Recent BES Results on Charmonium Decays

Changzheng YUAN

IHEP, Beijing

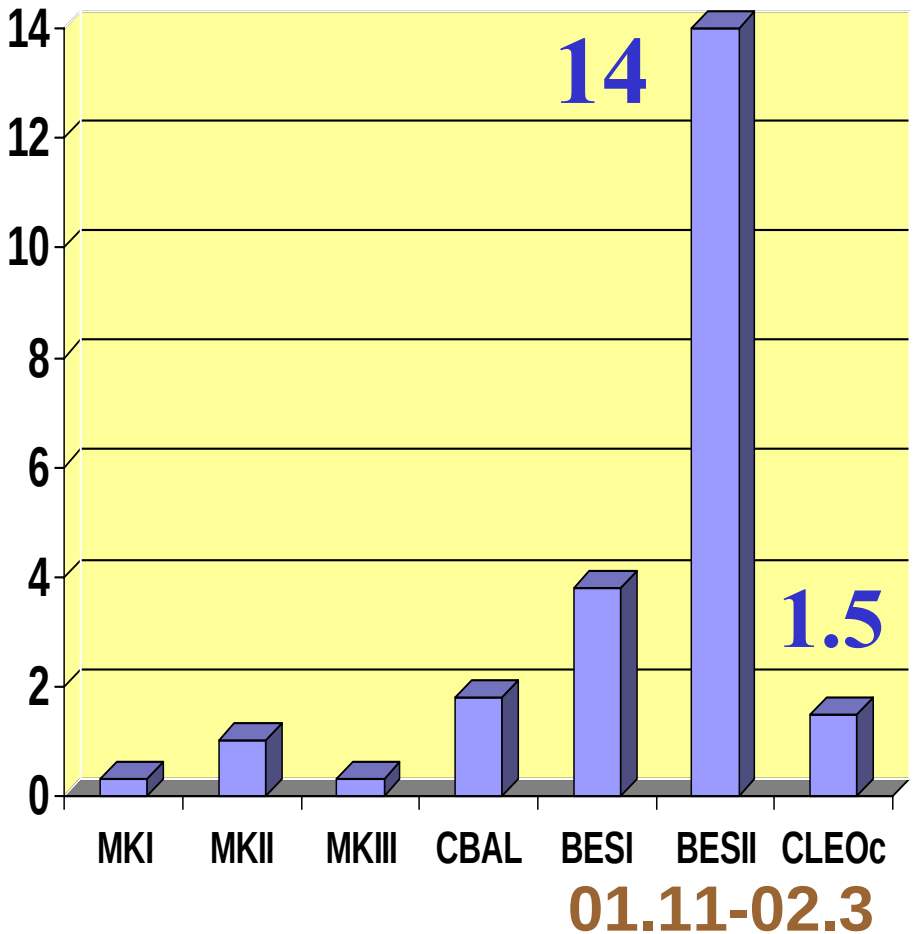
for the BES Collaboration

XXXIVth Rencontres de Moriond

QCD and Hadronic Interactions at High Energy

Mar. 28 – Apr. 4, 2004, La Thuile

BESII obtained 14 M ψ' events



- $\psi' \rightarrow V\ T$
- $\psi' \rightarrow K^0_S K^0_L$

  $(J/\psi \rightarrow K^0_S K^0_L)$
- $\psi' \rightarrow \gamma\gamma J/\psi$
- $\chi_{cJ} \rightarrow \Lambda\ \bar{\Lambda}$ and $p\bar{p}$
- $\psi' \rightarrow K^0_S K^0_S$

pQCD rule and "ρπ puzzle"

- **pQCD rule (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**

$\psi' \to VT$

❖ BES-I results [PRL81(1998)5080] [PRD67(2003)052002]

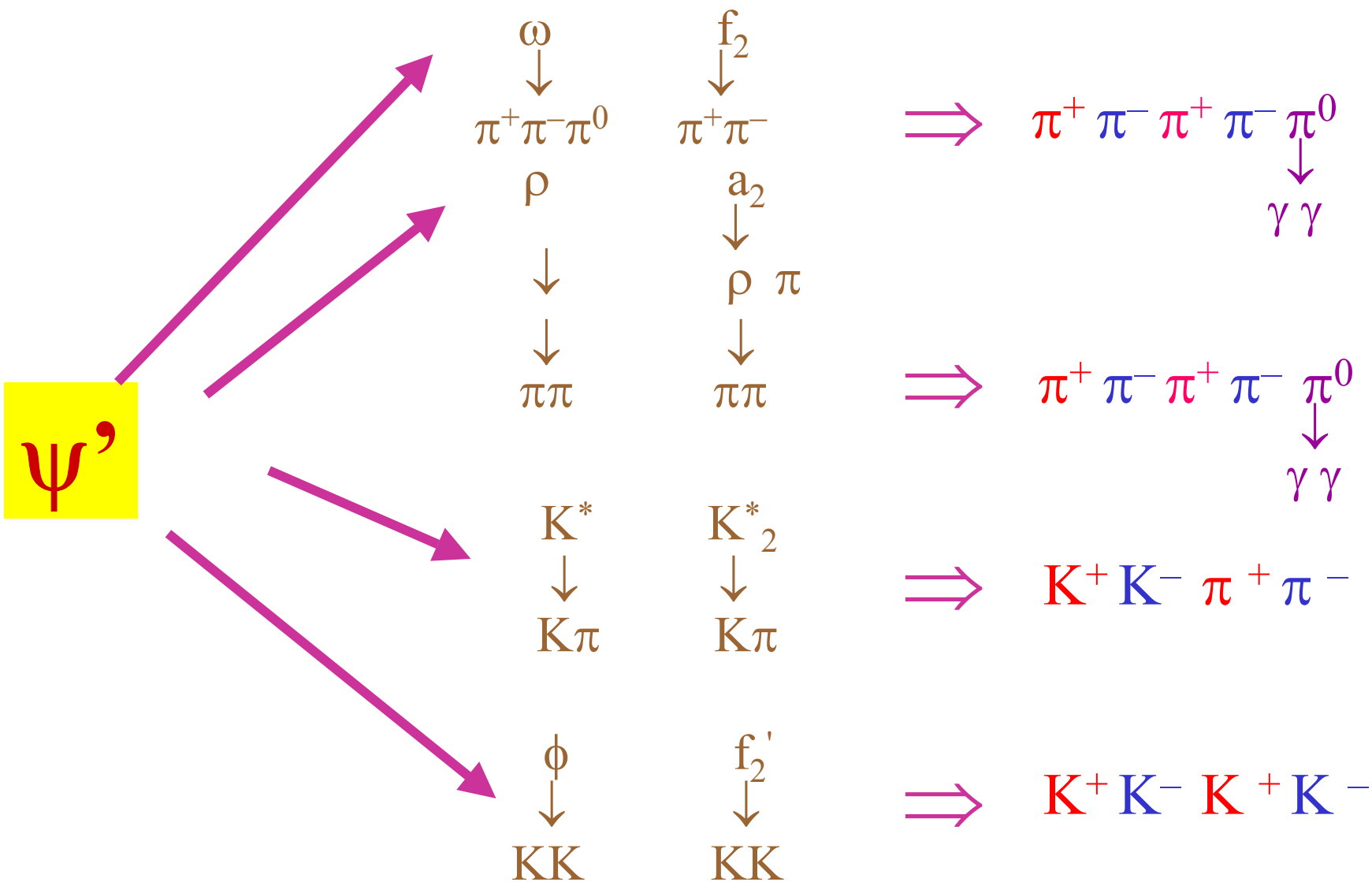
VT Mode	$B(\psi' \to X)(10^{-4})$ (PDG2002 from BES)	$B(J/\psi \to X)(10^{-3})$ (PDG2002)	Q_h (%)
ωf_2	< 1.7 (C.L. 90 %) 1.1 ±0.5 ±0.2	4.3±0.6	**< 4.0** **2.4 ±1.3**
ρa_2	< 2.3 (C.L. 90 %)	10.9±2.2	**< 2.1**
$K^* \overline{K^*_2}$	< 1.2 (C.L. 90 %)	6.7±2.6	**< 1.8**
$\phi f_2'$	< 0.45 (C.L. 90 %)	1.23±0.21 †	**< 3.7**

† This value from DM2 only

12 % rule (pQCD rule)

Suppressed!!

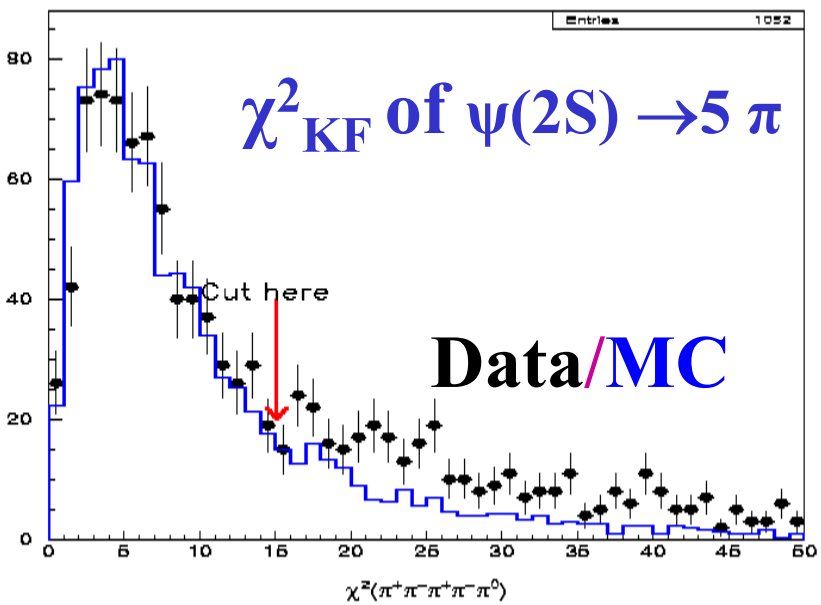
$\psi' \to V\,T$

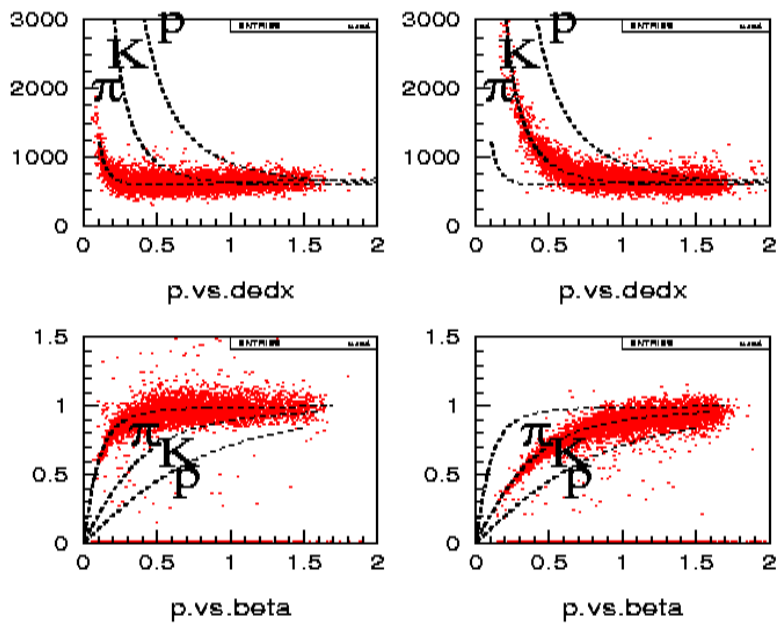

ψ'
ω
f2
π+π−π0
π+π−
ρ
a2
ρ π
ππ
ππ
K*
K*2
Kπ
Kπ
ϕ
f2'
KK
KK
π+ π− π+ π− π0
γ γ
π+ π− π+ π− π0
γ γ
K+ K− π + π −
K+ K− K + K −

$\psi' \to VT$

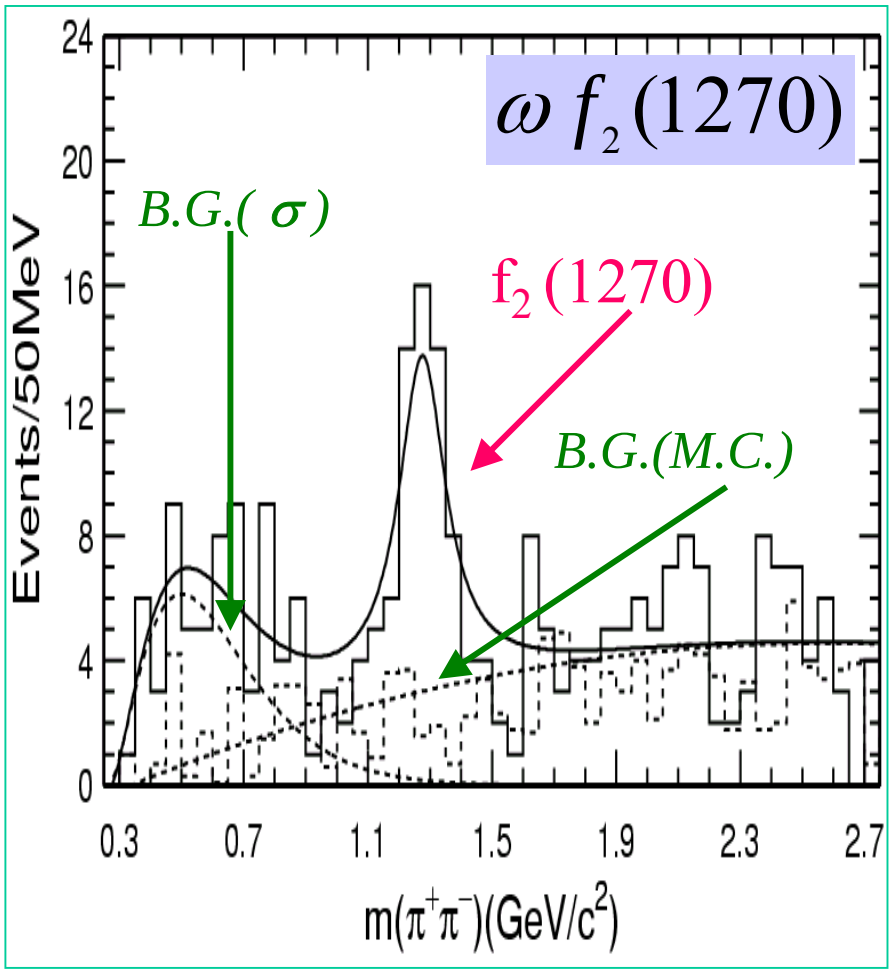
Event Selection

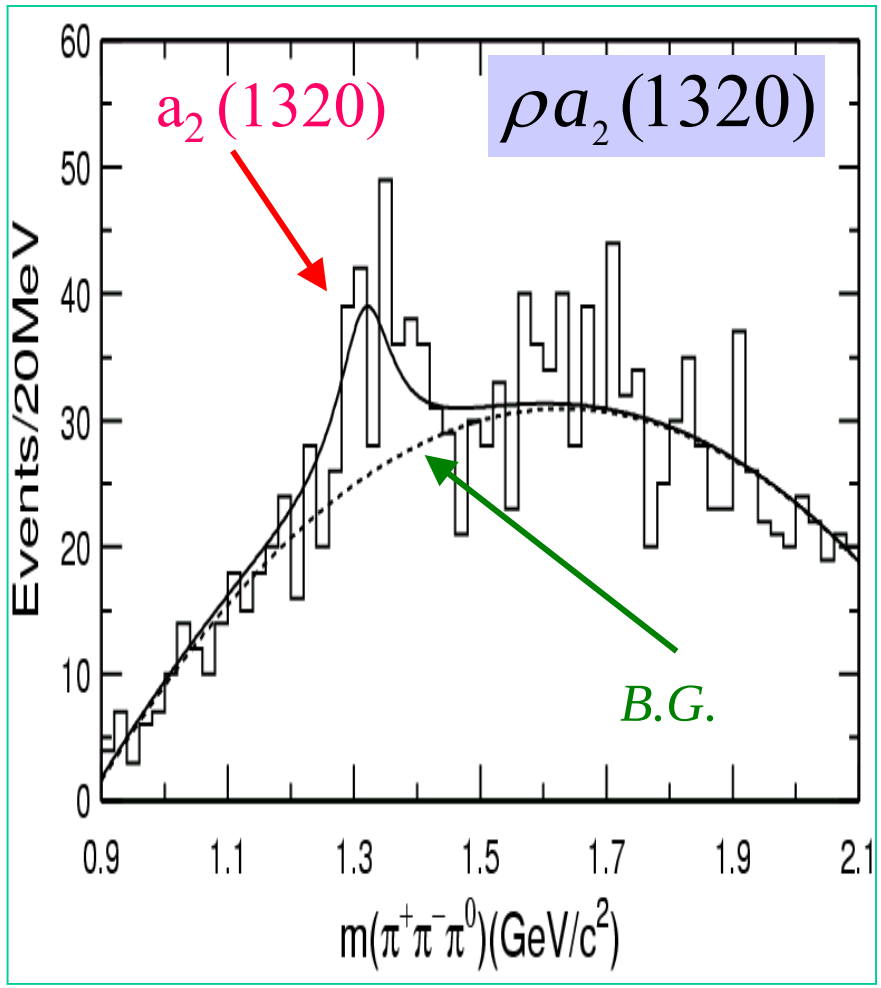
1. Four charged tracks with net charge zero;
2. $|\cos\theta|<0.80$ for all tracks;
3. PartID using TOF+dE/dx
4. At least 2 photon candidates for π^0 channels;
5. Remove $\psi(2S) \to \pi^+\pi^- J/\psi$ background;
6. Kinematic fit (4C/5C), Prob>0.01.



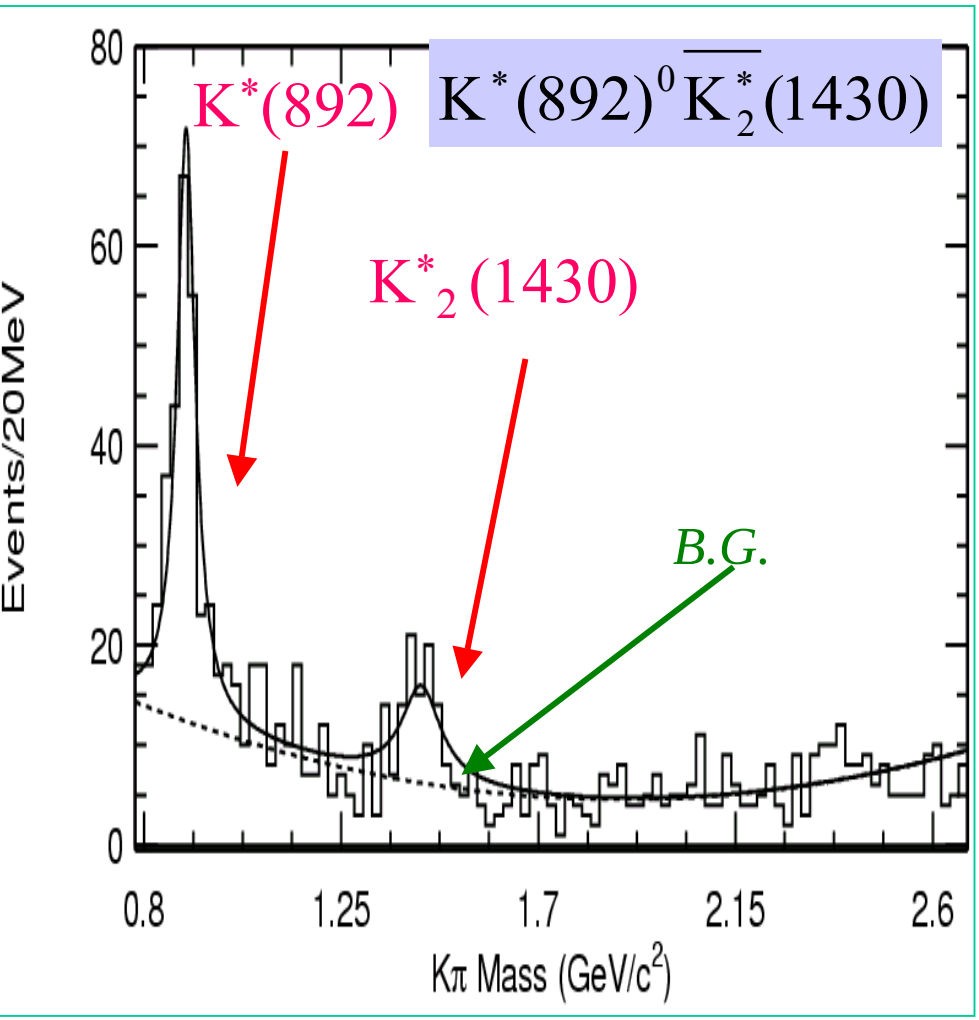


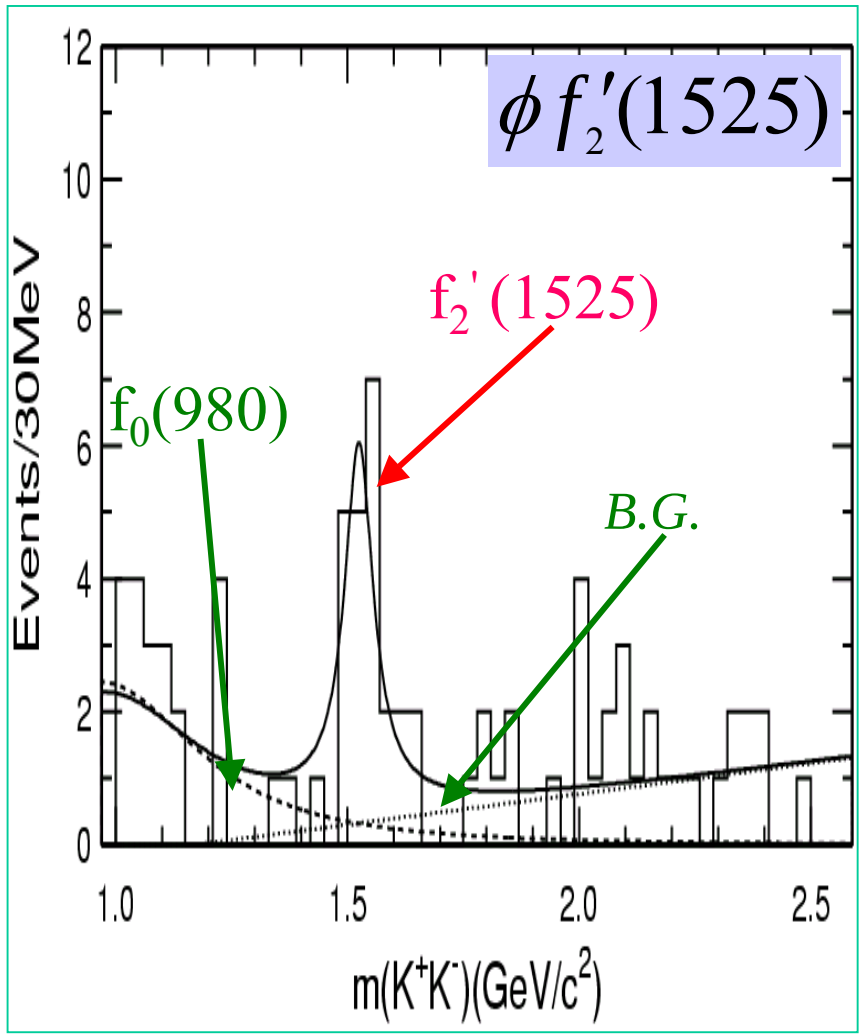
$\psi' \to V T$


$\omega f_2(1270)$
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
$m(\pi^+\pi^-\pi^0)(GeV/c^2)$

$\psi' \to V T$


K*(892)
K*(892)0 K*2(1430)
K*2(1430)
B.G.
Events/20MeV
Kπ Mass (GeV/c2)
0
20
40
60
80
0.8
1.25
1.7
2.15
2.6


φ f2'(1525)
f2'(1525)
f0(980)
B.G.
Events/30MeV
m(K+K-)(GeV/c2)
0
2
4
6
8
10
12
1.0
1.5
2.0
2.5

$\psi' \to VT$

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

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!!

Accepted by PRD

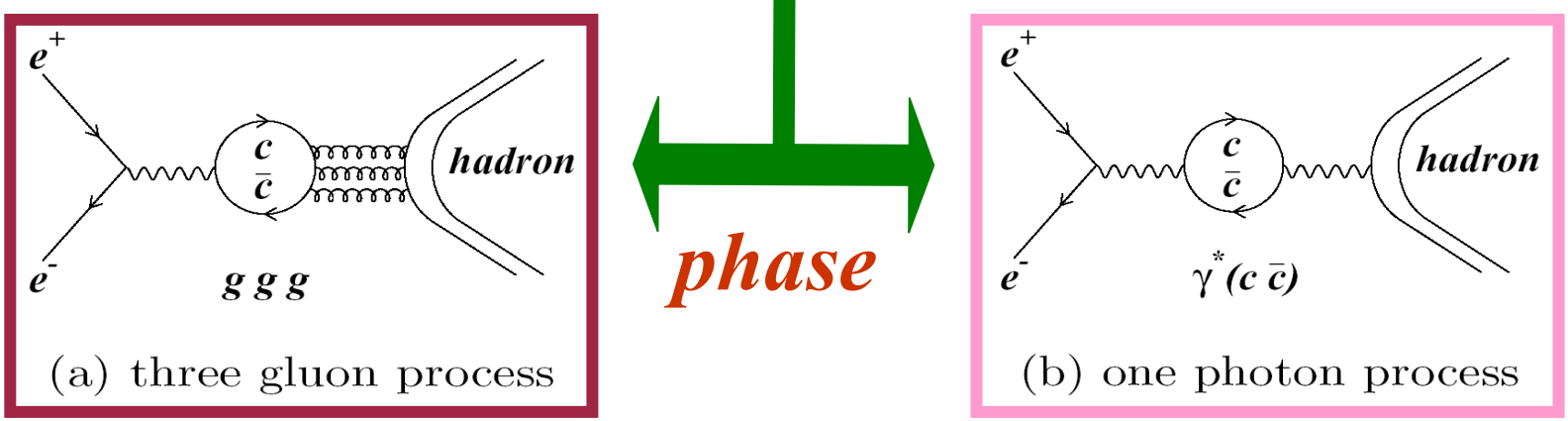
12 % rule (pQCD rule)

$\psi' \to K_S K_L$

Theoretical Background

- **pQCD rule & Phase Study**

$$B(\psi' \to K_S K_L)$$



The Relative Phase

$\psi' \to K_S K_L$

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)

ψ'→VP

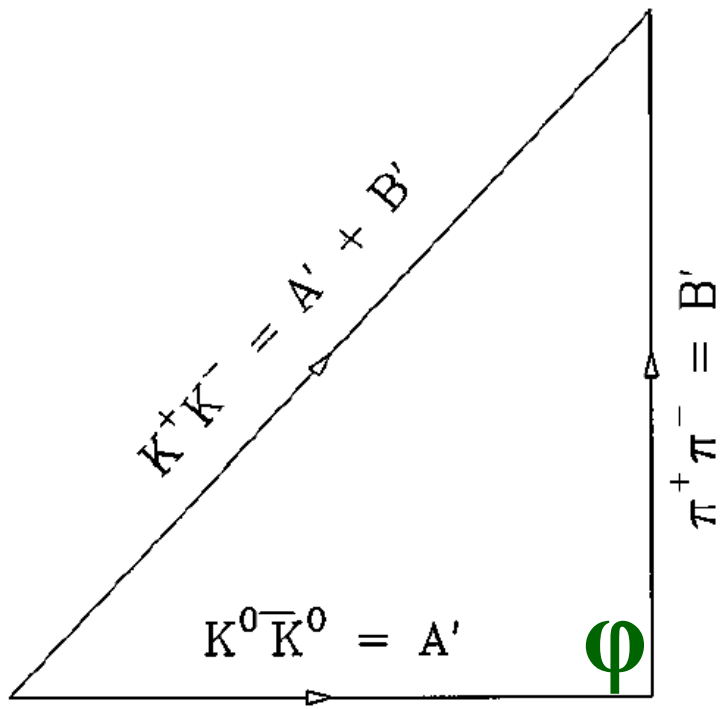
1. φ=180 ° (90 ° ruled out!)
   M. Suzuki, PRD63, 054021 (2001)
2. φ= - 90 ° or φ=180 ° (with continuum amplitude)
   P. Wang, C. Z. Yuan and X. H. Mo, PRD69, 057502 (2004)

The Relative Phase

$\psi' \to K_S K_L$

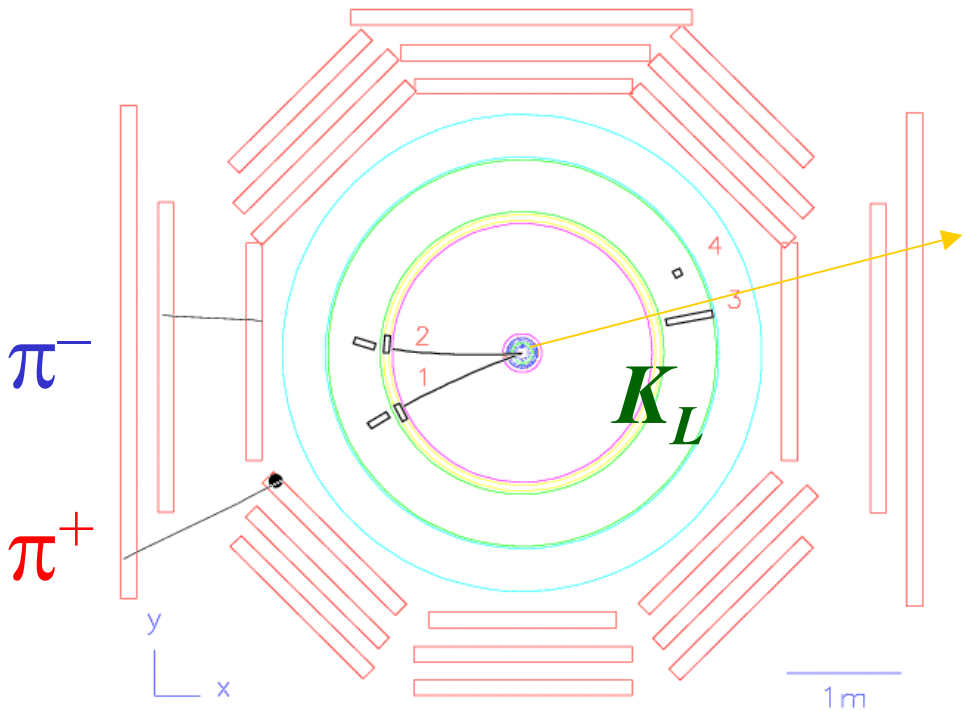
$\psi' \to$ *Pseudoscalar Pseudoscalar*

A' ($\pi^+\pi^-$) and
A'+B' (K^+K^-) known,
$K_S K_L$ is needed to extract the phase between A' and B'.



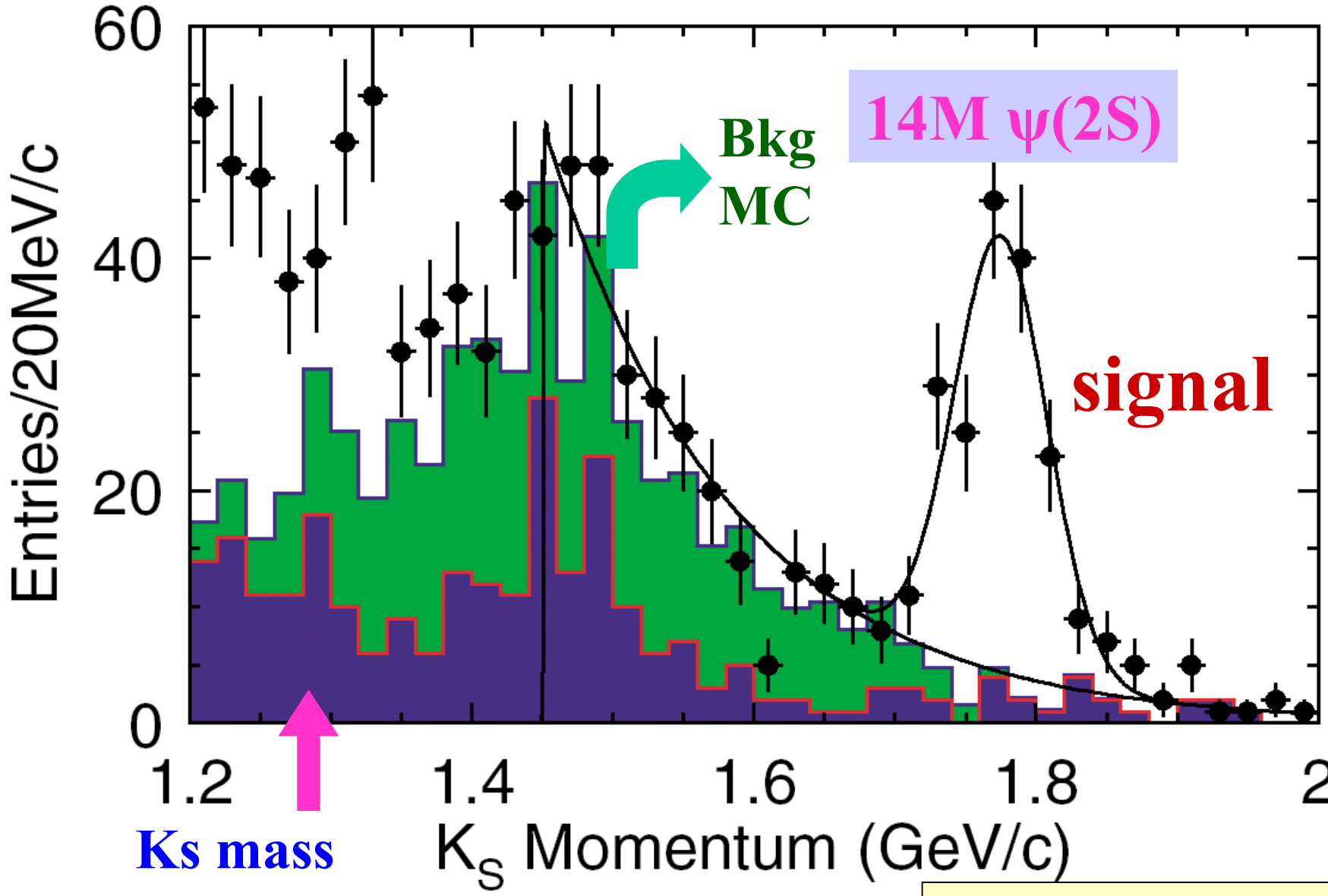
$\psi' \to K_S K_L$

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.*

$\psi' \to K_S K_L$



PRL 92, 052001 (2004)

$\psi' \to K_S K_L$

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

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

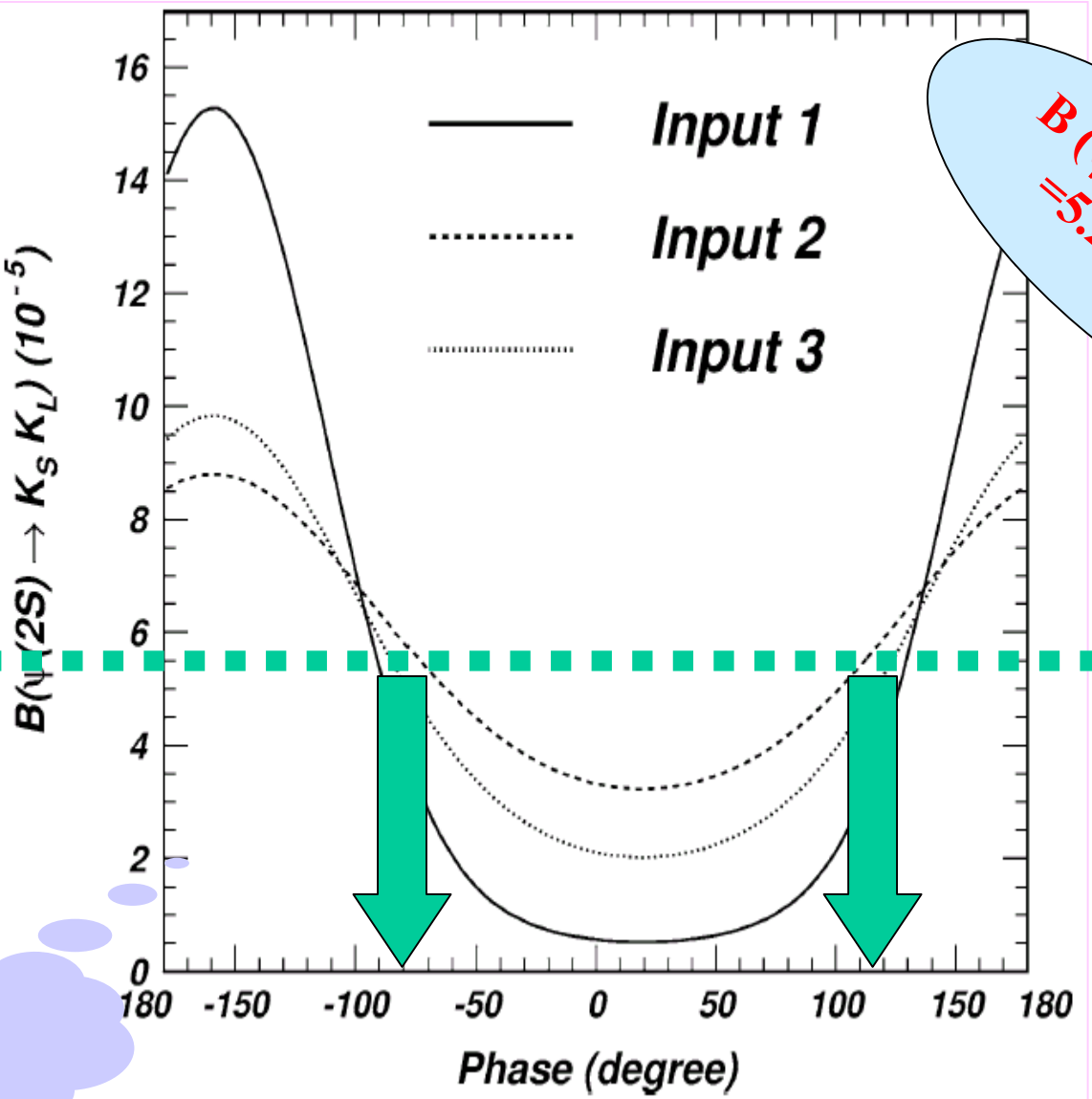
Quantity	*Value*
n^{obs}	156 ± 14
ε_{MC} (%)	41.59 ± 0.48
f (%)	74.6 ± 3.5
$N_{\psi'}$ (10^6)	14.0 ± 0.7
$B_{Ks \to \pi+\pi-}$	0.6860 ± 0.0027
$B_{\psi' \to Ks\,K\,L}$ (10^{-5})	5.24 ± 0.47 ± 0.48

PRL 92, 052001 (2004)

$\psi' \to K_S K_L$

First measurement of the phase in ψ' decays!

K^+K^- & $\pi^+\pi^-$ → inputs ;
Input 1:DASP;
Input 2:BESI ;
Input 3: K^+K^- from BESI & $\pi^+\pi^-$ by form factor.



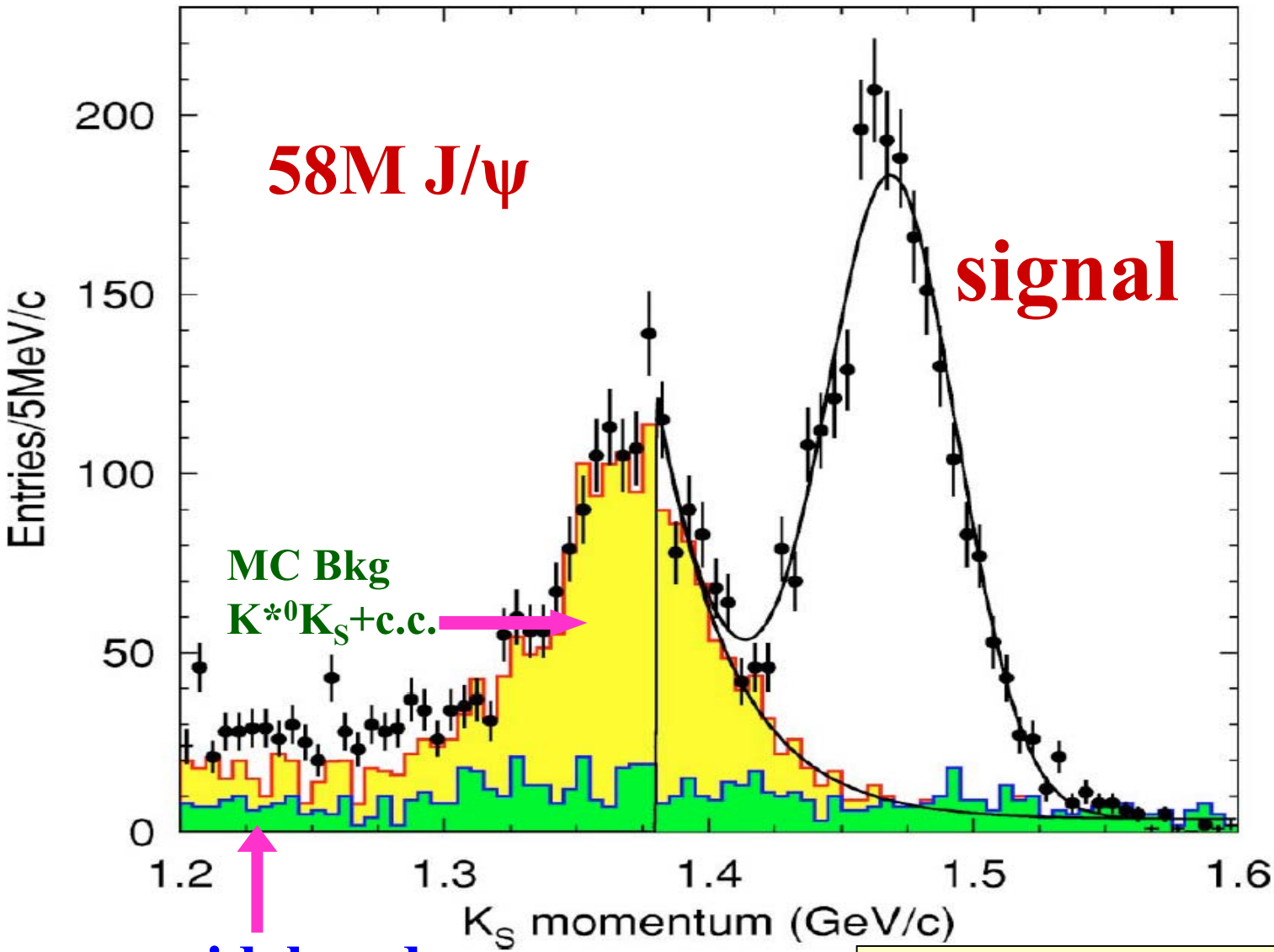
$B(\psi' \to K_S K_L) = 5.24 \times 10^{-5}$

PLB567 (2003)73

$-(82 \pm 29)°$

$(121 \pm 27)°$

$J/\psi \to K_S K_L$



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

〉 ~4σ diff.

PDG2002: $B_{J/\psi \to Ks\,K_L} = (1.08 \pm 0.14) \times 10^{-4}$

PRD 69, 012003 (2004)

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

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

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

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

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

$> 4\sigma$

B(ψ') enhanced!

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 $\psi(3770) \to K_S K_L$ to test the model!

Prediction on $\psi(3770)$ 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!

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

Measure 4 BRs:

$$\psi' \to \pi^0 J/\psi,\ \eta J/\psi$$

$$\psi' \to \gamma\ \chi_{cJ} \to \gamma\ \gamma\ J/\psi \quad (J=1,2)$$

- Different measurements deviate from each other
- **B($\psi' \to \pi^0 J/\psi$)** very crude (23 evts at CBAL, 7 evts at MRK2)
- Theoretical prediction for charmonium hadronic transition amplitude can be tested by the high statistics measurements

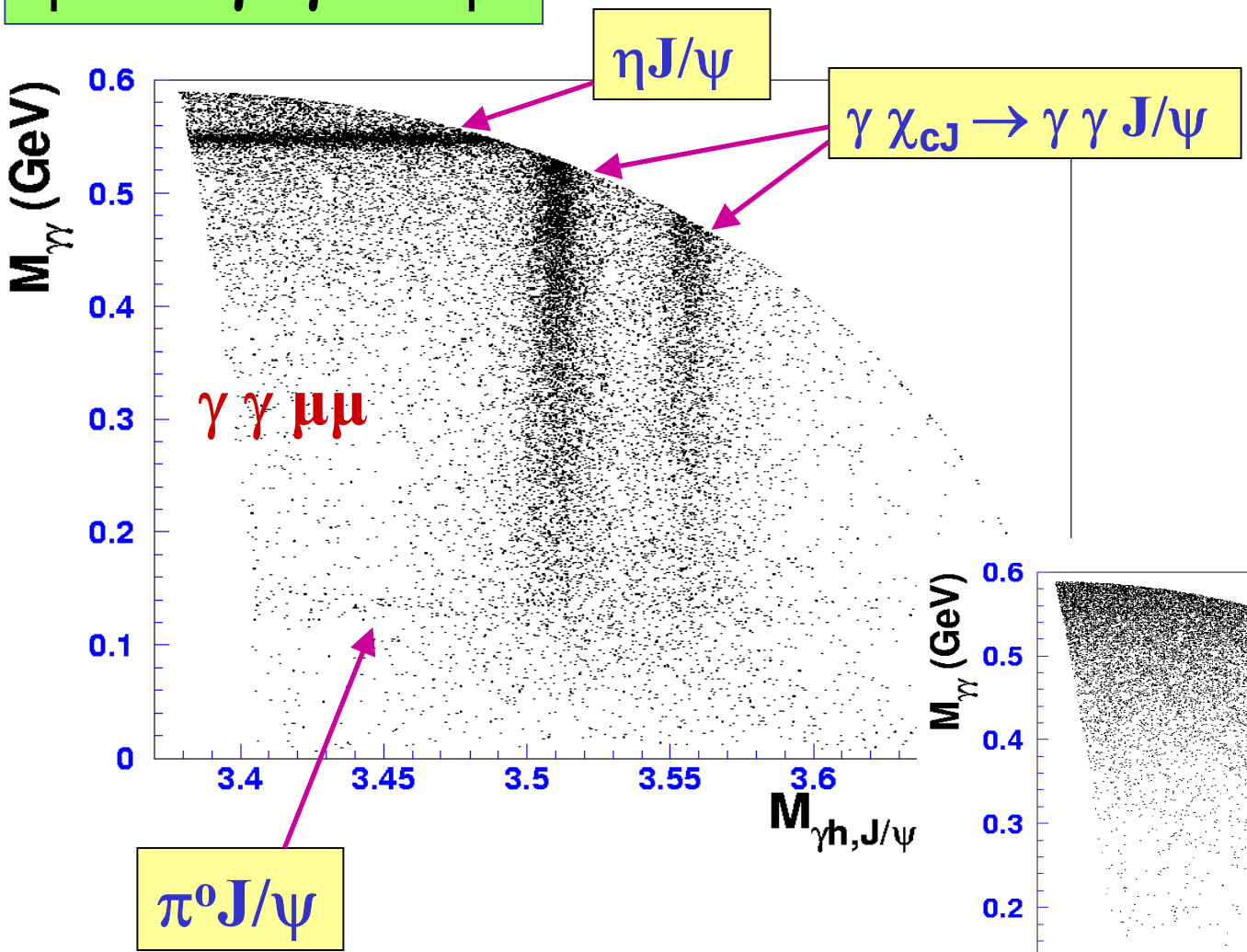
$$R = \frac{\Gamma(\psi(2S)\to\eta J/\psi)}{\Gamma(\psi(2S)\to\pi^0 J/\psi)} \qquad R' = \frac{\Gamma(\Upsilon'\to\eta\Upsilon)}{\Gamma(\psi(2S)\to\eta J/\psi)}$$

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

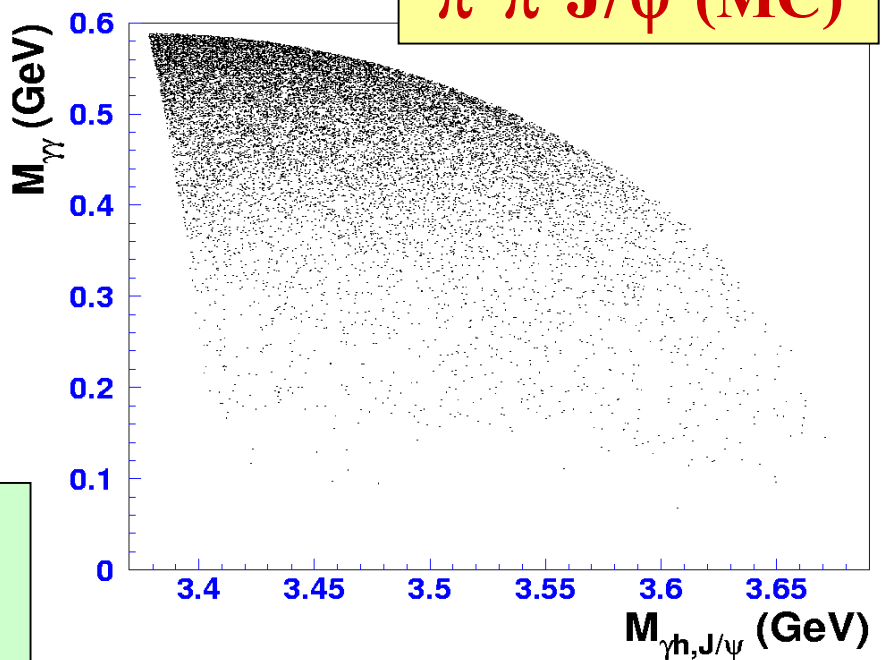
- Helicity amplitude analysis: not finished yet!

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

BES Preliminary



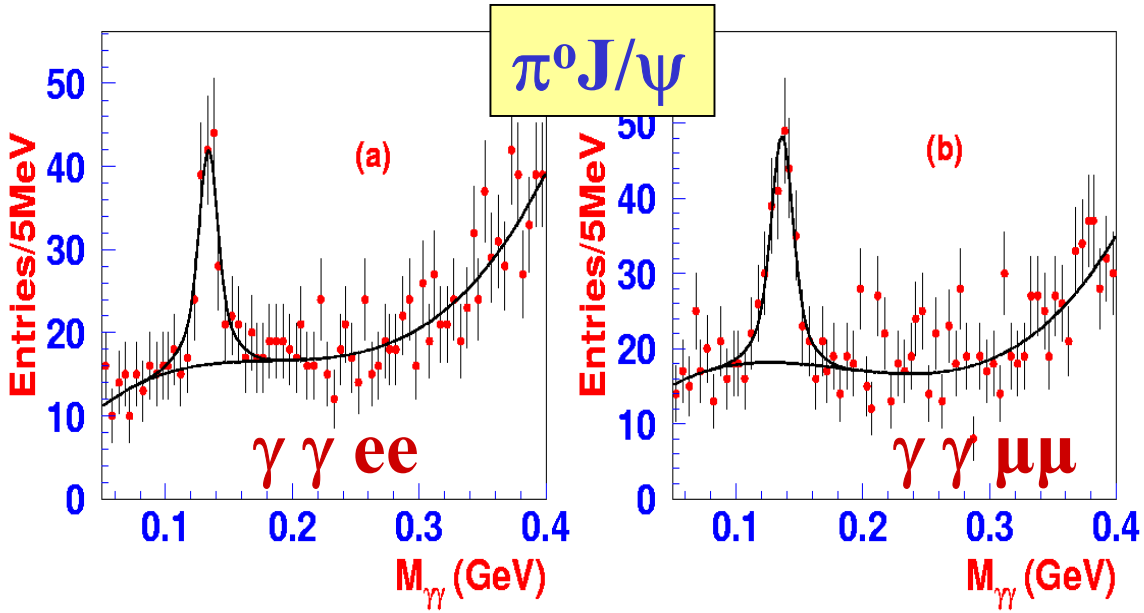
BKG from $\pi^o\pi^o J/\psi$ (MC)

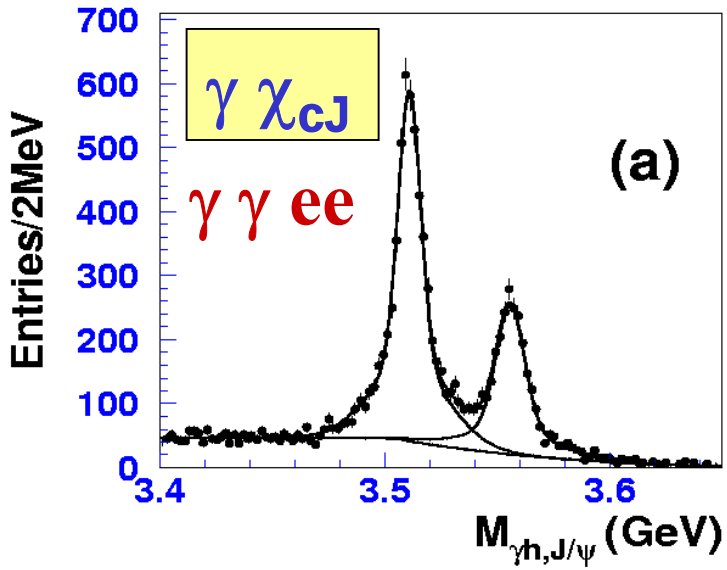


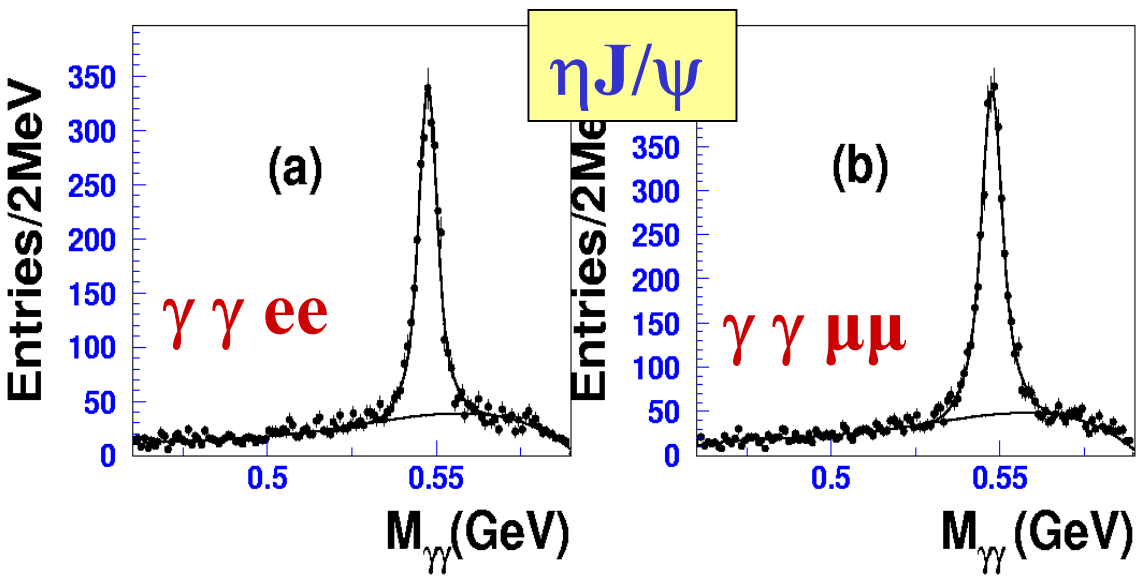
$J/\psi \to ee$ or $\mu\mu$, 5C (J/ψ mass) kinematic fit is applied!

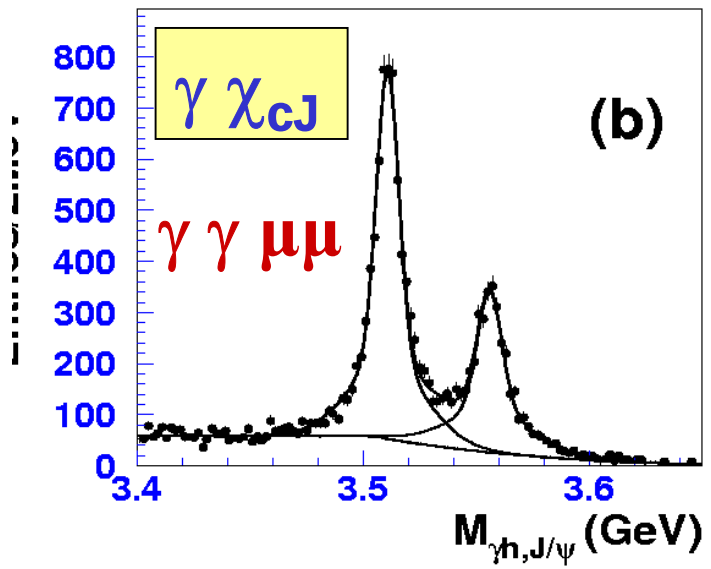
$\psi' \to \gamma\ \gamma\ J/\psi$

BES Preliminary









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

BES Preliminary

Channel	$\pi^0 J/\psi$		$\eta J/\psi$	
Final state	$\gamma\gamma e^+e^-$	$\gamma\gamma\mu^+\mu^-$	$\gamma\gamma e^+e^-$	$\gamma\gamma\mu^+\mu^-$
Number of events	123 ± 18	155 ± 20	2465 ± 101	3290 ± 148
Efficiency(%)	11.21	13.34	26.94	34.07
Sys. error (%)	9.68	8.77	8.54	8.40
Correction factor	0.962	0.974	0.962	0.974
BR (%)	$0.139 \pm 0.020 \pm 0.013$	$0.147 \pm 0.019 \pm 0.013$	$2.91 \pm 0.12 \pm 0.21$	$3.06 \pm 0.14 \pm 0.25$
Combine BR (%)	$0.143 \pm 0.014 \pm 0.013$		$2.98 \pm 0.09 \pm 0.23$	
PDG (%)	0.096 ± 0.021		3.13 ± 0.21	

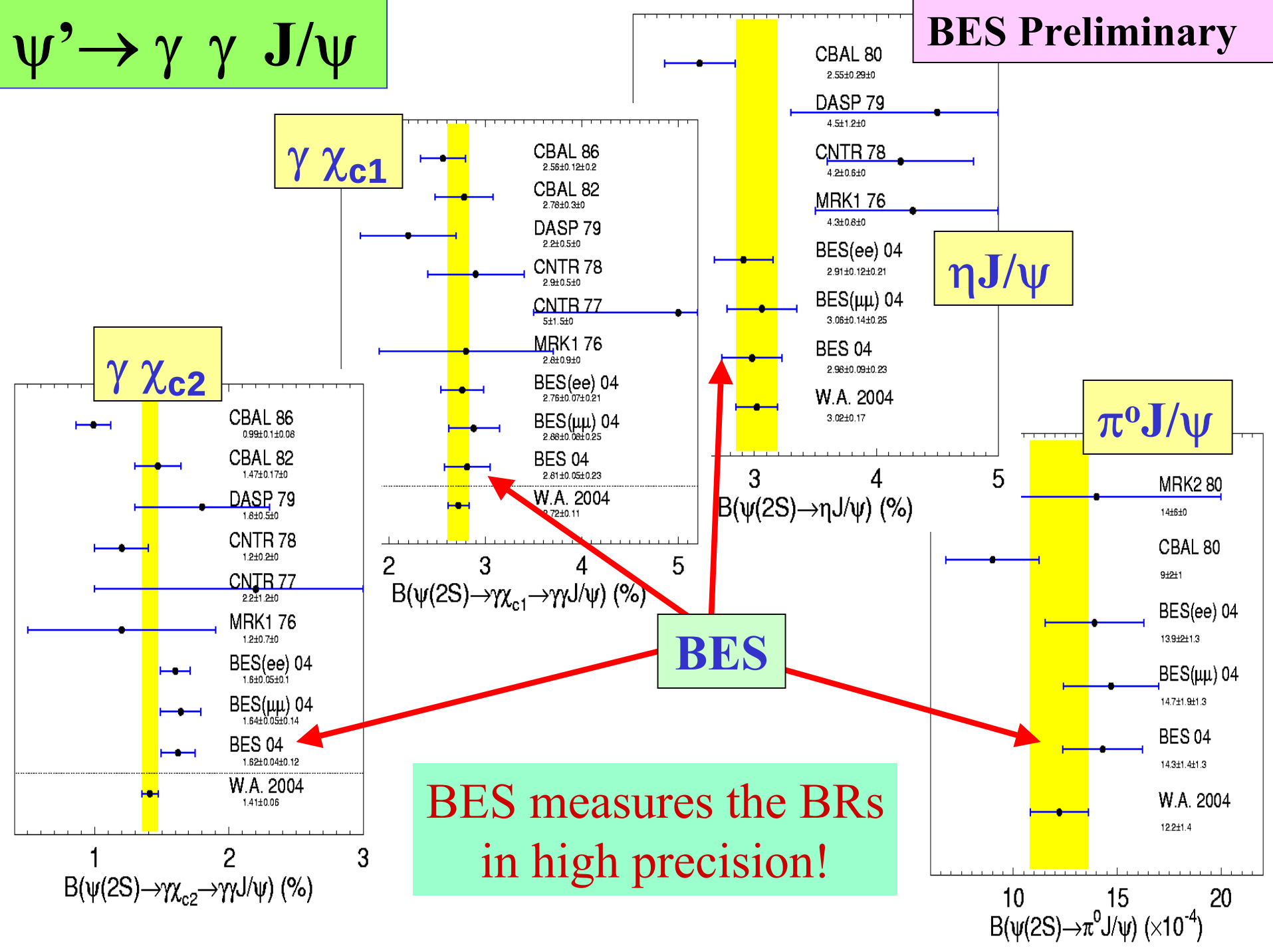
Channel	$\gamma\chi_{c1}$		$\gamma\chi_{c2}$	
Final state	$\gamma\gamma e^+e^-$	$\gamma\gamma\mu^+\mu^-$	$\gamma\gamma e^+e^-$	$\gamma\gamma\mu^+\mu^-$
Number of events	5263 ± 124	6752 ± 178	2512 ± 82	3358 ± 96
Efficiency(%)	23.88	29.24	19.70	25.54
Sys. error (%)	12.23	12.45	12.10	12.44
Correction factor	0.962	0.974	0.962	0.974
BR (%)	$8.73 \pm 0.21 \pm 1.00$	$9.11 \pm 0.24 \pm 1.12$	$7.90 \pm 0.26 \pm 0.88$	$8.12 \pm 0.23 \pm 0.99$
Combine BR (%)	$8.90 \pm 0.16 \pm 1.05$		$8.02 \pm 0.17 \pm 0.94$	
PDG (%)	8.4 ± 0.6		6.4 ± 0.6	

$$B(\psi(2S) \to \gamma\chi_{c1}) \cdot B(\chi_{c1} \to \gamma J/\psi) = (2.81 \pm 0.05 \pm 0.23)\%$$

$$B(\psi(2S) \to \gamma\chi_{c2}) \cdot B(\chi_{c2} \to \gamma J/\psi) = (1.62 \pm 0.04 \pm 0.12)\%$$

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

BES Preliminary



BES measures the BRs in high precision!

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

Discussions

BES Preliminary

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

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

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

COM for $\chi_{cJ} \rightarrow B\bar{B}$

- B($\chi_{cJ} \rightarrow$ pp-bar) from BES, PRL81, 3091 (1998); E760, NPB373, 35 (1992); R704, PLBB172, 455 (1986)

- **Nucleon wave function at small Q^2:**

$$|p,+\rangle = \frac{\varepsilon_{a_1a_2a_3}}{\sqrt{3!}} \int [\mathrm{d}x][\mathrm{d}^2\boldsymbol{k}_\perp] \times \left\{ \Psi^N_{123} |u^{a_1}_+ u^{a_2}_- d^{a_3}_+\rangle + \Psi^N_{213} |u^{a_1}_- u^{a_2}_+ d^{a_3}_+\rangle - (\Psi^N_{132} + \Psi^N_{231}) |u^{a_1}_+ u^{a_2}_+ d^{a_3}_-\rangle \right\}.$$

J.Bolz, P. Kroll, Z. Phys. A356, 327 (1996)
J.Bolz, P. Kroll, Eur. Phys. J. C2, 454 (1998)

For each s quark, introduces

$$\exp\left(-\frac{a^2_{B_8} m^2_s}{x_j}\right),$$

S. M. Wong, Eur. Phys. J. C14, 643 (2000)

BES can measure them!

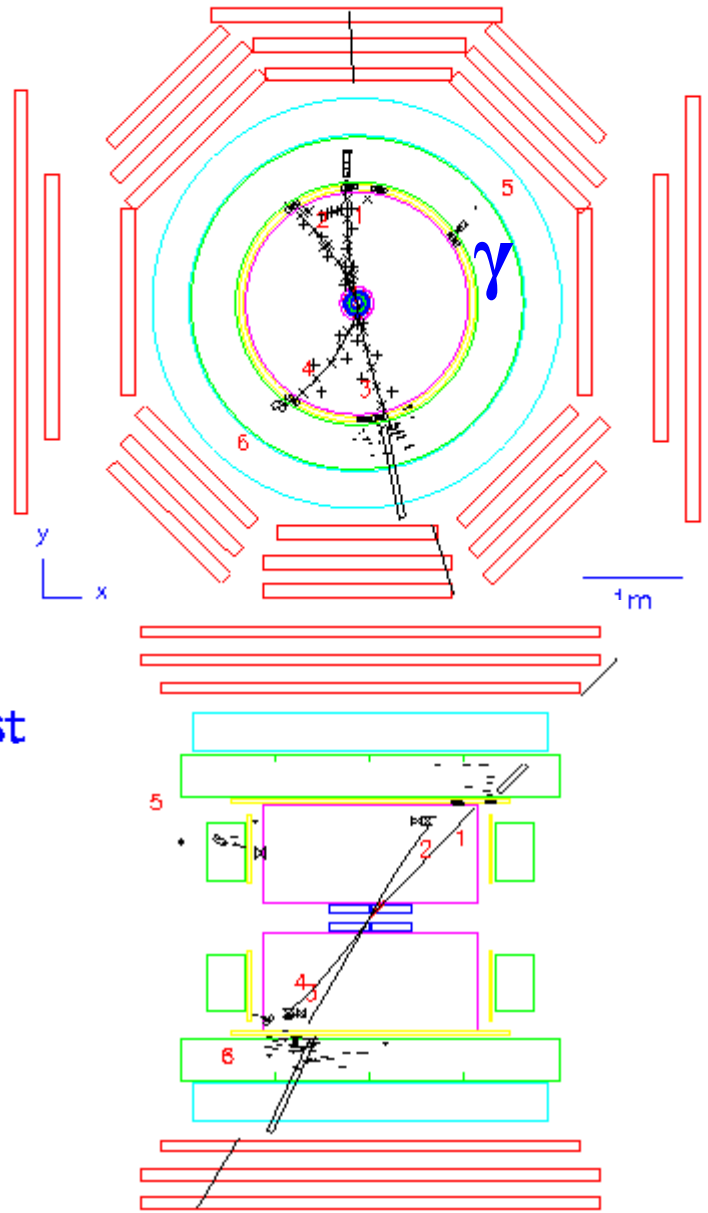
Octet Baryons	$\Gamma^{(1)+(8)}$ (eV) J=1	J=2	Decuplet Baryons	$\Gamma^{(1)+(8)}$ (eV) J=1	J=2
$\chi_J \to NN$	(56.27)	154.19	$\chi_J \to \Delta\Delta$	33.49	124.62
$\chi_J \to \Sigma\bar{\Sigma}$	28.42	97.69	$\chi_J \to \Sigma^*\bar{\Sigma}^*$	18.46	71.09
$\chi_J \to \Xi\bar{\Xi}$	21.49	72.62	$\chi_J \to \Xi^*\bar{\Xi}^*$	9.42	41.16
$\chi_J \to \Lambda\bar{\Lambda}$	33.64	69.19			

$\chi_{cJ} \to \Lambda\overline{\Lambda}$

Event Selection

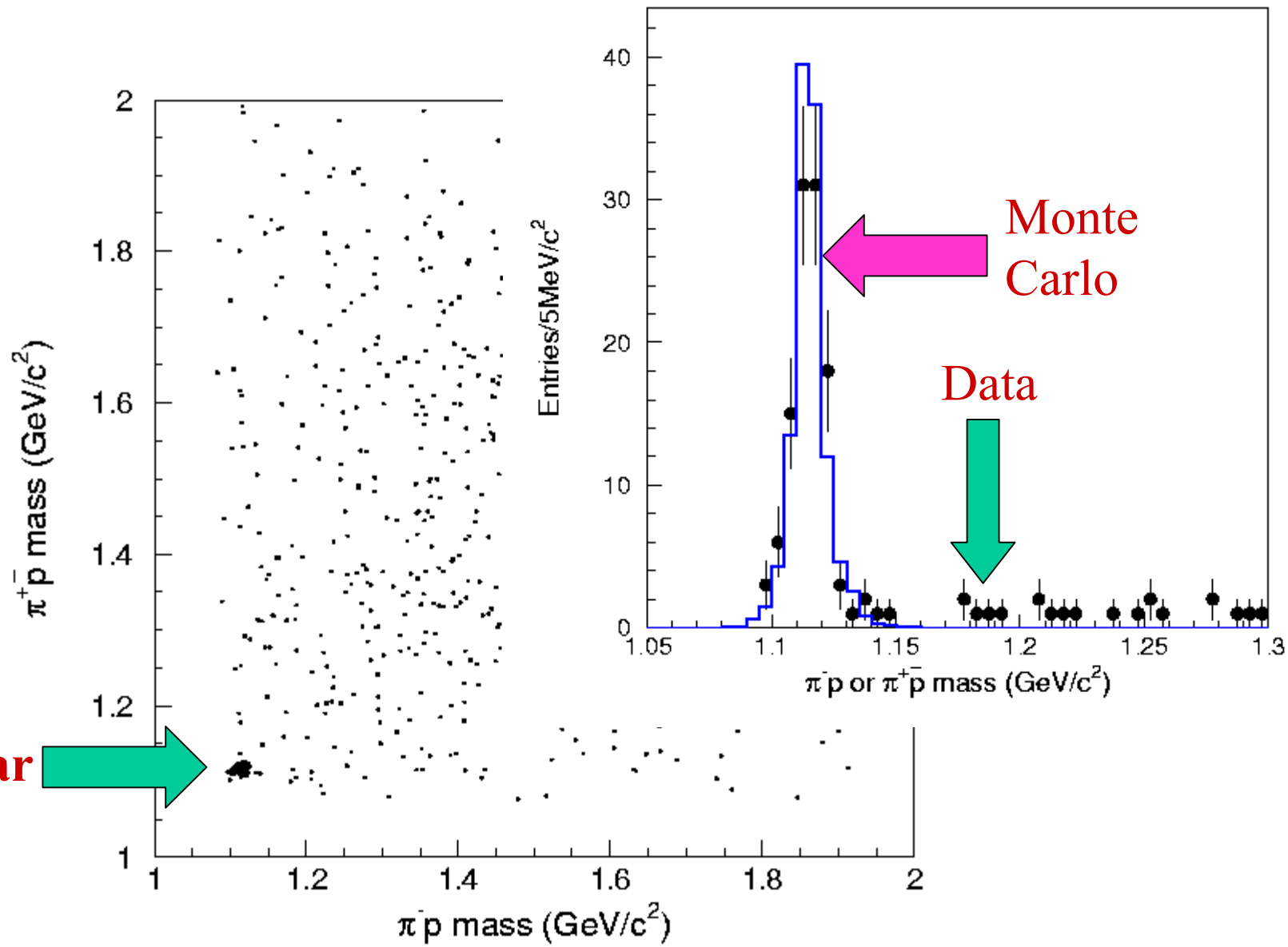
Final states: $\gamma\pi^+\pi^-$pp-bar

- NCHRG=4, MFIT=2, $\Sigma Q = 0$
- $|\cos\theta| < 0.8$
- Low momentum tracks: $\pi^{\pm}$
  High momentum tracks: $p/\overline{p}$
- Select photon which makes χ^2_{4C} smallest
  (photon ID = BESI)
- ProbID>1% for each track
  (PID code optimized for $\psi(2S)$ data)
- Prob4C>1%

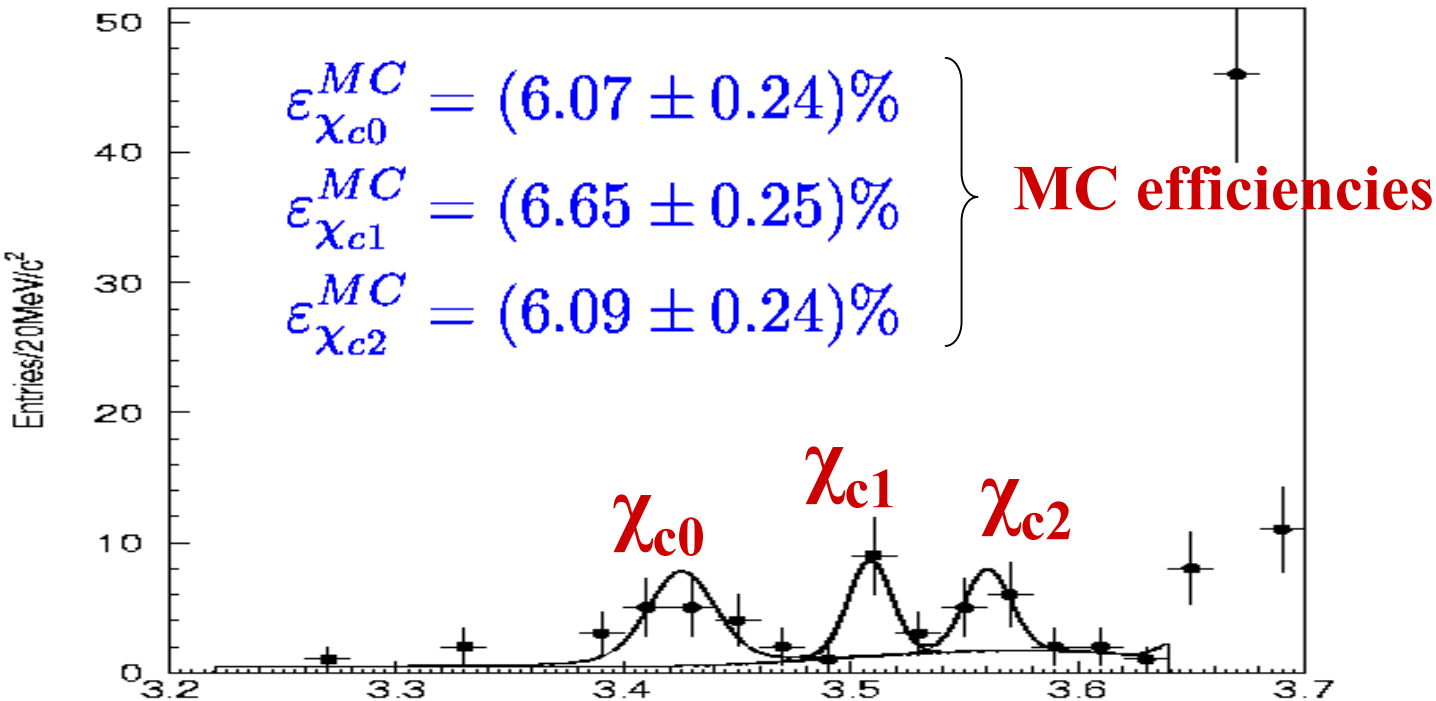


$\chi_{cJ} \rightarrow \Lambda\overline{\Lambda}$

Λ signal in πp mass



$\chi_{cJ} \to \Lambda\overline{\Lambda}$ Fit the mass spectrum



State	Stat. Sign.	Mass (MeV)	Events
χ_{c0}	4.5σ	3425.6 ± 6.3	$15.2^{+4.2}_{-4.0}$
χ_{c1}	3.5σ	3508.5 ± 3.9	$9.0^{+3.5}_{-3.1}$
χ_{c2}	2.6σ	3560.3 ± 4.6	$8.3^{+3.7}_{-3.4}$

$\chi_{cJ} \to \Lambda\bar{\Lambda}$

$$B_{\chi_{cJ}\to\Lambda\bar{\Lambda}} = \frac{n^{obs}/\varepsilon}{N_{\psi'}\cdot B_{\psi'\to\gamma\chi_{cJ}}\cdot B^2_{\Lambda\to\pi^- p}}$$

Quantity	χ_{c0}	χ_{c1}	χ_{c2}
n^{obs}	15.2	9.0	8.3
$\varepsilon(\%)$	6.07 ± 0.24	6.65 ± 0.25	6.09 ± 0.24
$N_{\psi'}$		14.9 ± 1.2	
$B_{\Lambda\to\pi^- p}$		0.639 ± 0.005	
$B_{\psi'\to\gamma\chi_{cJ}}$	8.7 ± 0.8	8.4 ± 0.7	6.8 ± 0.6
$B_{\chi_{cJ}\to\Lambda\bar{\Lambda}}\ (10^{-4})$	$4.7\ ^{+1.3}_{-1.2} \pm 1.0$	$2.6\ ^{+1.0}_{-0.9} \pm 0.6$	$3.3\ ^{+1.5}_{-1.3} \pm 0.7$

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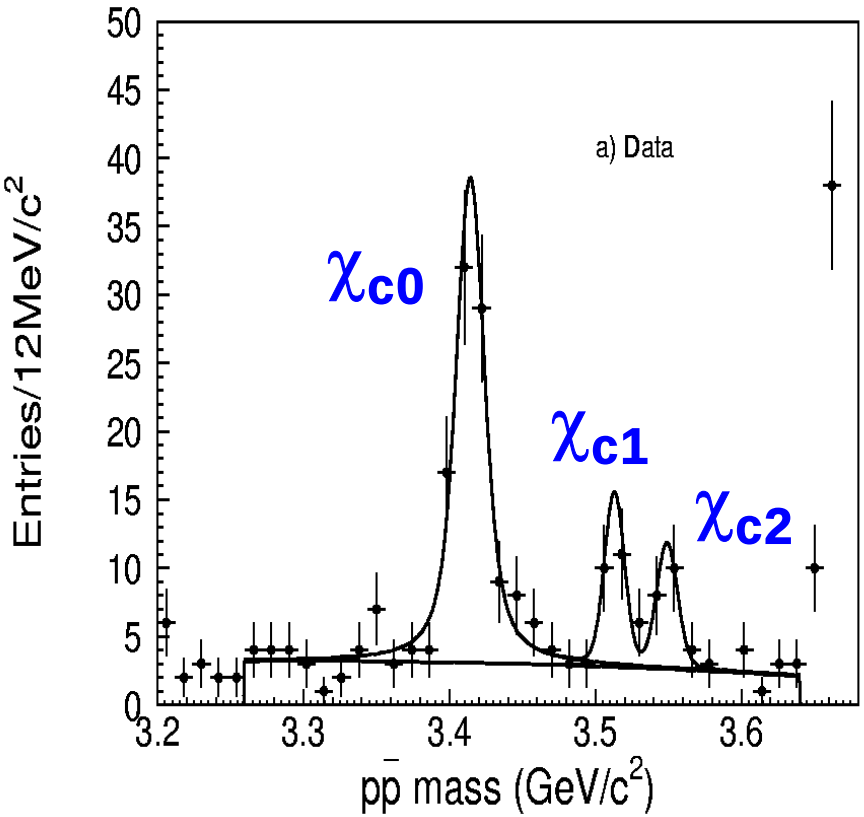
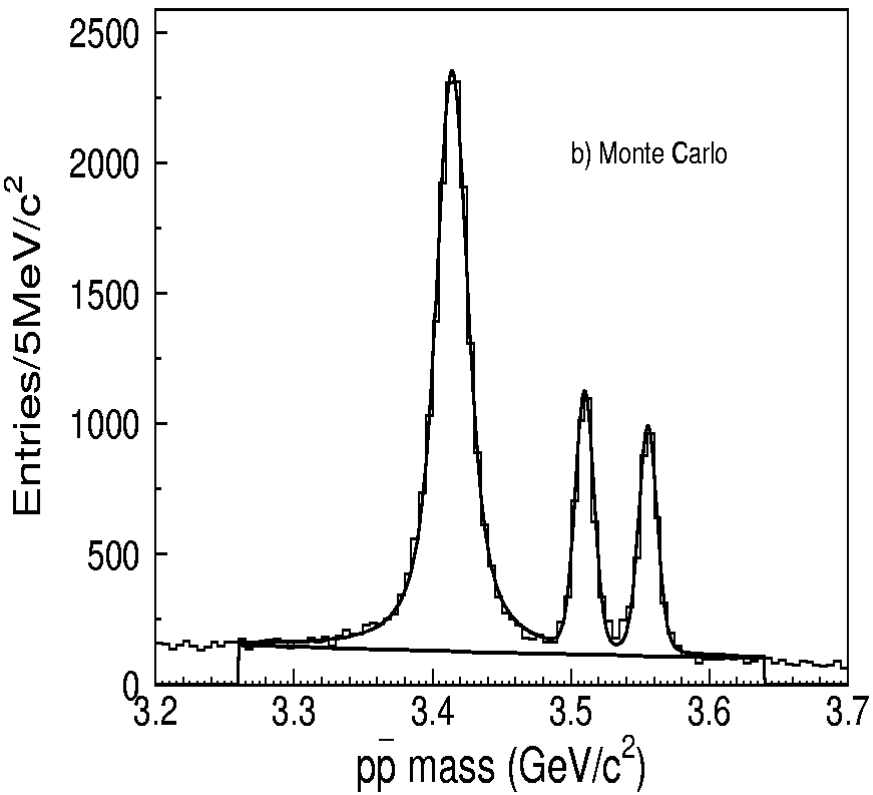
$\chi_{cJ} \to p\bar{p}$

Final states: γpp-bar





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$\chi_{cJ} \to p\bar{p}$

$$\mathcal{B}(\chi_{cJ} \to p\bar{p}) = \frac{n^{obs}/(\varepsilon \cdot f)}{N_{\psi(2S)} \cdot B[\psi(2S) \to \gamma\chi_{cJ}]}$$

quantity	χ_{c0}	χ_{c1}	χ_{c2}
n^{obs}	89.5^{+14}_{-13}	$18.2^{+5.5}_{-4.9}$	$14.3^{+5.2}_{-4.7}$
ε (%)	27.49±0.30	27.42±0.56	23.26±0.50
f	0.987	0.992	0.995
$N_{\psi(2S)}(10^6)$		14	
$\mathcal{B}[\psi(2S) \to \gamma\chi_{cJ}](\%)$	(8.7±0.8)%	(8.4±0.7)%	(6.8±0.6)%
$\mathcal{B}(\chi_{cJ} \to p\bar{p})$ (10^{-5})	$27.1^{+4.3}_{-3.9} \pm 4.7$	$5.7^{+1.7}_{-1.5} \pm 0.9$	$6.5^{+2.4}_{-2.1} \pm 1.0$
$R_{\mathcal{B}}$	1.73 ± 0.63	4.56 ± 2.34	5.08 ± 3.08

$$R_{\mathcal{B}} = \frac{n^{obs}_{\Lambda\bar{\Lambda}}/[\varepsilon_{\Lambda\bar{\Lambda}} \cdot \mathcal{B}(\Lambda \to \pi^- p)^2]}{n^{obs}_{p\bar{p}}/\varepsilon_{p\bar{p}}}$$

PRD, in press

COM for $\chi_{cJ} \to B\bar{B}$

Discussions

$(\times 10^{-4})$	χ_{c0}	χ_{c1}	χ_{c2}
$B(\chi_{cJ} \to \Lambda\bar{\Lambda})$	$4.7^{+1.3}_{-1.2} \pm 1.0$	$2.6^{+1.0}_{-0.9} \pm 0.6$	$3.3^{+1.5}_{-1.3} \pm 0.7$
$B(\chi_{cJ} \to p\bar{p})(PDG02)$	2.2 ± 0.5	0.72 ± 0.13	0.74 ± 0.10
$B(\chi_{cJ} \to p\bar{p})$	$2.71^{+0.43}_{-0.39} \pm 0.47$	$0.57^{+0.17}_{-0.15} \pm 0.09$	$0.65^{+0.24}_{-0.21} \pm 0.10$

- **COM predicts: for χ_{c1} and χ_{c2}.**

  $\Gamma(\chi_{cJ} \to \Lambda\ \Lambda$-bar) ~½ $\Gamma(\chi_{cJ} \to$ p p-bar)

- **BES results for $B(\chi_{cJ} \to \Lambda\bar{\Lambda})$ and $B(\chi_{cJ} \to p\bar{p})$**

  do NOT agree with COM prediction

- **No prediction for χ_{c0}**

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

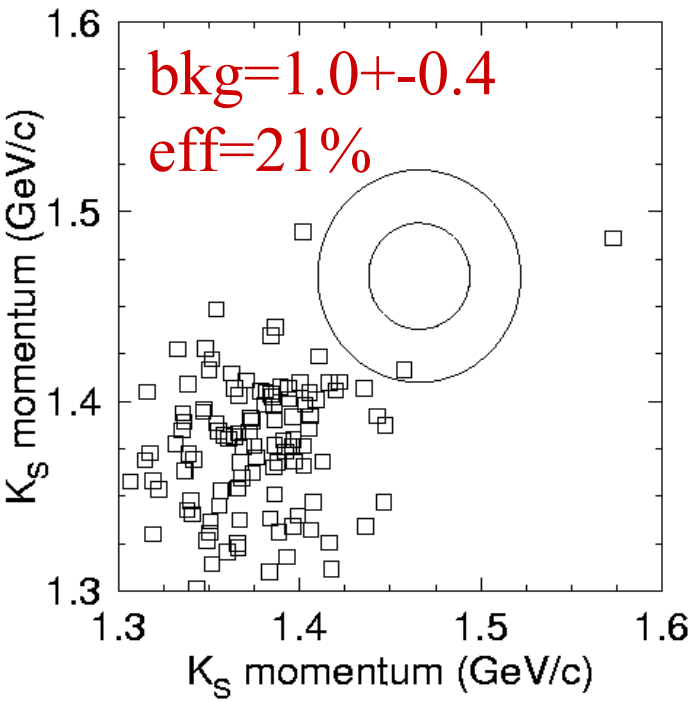
- 4 good charged tracks
- Q(sum) = 0
- $|\cos\theta| < 0.8$
- K_S decay length

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

ψ', $J/\psi \to K_S K_S$

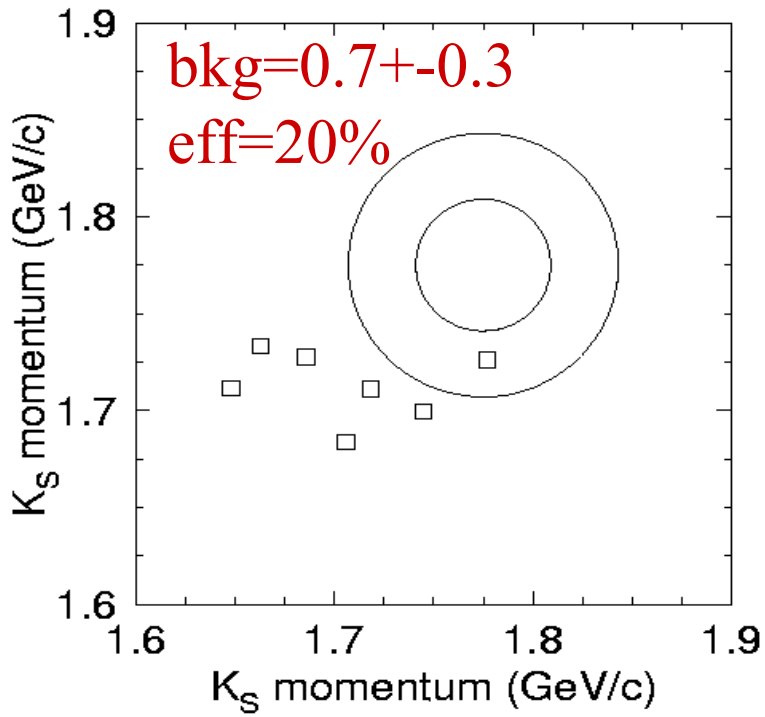
2 circles – 1 σ & 2 σ regions from MC

1 evt in 2 σ region



$J/\psi \to K_S K_S$ candidate

1 evt in 2 σ region



$\psi' \to K_S K_S$ candidate

ψ', $J/\psi \to K_S K_S$

Upper Limits (@95% C.L.)

R	J/ψ	$\psi(2S)$
n^{obs}	1	1
n_{UL}^{obs}	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
$\mathcal{B}(K_S^0 \to \pi^+\pi^-)$	0.6860 ± 0.0027	
$\mathcal{B}(R \to K_S^0 K_S^0) <$	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)

Summary

- $\psi' \rightarrow$ VT channels ωf_2 , ρa_2 , $K^* \overline{K^*}_2$ and $\phi f_2'$ are first observed and branching ratios are measured. The suppression of VT in ψ' is confirmed.
- First observation of $K^0_S K^0_L$ in ψ' decay. Improved measurement of $J/\psi \rightarrow K^0_S K^0_L$.

  ψ' is enhanced relative to the pQCD 12% rule.

  The phase for $\psi' \rightarrow$ PP is -82° or $+121^\circ$.
- $\psi' \rightarrow \gamma\gamma J/\psi$ is studied to measure the BRs.
- Relative BR between $\Lambda\overline{\Lambda}$ and $p\overline{p}$ in χ_{cJ} decays disagrees with "COM+baryon wave function" calculation.
- No $K^0_S K^0_S$ signal observed in ψ' and J/ ψ decays.

Thanks a lot !

谢谢！