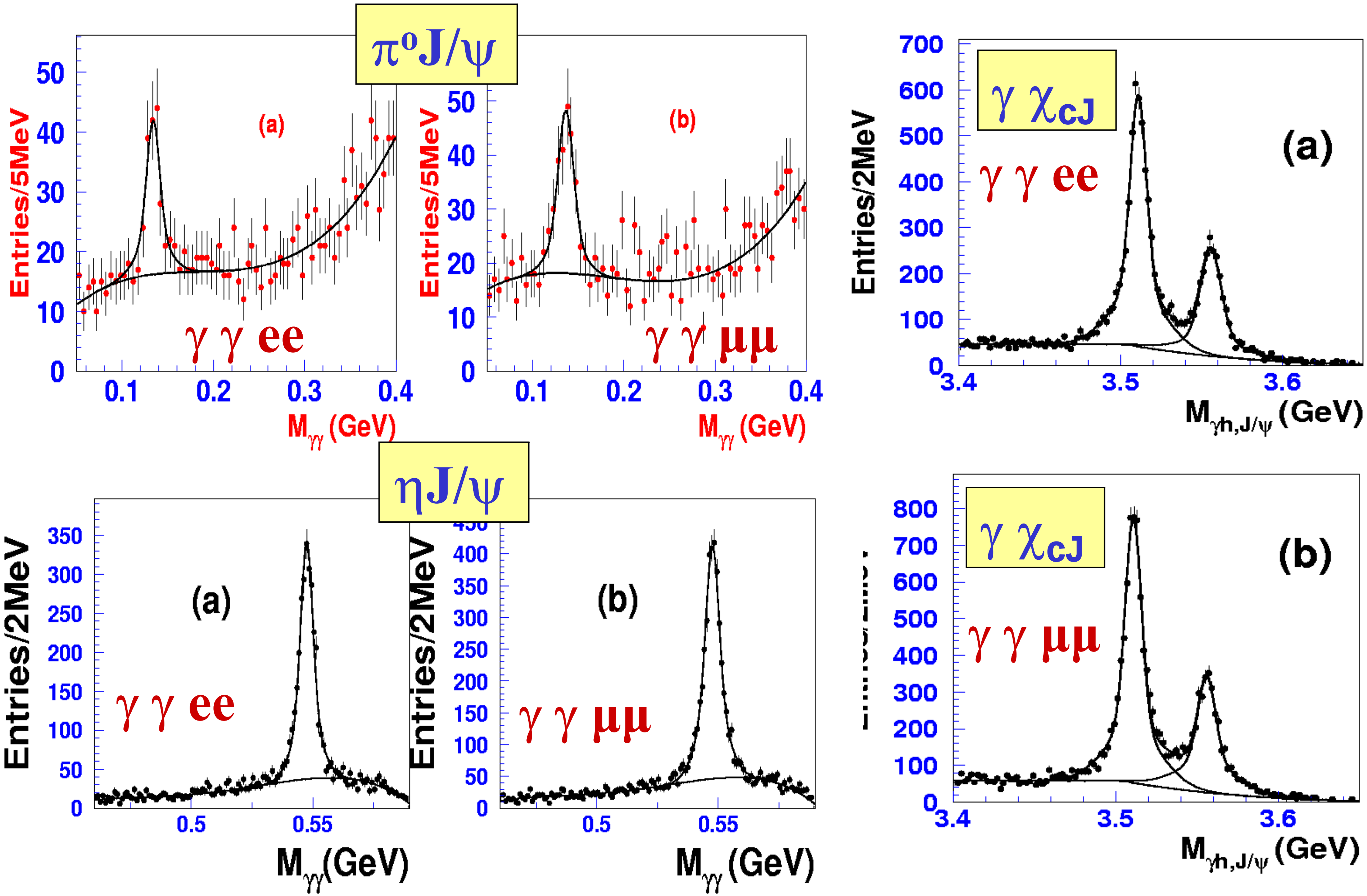


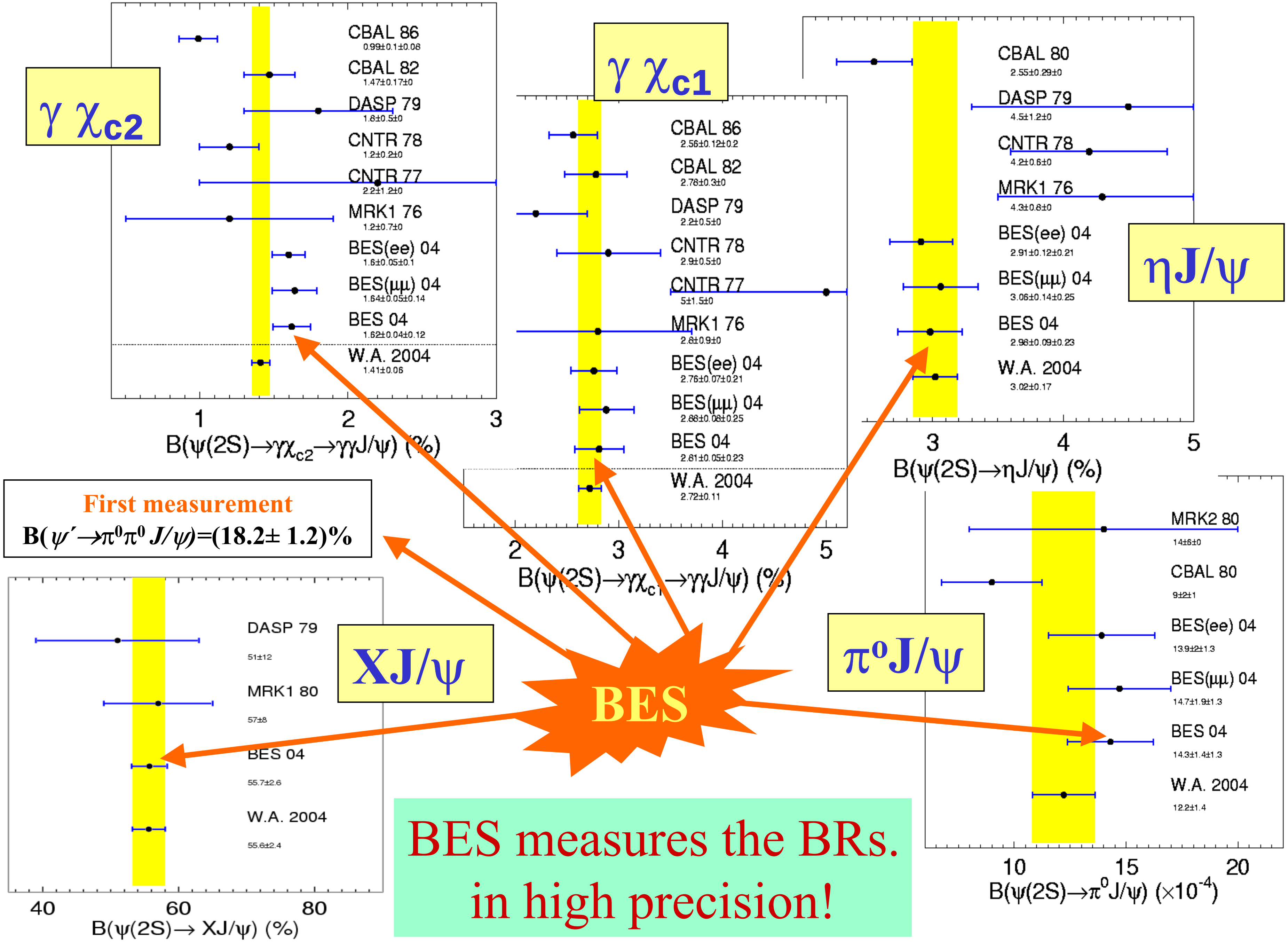
extra



$\psi' \to \gamma\ \gamma\ J/\psi$

Exclusive Method





γ χc2
CBAL 86 0.99±0.1±0.08
CBAL 82 1.47±0.17±0
DASP 79 1.8±0.5±0
CNTR 78 1.2±0.2±0
CNTR 77 2.2±1.2±0
MRK1 76 1.2±0.7±0
BES(ee) 04 1.6±0.05±0.1
BES(μμ) 04 1.64±0.05±0.14
BES 04 1.62±0.04±0.12
W.A. 2004 1.41±0.06
1 2 3
B(ψ(2S)→γχc2→γγJ/ψ) (%)
γ χc1
CBAL 86 2.56±0.12±0.2
CBAL 82 2.78±0.3±0
DASP 79 2.2±0.5±0
CNTR 78 2.9±0.5±0
CNTR 77 5±1.5±0
MRK1 76 2.8±0.9±0
BES(ee) 04 2.76±0.07±0.21
BES(μμ) 04 2.88±0.08±0.25
BES 04 2.81±0.05±0.23
W.A. 2004 2.72±0.11
2 3 4 5
B(ψ(2S)→γχc1→γγJ/ψ) (%)
CBAL 80 2.55±0.29±0
DASP 79 4.5±1.2±0
CNTR 78 4.2±0.6±0
MRK1 76 4.3±0.8±0
BES(ee) 04 2.91±0.12±0.21
BES(μμ) 04 3.06±0.14±0.25
BES 04 2.98±0.09±0.23
W.A. 2004 3.02±0.17
ηJ/ψ
3 4 5
B(ψ(2S)→ηJ/ψ) (%)
First measurement
B(ψ′→π0π0 J/ψ)=(18.2± 1.2)%
DASP 79 51±12
MRK1 80 57±8
BES 04 55.7±2.6
W.A. 2004 55.6±2.4
XJ/ψ
40 60 80
B(ψ(2S)→ XJ/ψ) (%)
BES
π0J/ψ
MRK2 80 14±6±0
CBAL 80 9±2±1
BES(ee) 04 13.9±2±1.3
BES(μμ) 04 14.7±1.9±1.3
BES 04 14.3±1.4±1.3
W.A. 2004 12.2±1.4
10 15 20
B(ψ(2S)→π0J/ψ) (×10-4)
BES measures the BRs.
in high precision!

$\psi' \to \gamma\gamma J/\psi$

Discussions

BES (+PDG for Υ):

R=0.048±0.007
R' <0.0098
R''<0.0065

$$R = \frac{\Gamma(\psi(2S)\to\eta J/\psi)}{\Gamma(\psi(2S)\to\pi^0 J/\psi)}$$

$$R' = \frac{\Gamma(\Upsilon'\to\eta\Upsilon)}{\Gamma(\psi(2S)\to\eta J/\psi)}$$

$$R'' = \frac{\Gamma(\Upsilon''\to\eta\Upsilon)}{\Gamma(\psi(2S)\to\eta J/\psi)}$$

- PCAC [G. A. Miller, Phys. Rep. 194,1(1990)]: **R=0.0162** **(too small!)**

$$R = \frac{27}{16}\left(\frac{p_\pi}{p_\eta}\right)^3 r^2, \quad r = (m_d - m_u)/(m_s - 0.5\cdot(m_d+m_u))$$

- QCD Multipole Expansion & BTG potential model
[Y. P. Kuang, PRD24, 2874(1981), *ibid.* 37, 1210(1988)]

R' =0.0025
R''=0.0013

$$R' \approx \left(\frac{m_c}{m_b}\right)^2 \cdot \left(\frac{p_\eta(\Upsilon')}{p_\eta(\psi(2S))}\right)^3 \cdot \left(\frac{f(\Upsilon')}{f(\psi(2S))}\right)^2$$

$$R'' \approx \left(\frac{m_c}{m_b}\right)^2 \cdot \left(\frac{p_\eta(\Upsilon'')}{p_\eta(\psi(2S))}\right)^3 \cdot \left(\frac{f(\Upsilon'')}{f(\psi(2S))}\right)^2$$

Summary

- Studies are made for $K^* \overline{K}$ and $\omega\pi$ channels, about which the cont. contr. and its interference are taken into account.
- For VT channel, ωf_2 , ρa_2 , $K^* K^*_2$ and $\phi f_2'$ are measured.
- For PP channel, $K^0_S K^0_L$ **is first observed** in ψ' decay; and the precision is **improved** for $J/\psi \rightarrow K^0_S K^0_L$.
- $\psi' \rightarrow$ **J/ψ-contained** final states are studied to improve experimental precision and test theoretical predications.

- Test of 12% rule ;
- Study of phase between strong and EM amplitudes ;
- Prediction & Evaluation involving mixing model.

Thanks a lot !

谢谢！

Search for ψ', $J/\psi \to K_S K_S$

- CP violating process
- Test EPR paradox

  (Einstein-Podolsky-Rosen)
- MarkIII: 2.7M J/ψ

  $B(J/\psi \to K_S K_S) < 5.2\times10^{-6}$

  (@90% C.L.)
- BESII: 58M J/ψ

  14M ψ'

Events selection

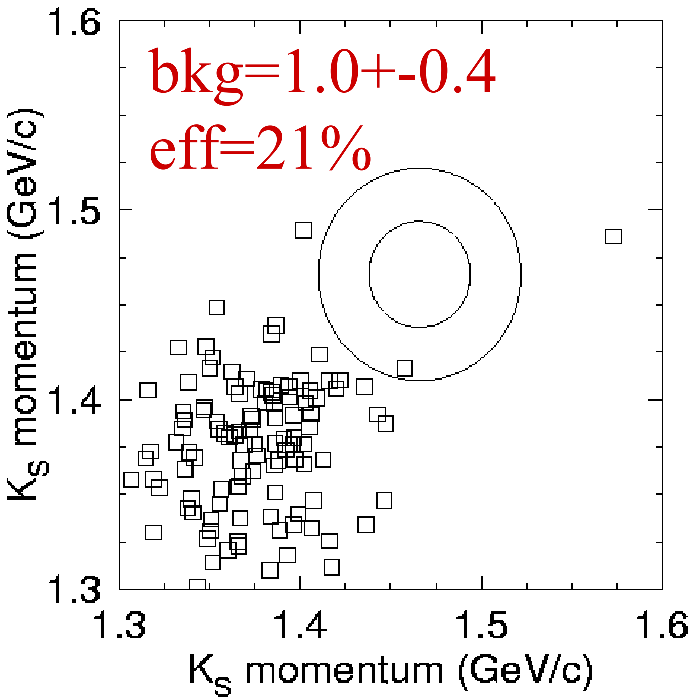
- 4 good charged tracks
- Q(sum) = 0
- $|\cos\theta| < 0.8$
- K_S decay length

  $Lxy > 3$ mm
- $|M_{\pi\pi} - M_{K_S}| > 2\,\sigma_M$

ψ', $J/\psi \rightarrow K_S K_S$

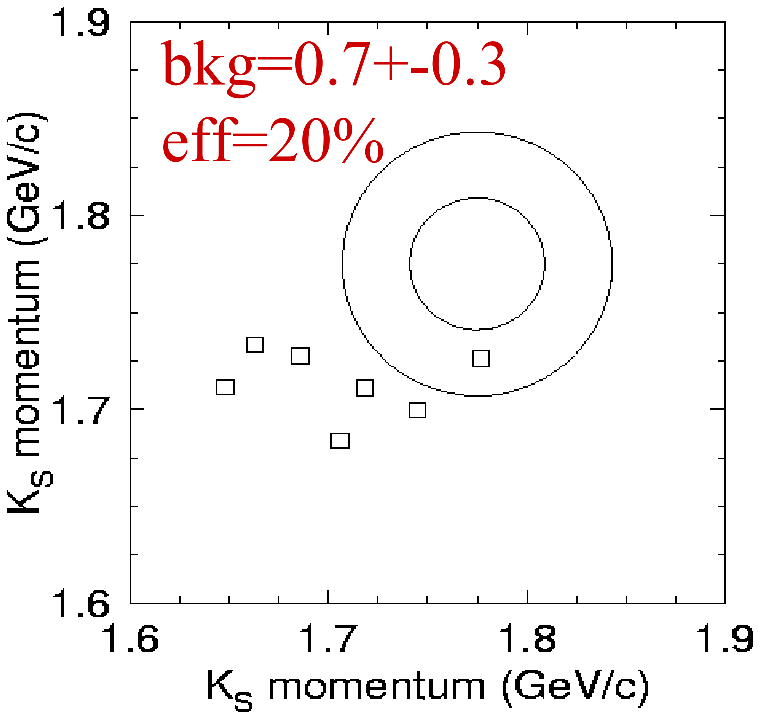
2 circles – 1 σ & 2 σ regions from MC

1 evt in 2 σ region



$J/\psi \rightarrow K_S K_S$ candidate

1 evt in 2 σ region



$\psi' \rightarrow K_S K_S$ candidate

ψ', $J/\psi \to K_S K_S$

Upper Limits (@95% C.L.)

R	J/ψ	$\psi(2S)$
n^{obs}	1	1
n^{obs}_{UL}	4.74	4.74
ε_{MC} (%)	20.74 ± 0.41	19.18 ± 0.39
ε_{trg} (%)	98.2 ± 0.2	96.5 ± 0.7
ε_{2nd} (%)	92.9 ± 4.5	96.2 ± 5.8
$N_{\psi(2S)}(10^6)$	57.7 ± 2.7	14.0 ± 0.7
$\mathcal{B}(K^0_S \to \pi^+\pi^-)$	0.6860 ± 0.0027	
$\mathcal{B}(R \to K^0_S K^0_S) <$	1.0×10^{-6}	4.6×10^{-6}

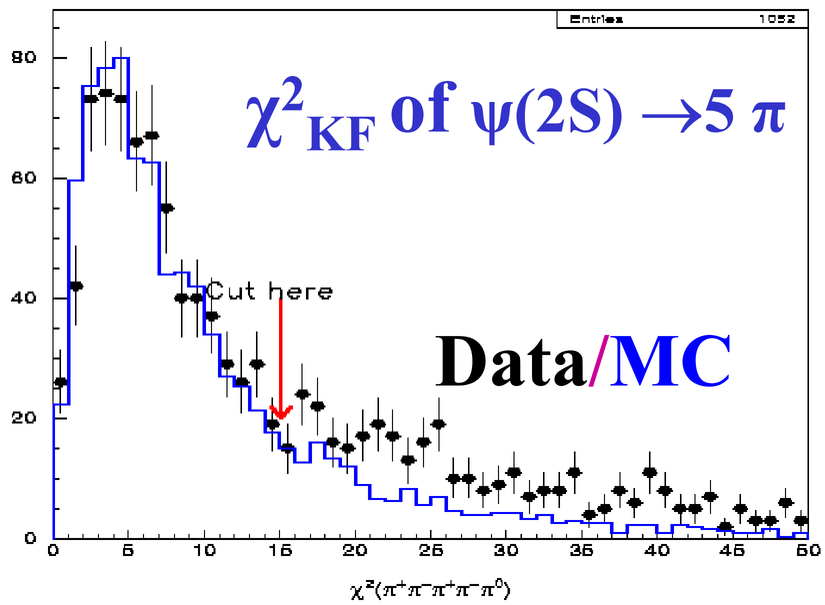
- 1st upper limit for B($\psi' \to K_S K_S$).
- Higher sensitivity for B($J/\psi \to K_S K_S$) upper limit.
- Sensitivity insufficient for testing EPR paradox and CP violation.

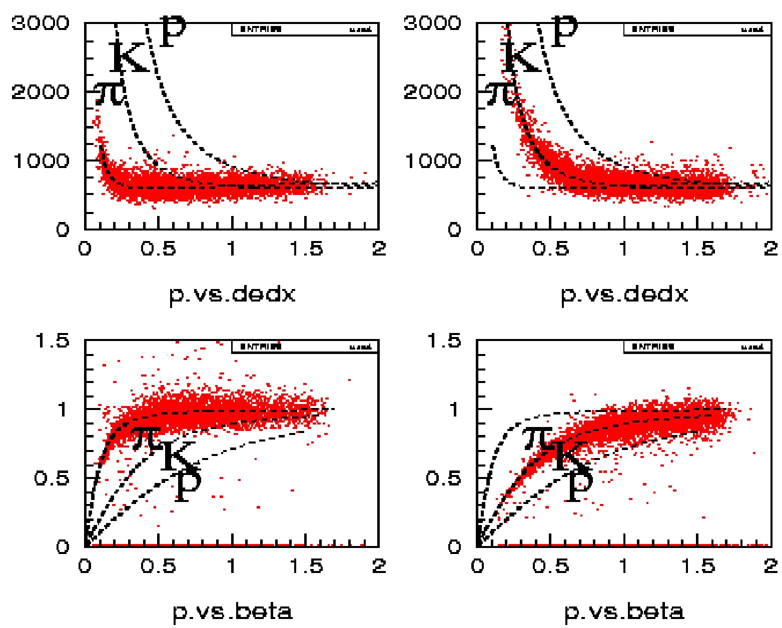
PLB (in press)

$\psi' \to V\,T$

Event Selection

1. **Four charged tracks with net charge zero;**
2. **$|\cos\theta|<0.80$ for all tracks;**
3. **PartID using TOF+dE/dx**
4. **At least 2 photon candidates for π^0 channels;**
5. **Remove $\psi(2S) \to \pi^+\pi^- J/\psi$ background;**
6. **Kinematic fit (4C/5C), Prob>0.01.**



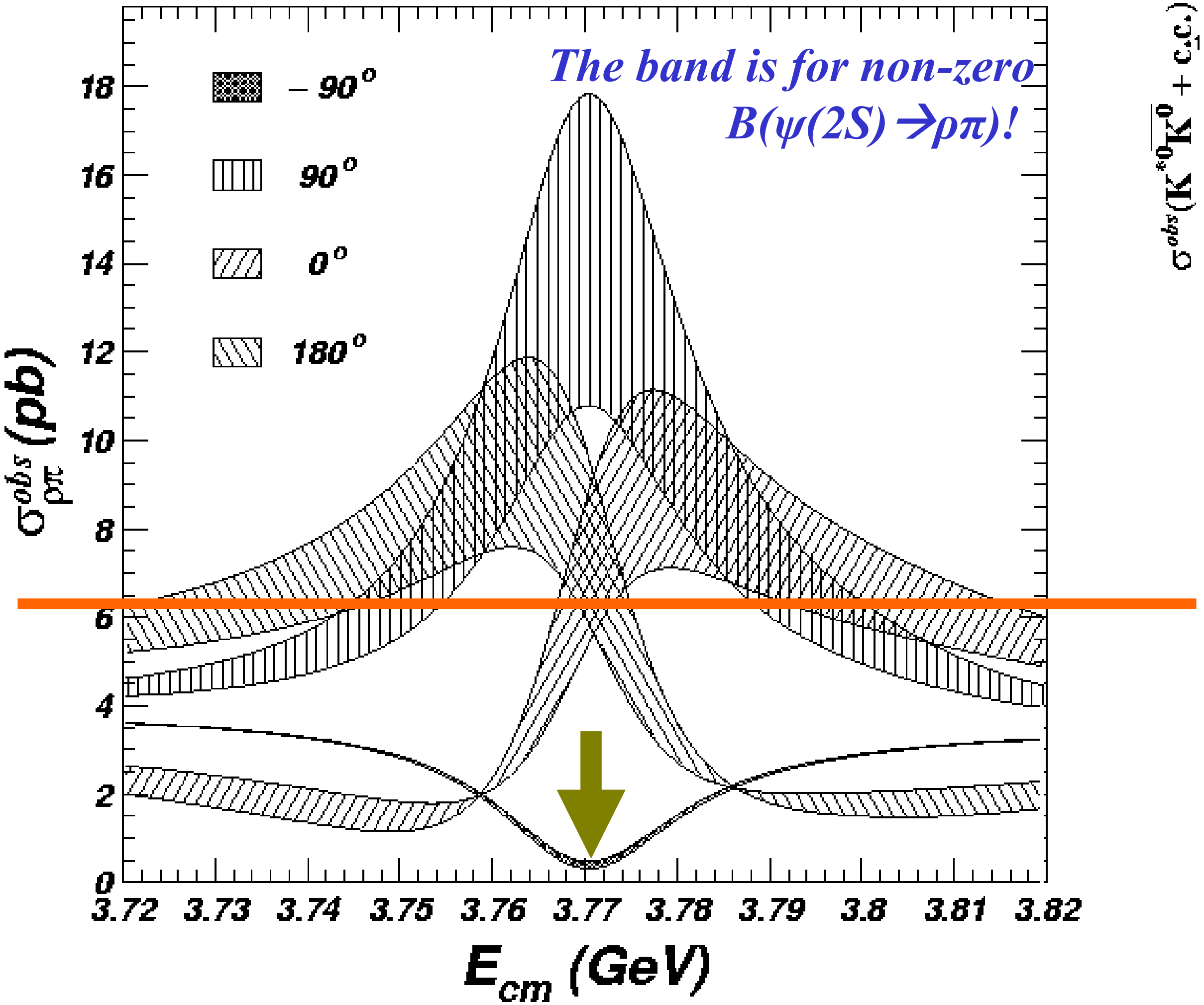


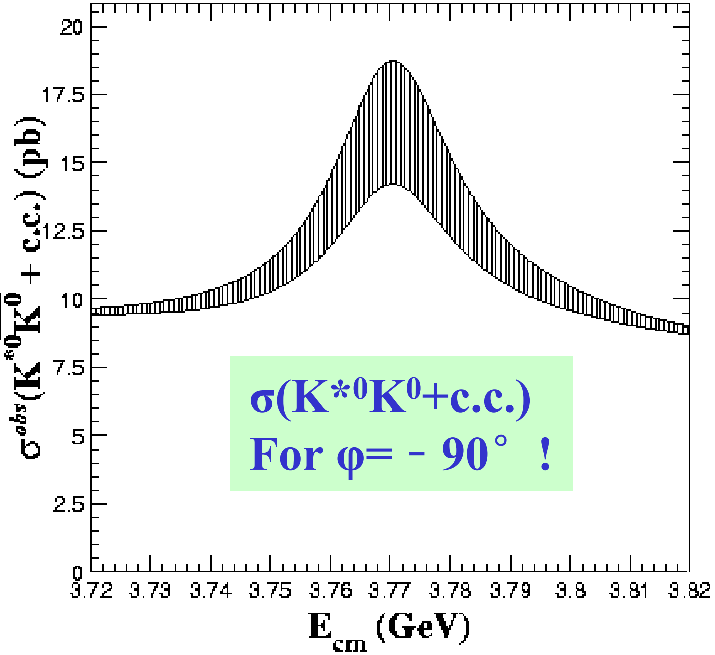
J/ψ , $\psi' \to \rho\pi$

A solution of ψ' suppress

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

To measure B(ψ'' →ρπ), the best way is to do the energy scan!





MK3 UL (<6.3pb)
Favors φ= - 90° !

Missing ρπ signal and/or enhanced $K^{*0}K^0$ signal indicate BRs at 10^{-4} level.

$\psi' \to J/\psi$-Contained

Both Accepted by PRD

J/ψ-contained final state (XJ/ψ , $J/\psi \to \mu^+\mu^-$) Inclusive Method [BES-I]		
Channel	$B_{X J/\psi} / B_{\pi\pi J/\psi}$ (%)	$B_{X J/\psi}$ (%) [$B_{\pi\pi J/\psi}$ = (30.5 ± 1.6)%]
Anything J/ψ	1.867 ± 0.026 ± 0.055	56.9 ± 0.8 ± 3.4
$\pi^0\pi^0 J/\psi$	0.570 ± 0.009 ± 0.026	17.4 ± 0.3 ± 1.2
$\eta J/\psi$	0.098 ± 0.005 ± 0.010	3.00 ± 0.16 ± 0.33
$\gamma \chi_{c1}, \chi_{c1} \to \gamma J/\psi$	0.126 ± 0.003 ± 0.038	3.9 ± 0.16 ± 1.2
$\gamma \chi_{c2}, \chi_{c2} \to \gamma J/\psi$	0.060 ± 0.000 ± 0.028	1.84 ± 0.01 ± 0.86

J/ψ-contained final state ($\gamma\gamma J/\psi$, $J/\psi \to l^+ l^-$) Exclusive Method [BES-II]			
Channel	$B_{\gamma\gamma J/\psi,\, J/\psi \to \mu+\mu-}$ (%)	$B_{\gamma\gamma J/\psi,\, J/\psi \to e+e-}$ (%)	*Combine* $B_{\gamma\gamma J/\psi}$ (%)
$\pi^0 J/\psi$	0.147 ± 0.019 ± 0.013	0.139 ± 0.020 ± 0.013	0.143 ± 0.014 ± 0.013
$\eta J/\psi$	3.06 ± 0.14 ± 0.25	2.91 ± 0.12 ± 0.21	2.98 ± 0.09 ± 0.23
$\gamma \chi_{c1}, \chi_{c1} \to \gamma J/\psi$	9.11 ± 0.24 ± 1.12	8.73 ± 0.21 ± 1.00	8.90 ± 0.16 ± 1.05
$\gamma \chi_{c2}, \chi_{c2} \to \gamma J/\psi$	8.12 ± 0.23 ± 0.99	7.90 ± 0.26 ± 0.88	8.02 ± 0.17 ± 0.94