Recent results on Charmonium decays at BESII

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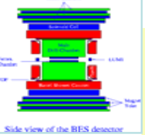
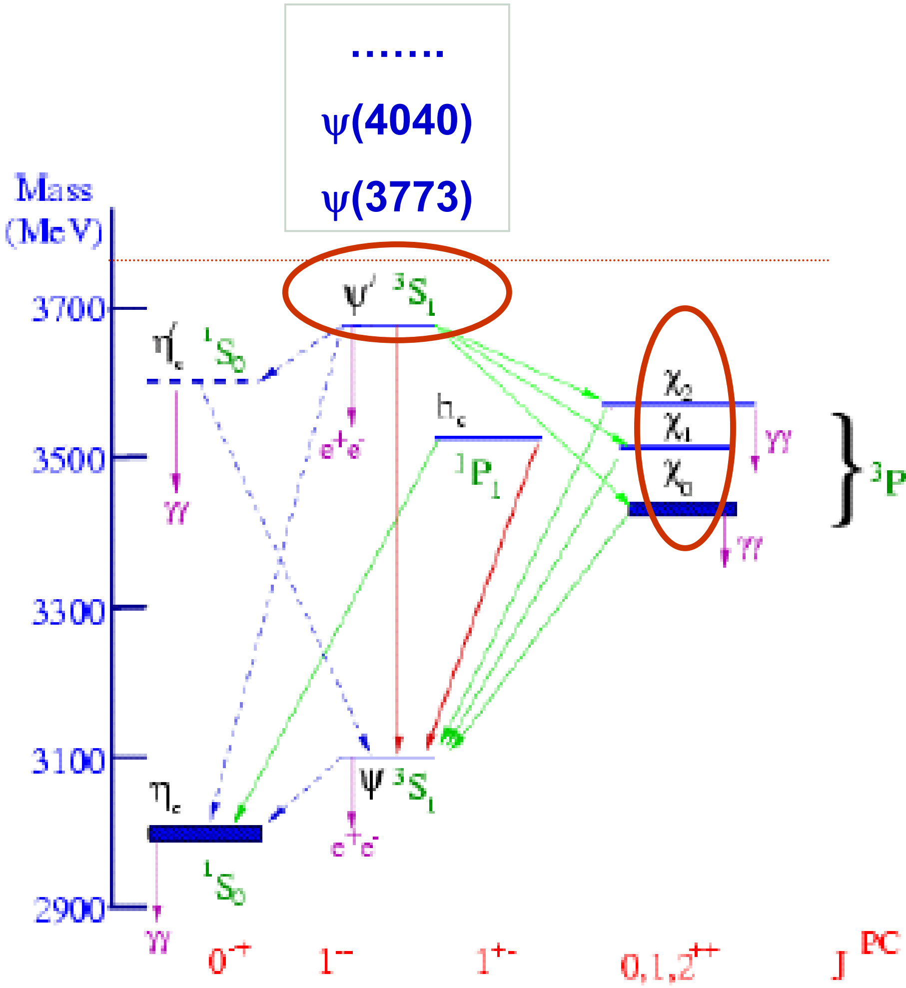
For BES Collaboration.

Results and perspective of particle physics
20th Les Rencontres de Physique de la Vallée d'Aoste
La Thuile, Aosta Valley, March 5-11, 2006

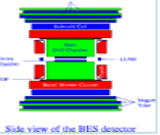


Focus on $\psi(2S)$ and χ_{cJ} decays from BES:

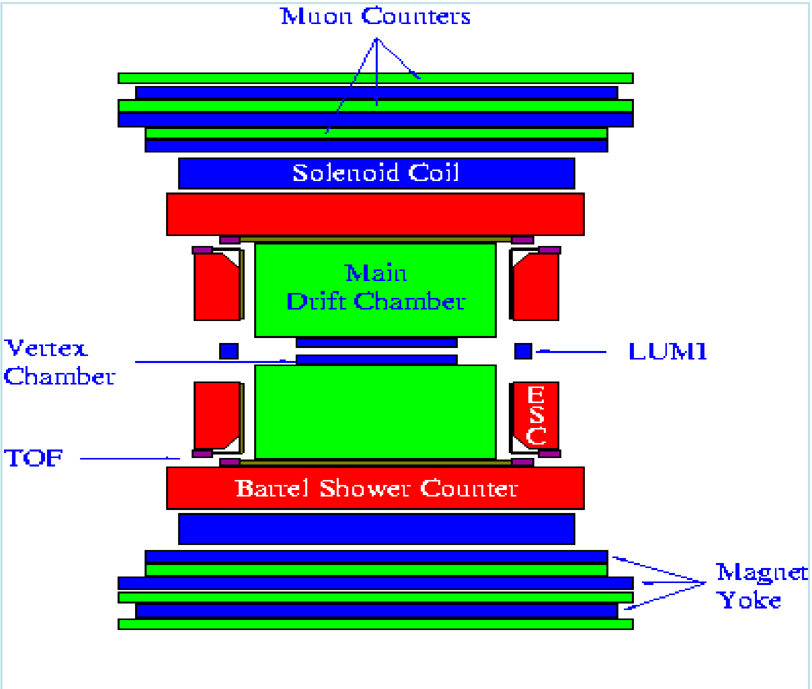


Charmonium states under the $D\overline{D}$ threshold.

- Partial Wave Analysis of $\chi_{c0}\to K^+K^-\pi^+\pi^-$
- Observation of $\chi_{c0,2}\to\omega\omega$.
- Analysis of $\chi_{cJ}\to 2(K^+K^-)$
- Measurement of $\chi_{cJ}\to 2(\pi^+\pi^-)p\overline{p}$
- Measurements of $\psi(2S)\to \gamma K\overline{K}\pi,\ \gamma\eta\pi^+\pi^-,$ $K^+K^-\pi^+\pi^-\pi^0$



BES Detector and the data

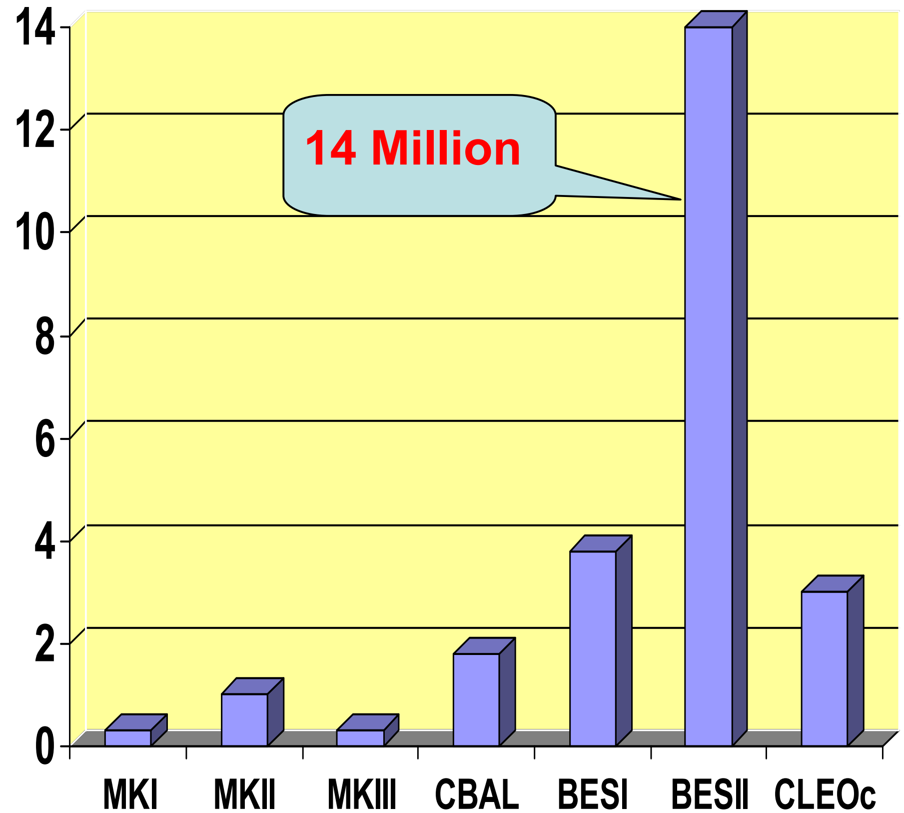


Side view of the BES detector

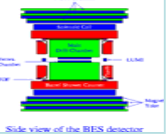
Tracking: Main Drift Chamber

Photon ID: BSC

Hadron ID: MDC(dE/dx)+TOF



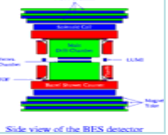
6.42 pb^{-1} continuum data (Ecm=3.65GeV) was used to estimate the continuum bg.



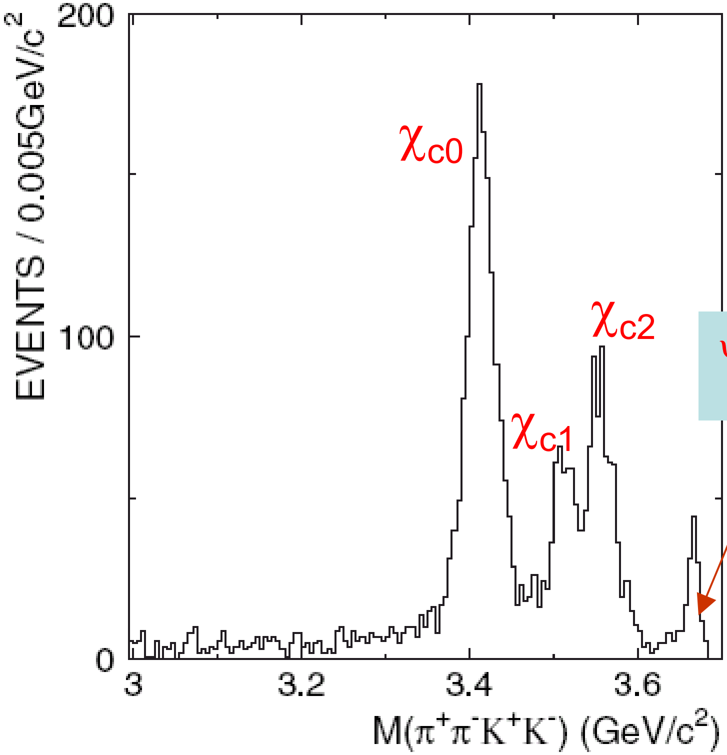
Introduction

♣$\psi(2S)$ and χ_{cJ} decay properties are essential to test perturbative QCD models and QCD based calculations, such as the "12% rule", COM...

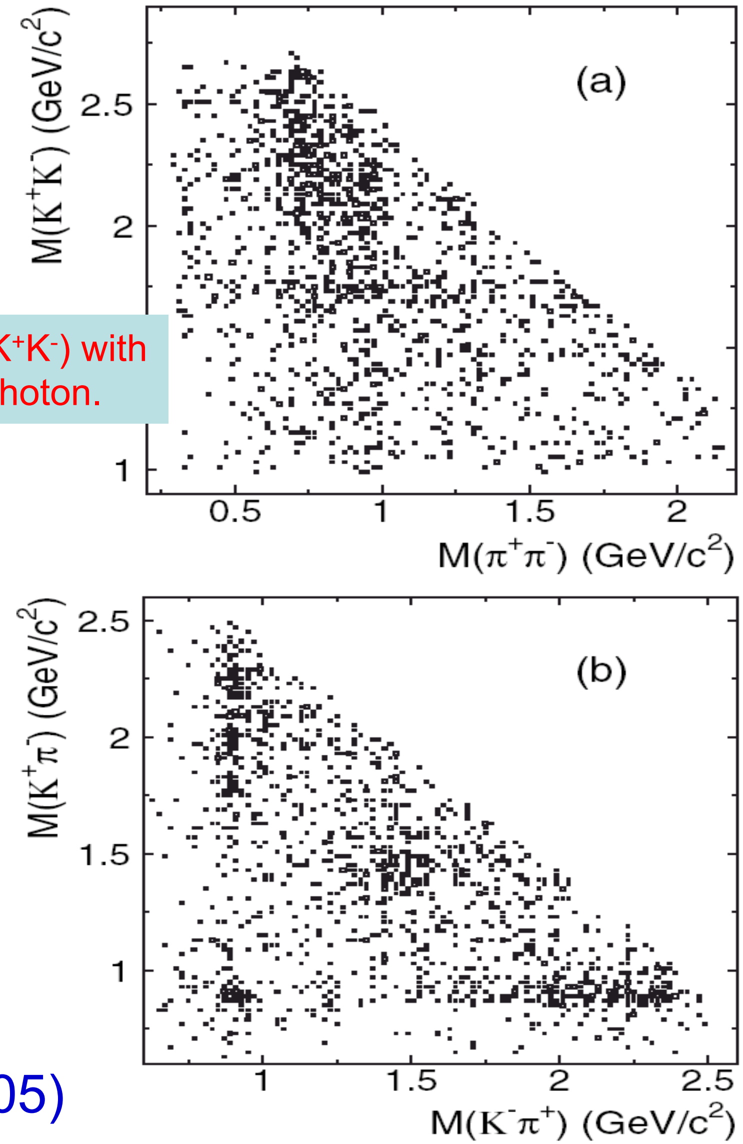
♣The decays of χ_{cJ} provide a direct window on gluecall dynamics in the 0^{++} and 2^{++} channels, as the χ_{cJ} hadronic decays may proceed via $c\bar{c} \rightarrow gg \rightarrow q\bar{q}q\bar{q}$



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



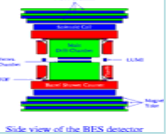
$\psi(2S) \to 2(K^+K^-)$ with a fake photon.



1371 samples for PWA;

About 29 background;

P.R.D72, 092002 (2005)



PWA of $\chi_{c0} \rightarrow \pi^+ \pi^- K^+K^-$

•Selected events are fitted with the unbinned ML method;

•The amplitude of the process $\psi(2S) \rightarrow \gamma\chi_{c0}$, $\chi_{c0} \rightarrow X+Y \rightarrow \pi^+ \pi^- K^+K^-$ are described by the relativistic covariant tensor amplitudes.

$$A = \psi_\mu(m_1)e^*_\nu(m_2)A^{\mu\nu} = \psi_\mu(m_1)e^*_\nu(m_2)\sum_i \Lambda_i U_i^{\mu\nu}$$

•$\psi(2S)$ polarization four-vector;

•Polarization four-vector of the photon (Coulonb gauge are assumed;

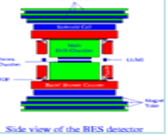
•Particle wave amplitude with different J^{pc};

•Coupling strength(complex)

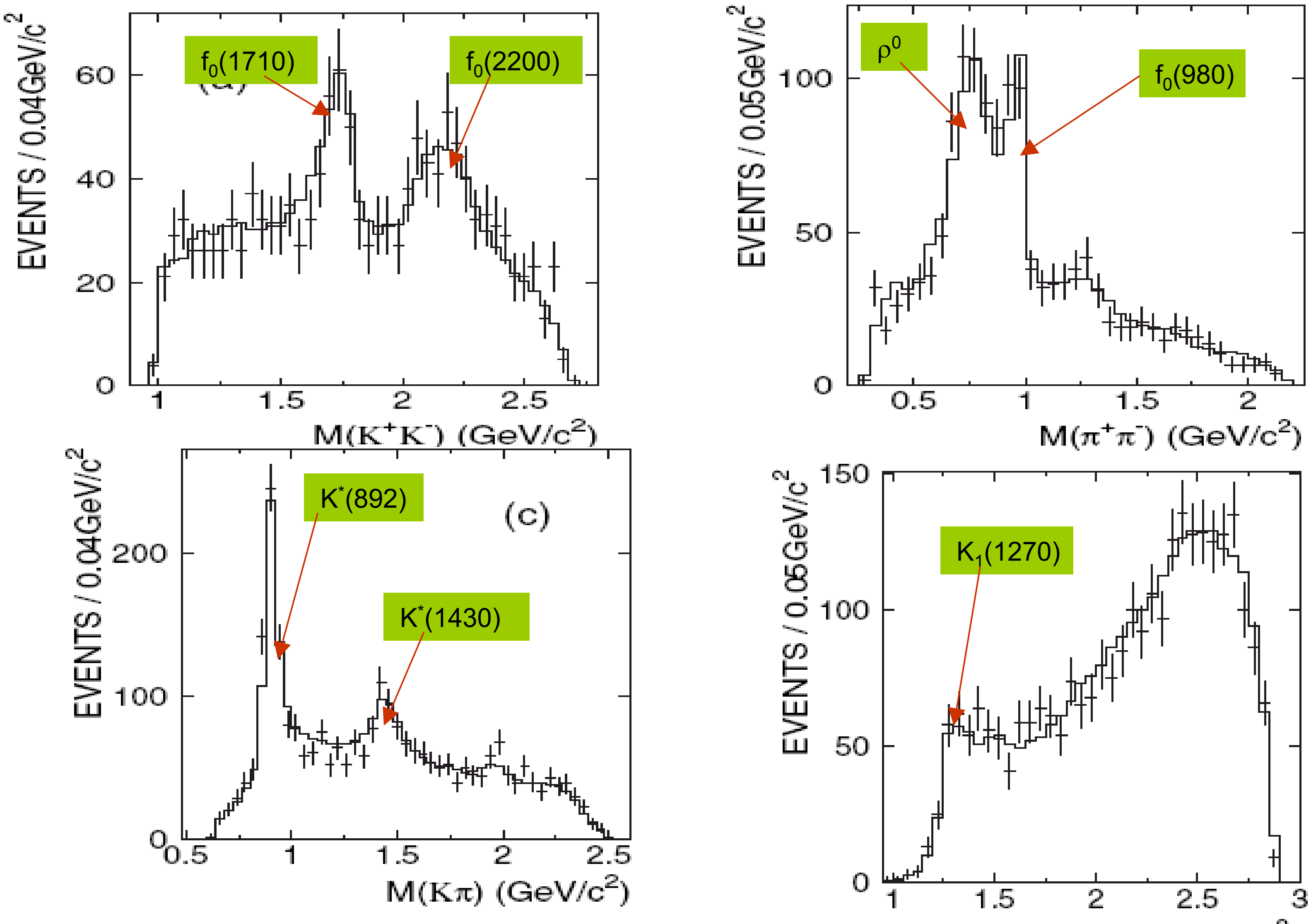
For detail, can see B.S.Zou and D. V. Bugg, Eur. Phys. J. A16, 537 (2003);

S. Dulat and B.S.Zou, Eur. Phys. J. A26, 125 (2005);

P.R.D72, 092002 (2005)

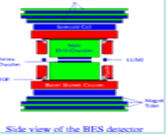


$\chi_{c0} \rightarrow \pi^+ \pi^- K^+ K^-$



Goodness of the fit: χ^2/ndf=219.8/(237-52)=1.2.

P.R.D72, 092002 (2005)



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

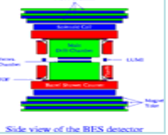
Decay mode	$N^{\rm fit}$	ϵ (%)	$\mathcal{B}[\chi_{c0} \to X \to \pi^+\pi^-K^+K^-]$ ($\times 10^{-4}$)
$f_0(980)f_0(980)$	27.9 ± 8.7	6.25 ± 0.01	$3.46 \pm 1.08^{+1.93}_{-1.57}$
$f_0(980)f_0(2200)$	77.1 ± 13.0	7.09 ± 0.01	$8.42 \pm 1.42^{+1.65}_{-2.29}$
$f_0(1370)f_0(1710)$	60.6 ± 15.7	6.59 ± 0.01	$7.12 \pm 1.85^{+3.28}_{-1.68}$
$K^*(892)^0\bar{K}^*(892)^0$	64.5 ± 13.5	6.18 ± 0.01	$8.09 \pm 1.69^{+2.29}_{-1.99}$
$K_0^*(1430)\bar{K}_0^*(1430)$	82.9 ± 18.8	6.15 ± 0.01	$10.44 \pm 2.37^{+3.05}_{-1.90}$
$K_0^*(1430)\bar{K}_2^*(1430)$ + c.c.,	62.0 ± 12.1	5.66 ± 0.01	$8.49 \pm 1.66^{+1.32}_{-1.99}$

$$Br[\chi_{c0} \to K_1(1270)^+K^- + c.c.] = (6.66 \pm 1.31^{+1.60}_{-1.51}) \times 10^{-3}$$

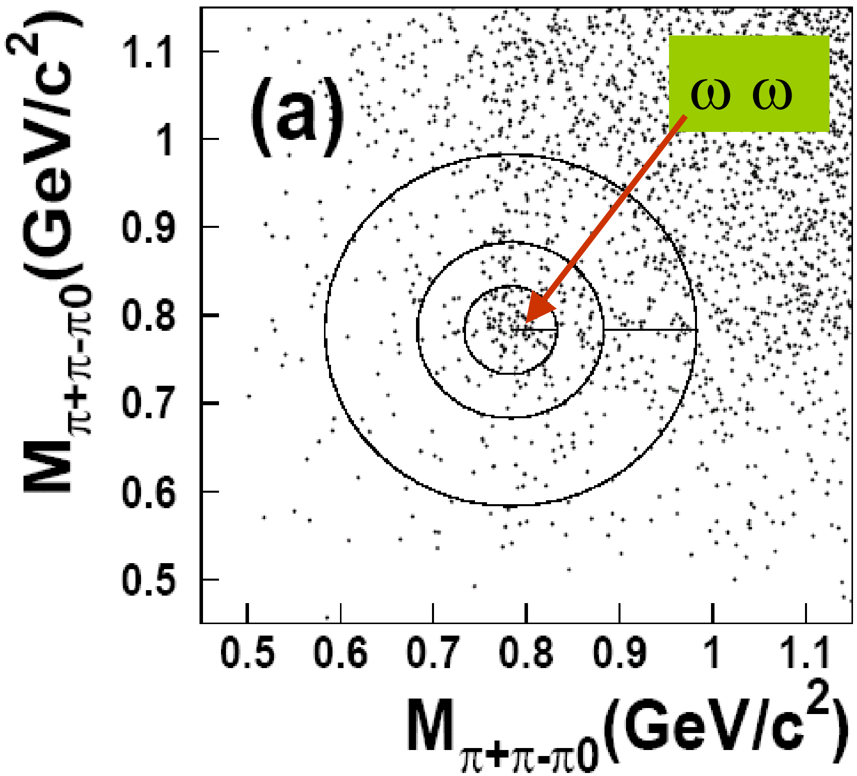
$$Br[\chi_{c0} \to K_1(1400)^+K^- + c.c.] < 2.85 \times 10^{-3} \;\; 90\% \; C.L.$$

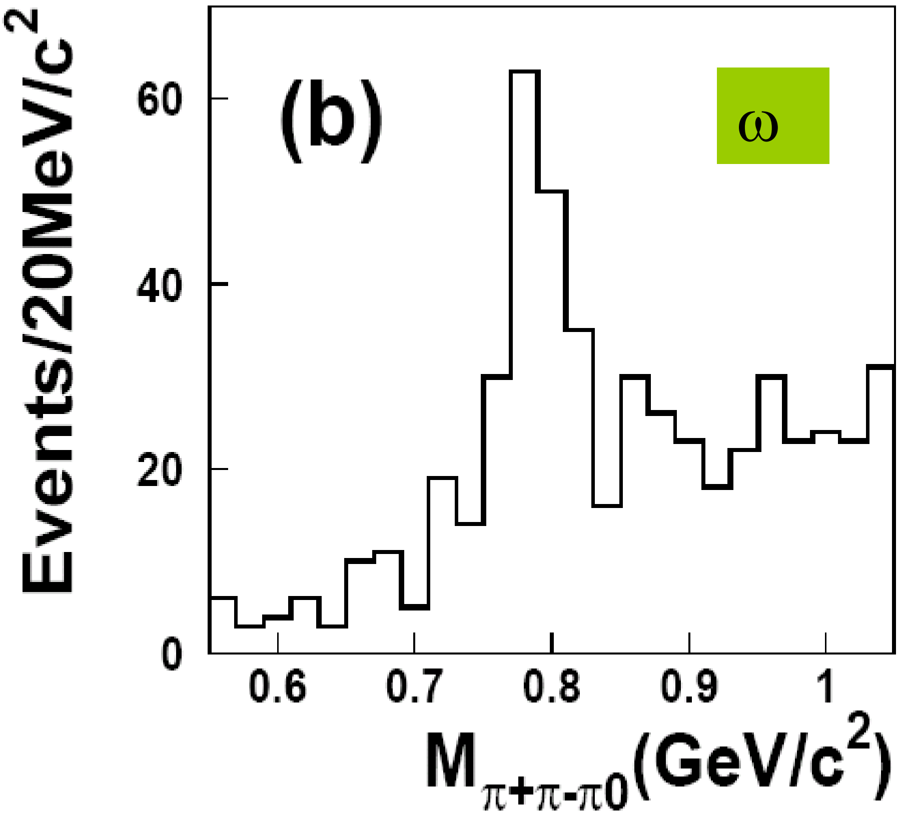
Flavor-SU(3)-violating $K_1(1270)$-$K_1(1400)$ asymmetry is observed.

P.R.D72, 092002 (2005)

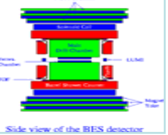


Observation of $\chi_{c0,2} \to \omega\omega$



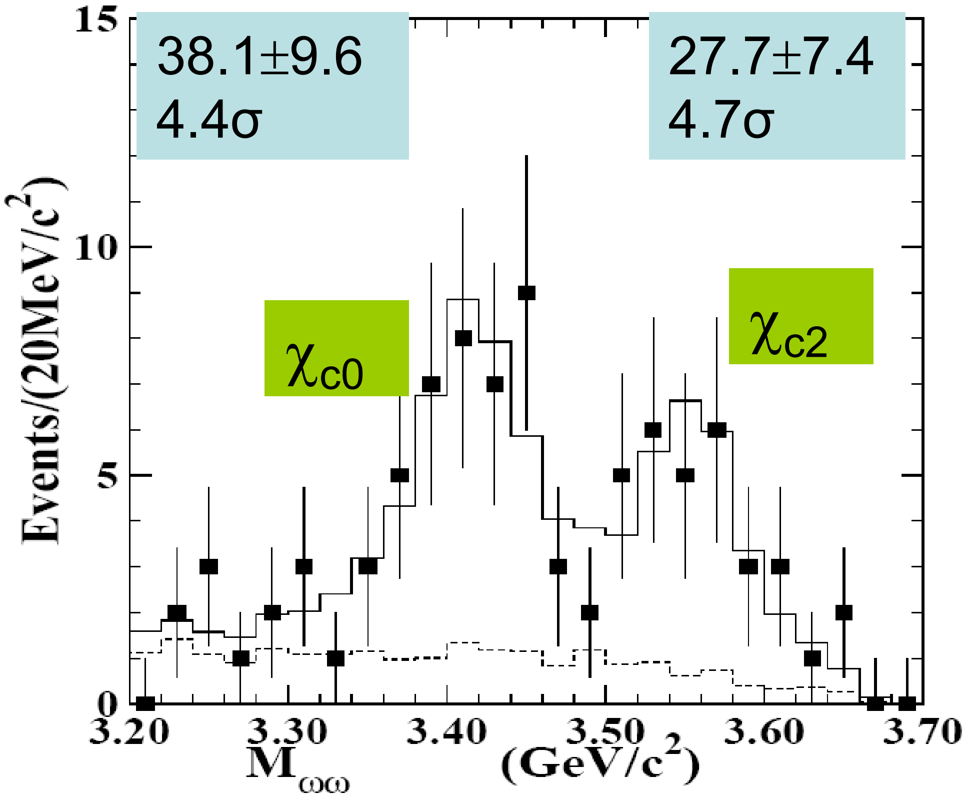


P.L.B630:7-13, 2005



Observation of $\chi_{c0,2} \to \omega\omega$

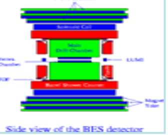
$\chi_{c1} \to \omega\omega$ is forbidden by requirement of quantum statistics rule.



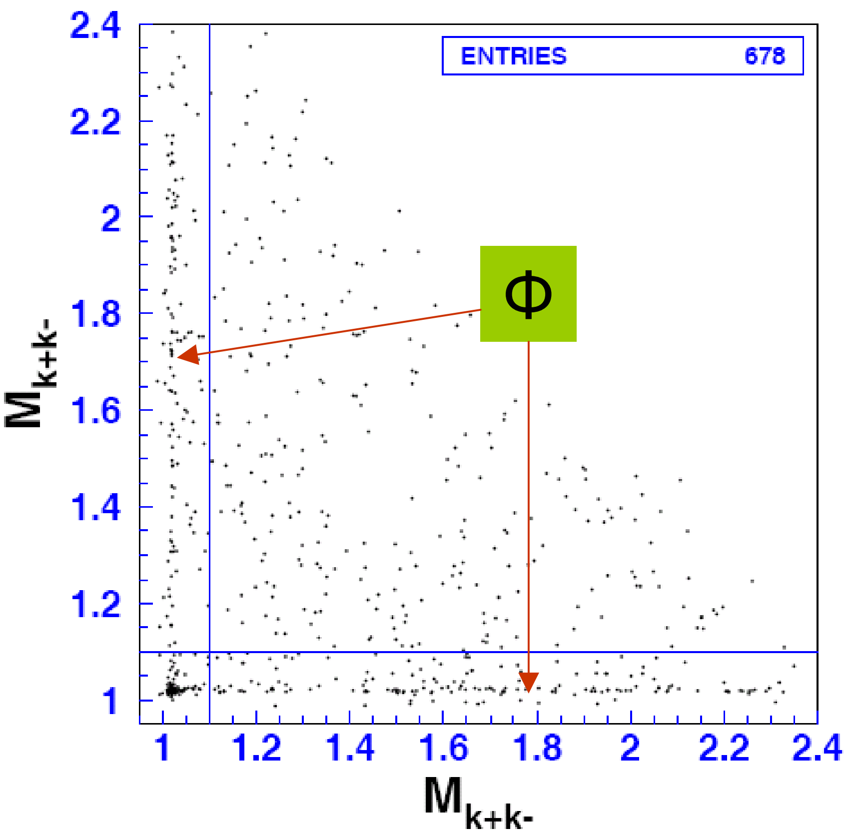
$$\chi_{c0} \to \omega\omega = (2.29 \pm 0.58 \pm 0.41) \times 10^{-3}$$

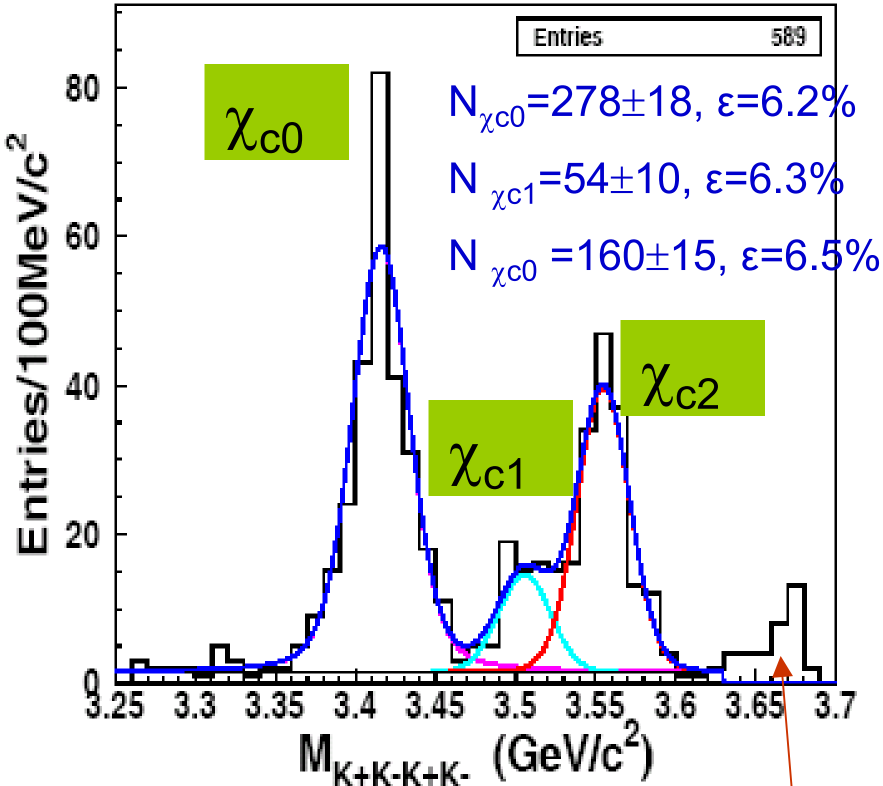
$$\chi_{c2} \to \omega\omega = (1.77 \pm 0.47 \pm 0.36) \times 10^{-3}$$

P.L.B630:7-13, 2005



$\chi_{cJ} \rightarrow K^+ K^- K^+ K^-$





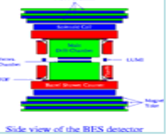
$\psi(2S) \rightarrow 2(K^+K^-)$ with a fake photon.

$$\mathcal{B}(\chi_{c0} \rightarrow 2(K^+K^-)) = (3.47 \pm 0.22 \pm 0.48) \times 10^{-3}$$

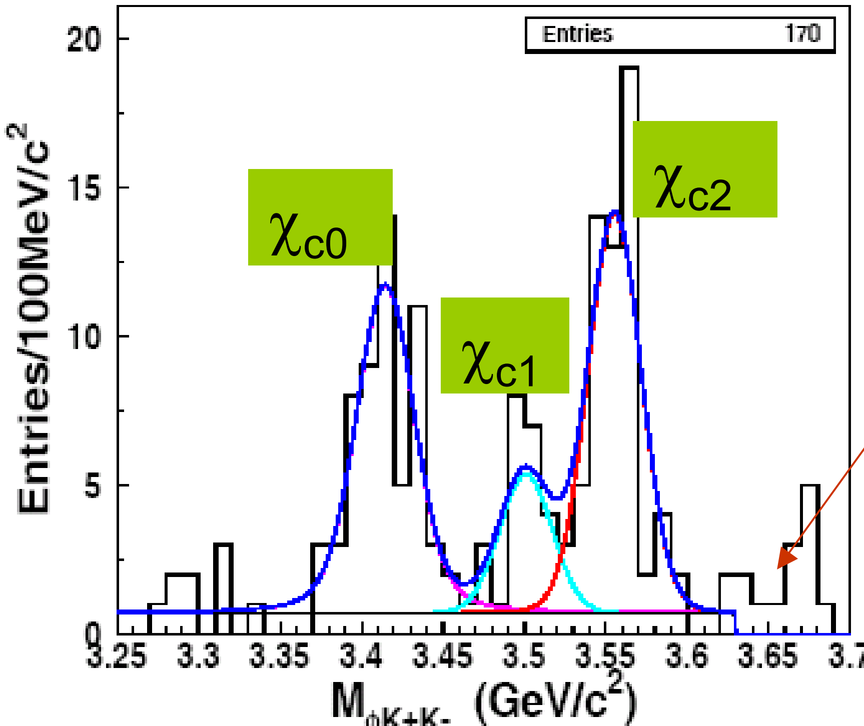
$$\mathcal{B}(\chi_{c1} \rightarrow 2(K^+K^-)) = (0.68 \pm 0.13 \pm 0.10) \times 10^{-3}$$

$$\mathcal{B}(\chi_{c2} \rightarrow 2(K^+K^-)) = (1.88 \pm 0.18 \pm 0.27) \times 10^{-3}$$

BES preliminary



$Br(\chi_{cJ} \to \phi K^+K^-)$



$\psi(2S) \to 2(K^+K^-)$ with a fake photon.

After the bg. Subtraction,

$N_{\chi c0}$=39.0±8.4, ε=5.9%

$N_{\chi c1}$=17.0±5.6, ε=6.2%

$N_{\chi c2}$=52.3±8.2, ε=5.6%

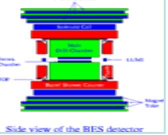
$$\mathcal{B}(\chi_{c0} \to \phi K^+K^-) = (10.4 \pm 2.2 \pm 1.4) \times 10^{-4}$$

$$\mathcal{B}(\chi_{c1} \to \phi K^+K^-) = (0.44 \pm 0.14 \pm 0.06) \times 10^{-4}$$

$$\mathcal{B}(\chi_{c2} \to \phi K^+K^-) = (14.6 \pm 2.1 \pm 2.3) \times 10^{-4}$$

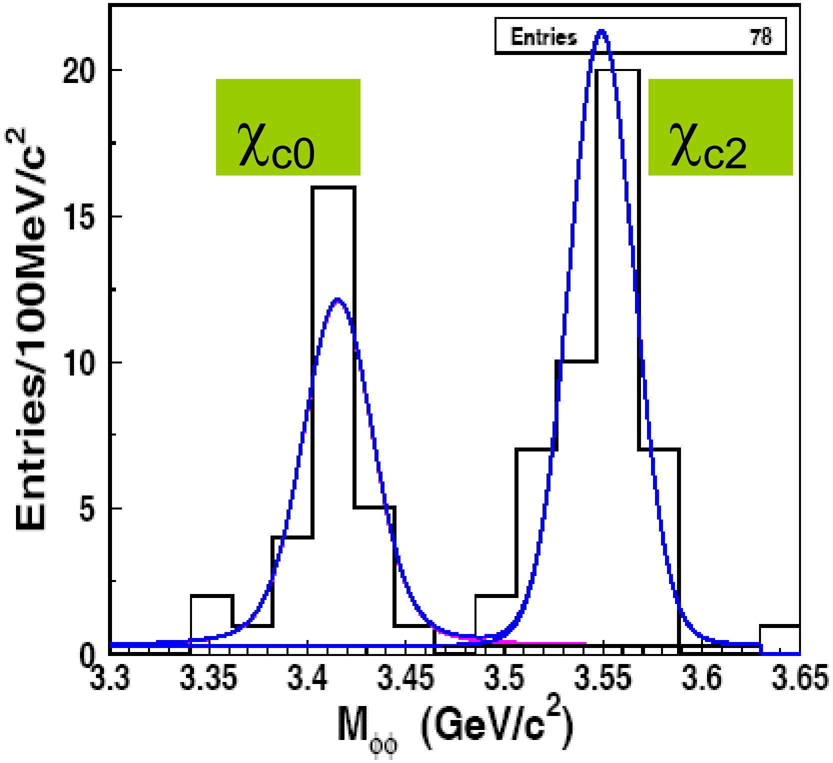
BES preliminary

First measurement



$Br(\chi_{c0,2} \to \phi\,\phi)$

$\chi_{c1} \to \phi\phi$ is forbidden by requirement of quantum statistics rule.



BES preliminary

After the bg. Subtraction,

$N_{\chi c0}$=26.2±5.8, ε=9.0%

$N_{\chi c2}$=41.0±7.1, ε=8.8%

$$\mathcal{B}(\chi_{c0} \to \phi\phi) = (0.94 \pm 0.21 \pm 0.13) \times 10^{-3}$$

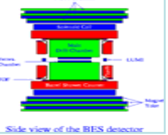
$$\mathcal{B}(\chi_{c2} \to \phi\phi) = (1.48 \pm 0.26 \pm 0.22) \times 10^{-3}$$

BES $Br(\chi_{cJ} \to VV)$ are helpful in determining the parameters in the general factorization scheme in Zhao Qiang, PRD72, 074001 (2005),

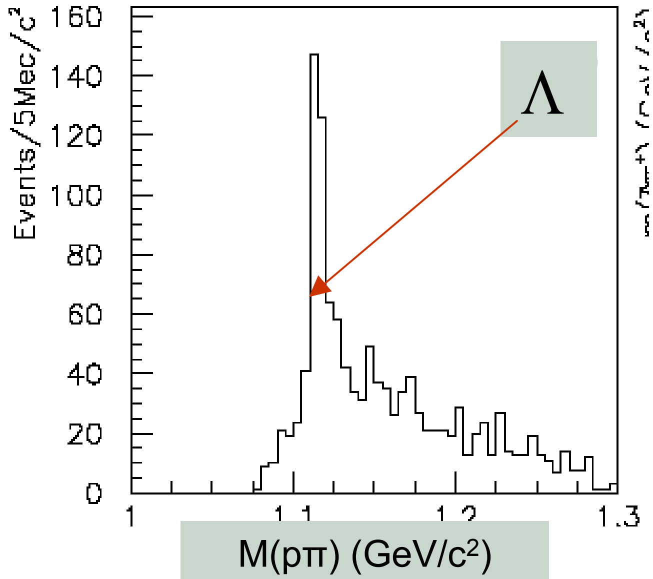
clarify the role played by OZI-rule Viol., SU(3) flav. Breaking in decay transitions.

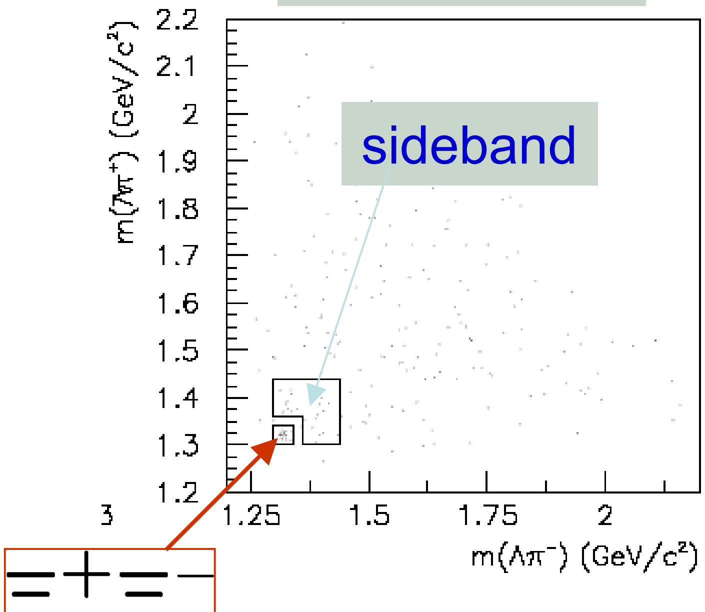
r=0.45±0.48, R= 0.45±0.48, g_0= 0.45±0.48 for χ_{c0} decay,

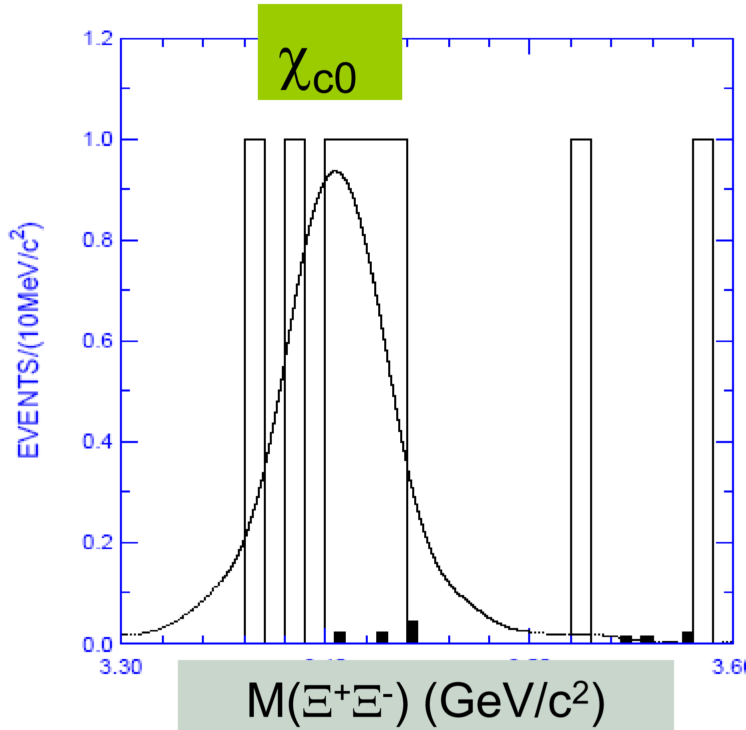
r=0.24±0.29, R= 1.09±0.21, g_0= 0.26±0.06 for χ_{c0} decay,



Search for $\chi_{cJ} \rightarrow \Xi^+ \Xi^- \rightarrow 2(\pi^+\pi^-)p\bar{p}$







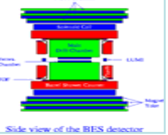
$$Br(\chi_0 \rightarrow \Xi^-\Xi^+) = (5.3 \pm 2.7 \pm 0.9) \times 10^{-4}$$

$$or \ < 10.3 \times 10^{-4} \ (90\% \ C.L.)$$

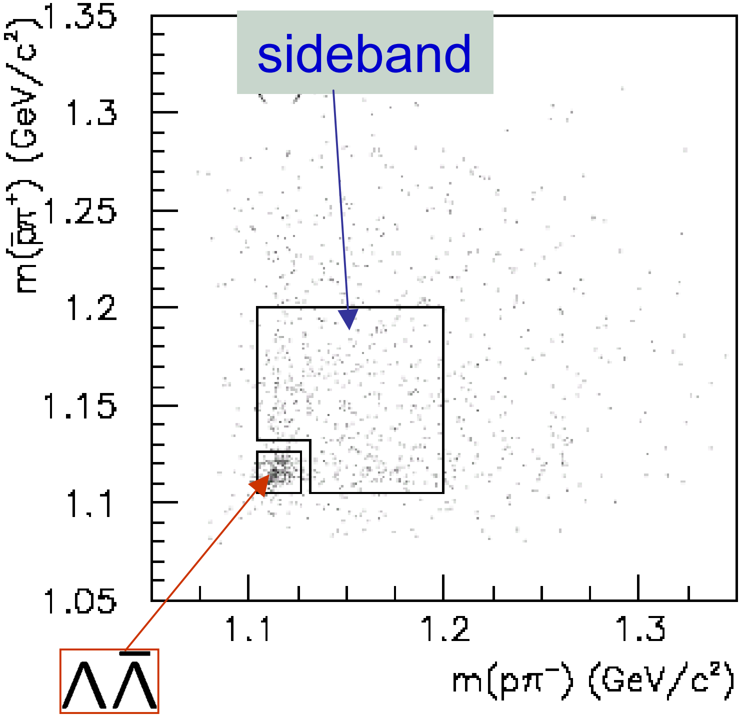
$$Br(\chi_1 \rightarrow \Xi^-\Xi^+) < 3.4 \times 10^{-4} \ (90\% \ C.L.)$$

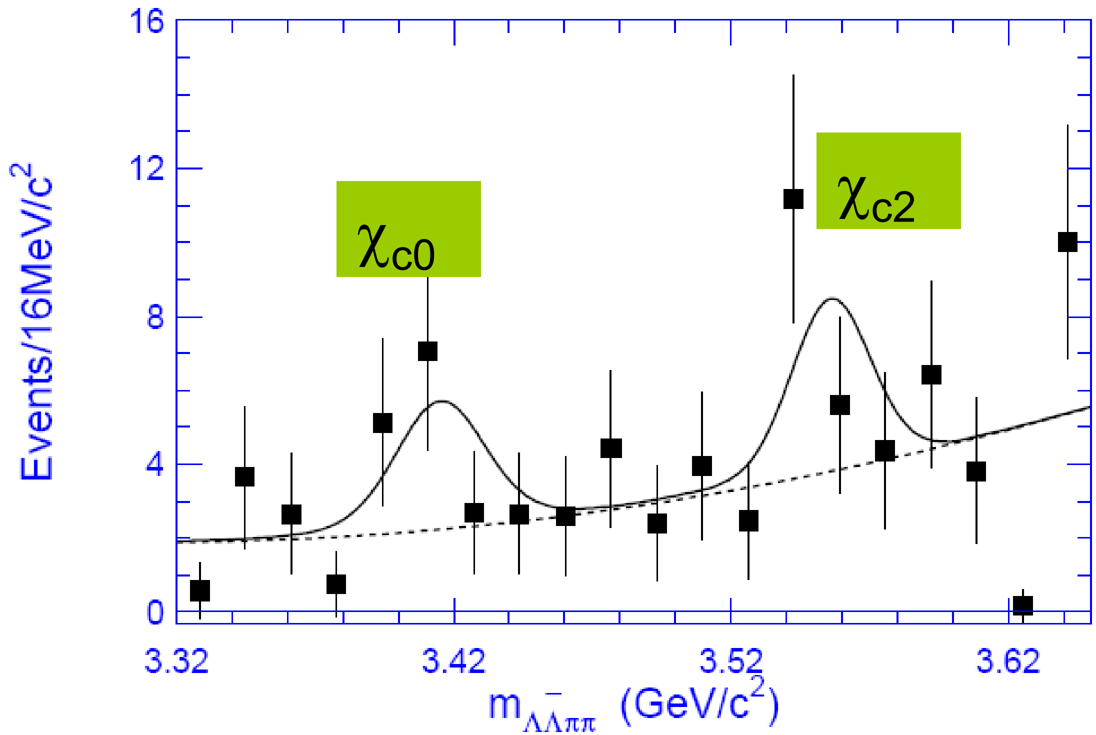
$$Br(\chi_2 \rightarrow \Xi^-\Xi^+) < 3.7 \times 10^{-4} \ (90\% \ C.L.)$$

Hep-ex/0602033,accepted by PRD



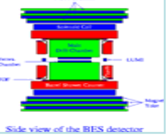
Search for $\chi_{cJ} \to \Lambda\bar{\Lambda}\pi^+\pi^- \to 2(\pi^+\pi^-)p\bar{p}$



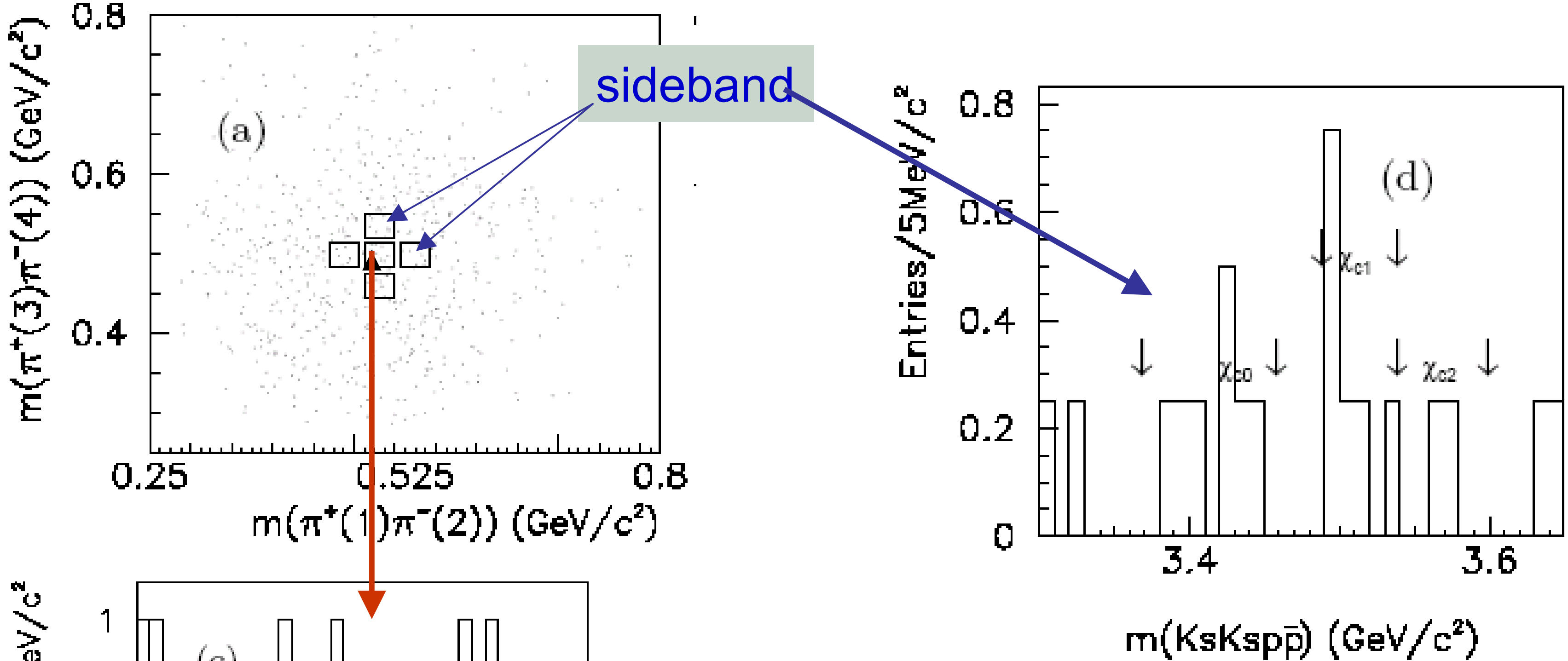


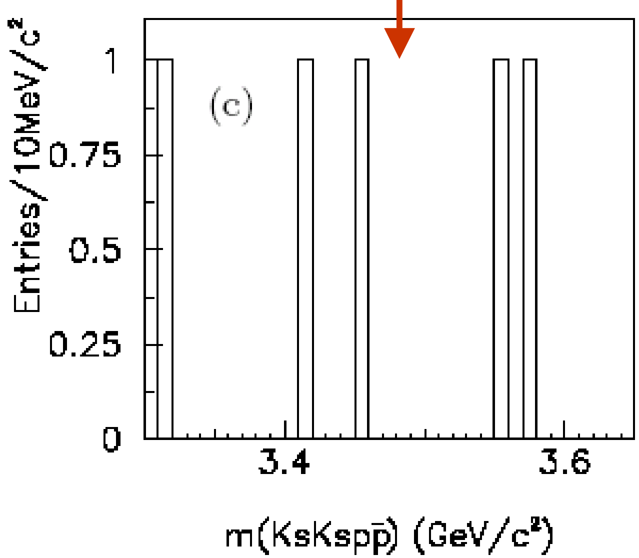
	χ_{c0}	χ_{c1}	χ_{c2}
$Br(\chi_{cJ} \to \pi^+\pi^-\Lambda\bar{\Lambda})\ \times 10^{-3}$	$2.0 \pm 1.1 \pm 0.4\ (2.5\sigma)$	—	$1.8 \pm 1.0 \pm 0.3\ (2.5\sigma)$
upper limit $\times 10^{-3}$ $(90\% C.L.)$	< 4.0	< 1.5	< 3.5

Hep-ex/0602033, accepted by PRD.



Search for $\chi_{cJ} \rightarrow K_S^0 K_S^0 p\bar{p} \rightarrow 2(\pi^+\pi^-)p\bar{p}$



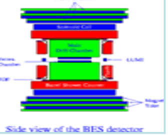


$$Br(\chi_0 \rightarrow K_S^0 K_S^0 P\bar{P}) < 8.8 \times 10^{-4} \ (90\% \ C.L.)$$

$$Br(\chi_1 \rightarrow K_S^0 K_S^0 P\bar{P}) < 4.9 \times 10^{-4} \ (90\% \ C.L.)$$

$$Br(\chi_2 \rightarrow K_S^0 K_S^0 P\bar{P}) < 7.9 \times 10^{-4} \ (90\% \ C.L.)$$

Hep-ex/0602033, accepted by PRD



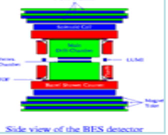
Measurement of $\psi(2S) \to \gamma K \bar{K} \pi, \gamma \eta \pi^+ \pi^-$

$$\psi(2S) \to \gamma K_S^0 K \pi + c.c.$$
$$\gamma K^+ K^- \pi^0$$
$$\gamma \eta \pi^+ \pi^-$$

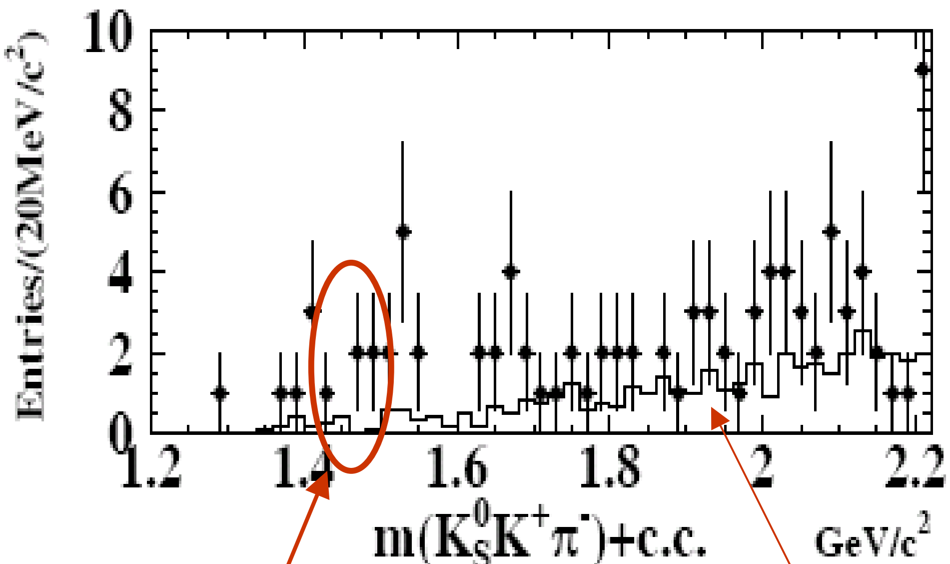
Search for glueball candidate, η(1440), or say it as η(1405) and η(1475), which maybe have large branching fraction in J/ψ decays.

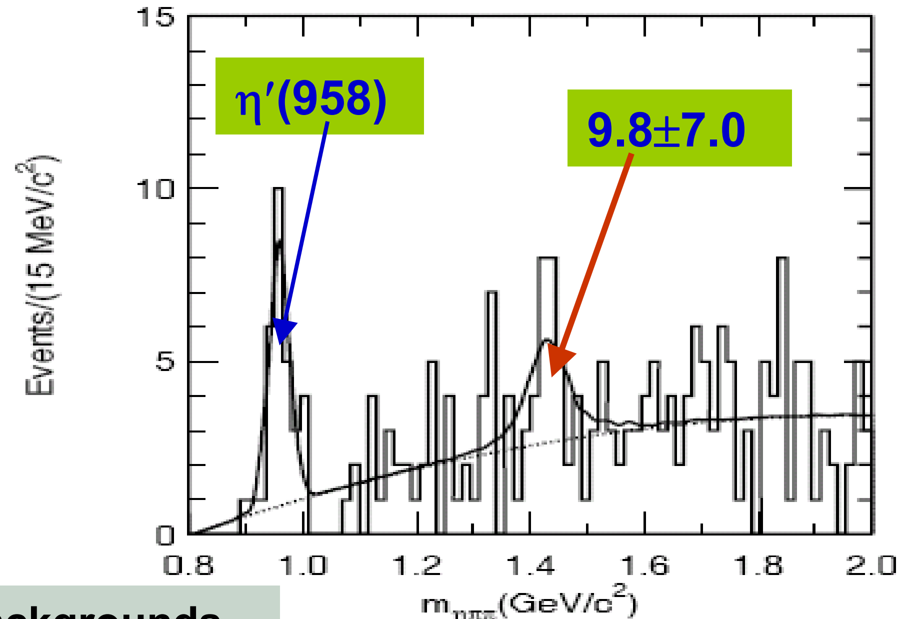
We also measured :

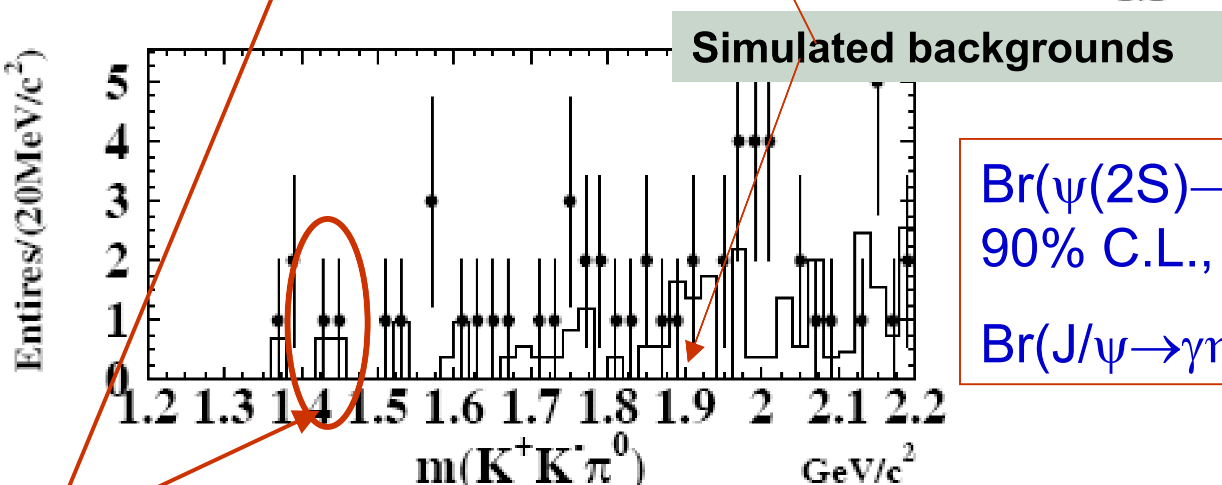
$$Br(\chi_{cJ} \to K_S^0 K \pi)$$
$$Br(\chi_{c1} \to K^*(892, 1430) K \to K_S^0 K \pi)$$
$$Br(\chi_{c1} \to a_0(980)^{\pm} \pi^{\mp} \to \eta \pi^+ \pi^-)$$
$$Br(\chi_{c1} \to f_0(1270) \eta \to \eta \pi^+ \pi^-)$$



$\eta(1440)$ in $\psi(2S) \rightarrow \gamma K_S^0 K^+ \pi^- + c.c$, $\gamma K^+ K^- \pi^0$ **and** $\gamma\ \eta\pi^+\pi^-$





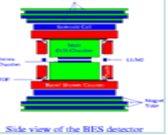


$Br(\psi(2S) \rightarrow \gamma\eta(1440)) < 2.0 \times 10^{-4}$, 90% C.L.,

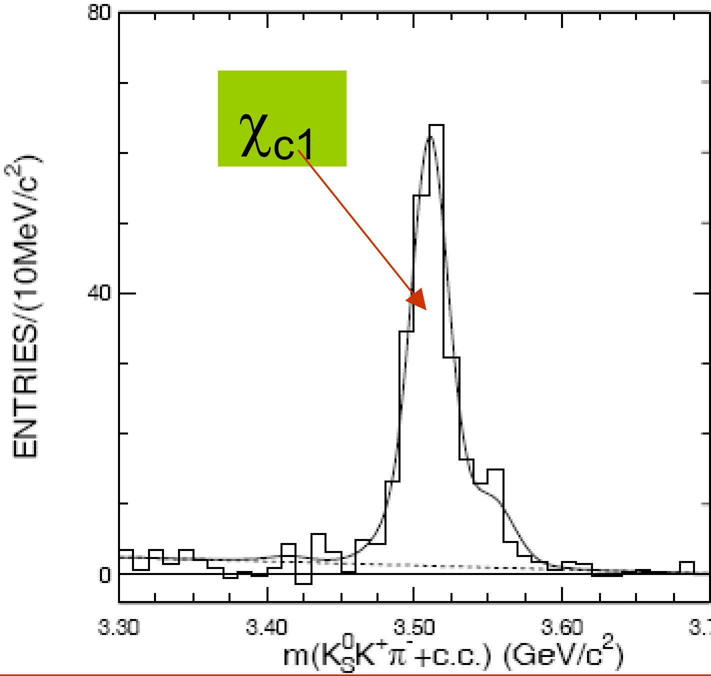
$Br(J/\psi \rightarrow \gamma\eta(1440)) = (2.8 \pm 0.6) \times 10^{-3}$.

BES preliminary

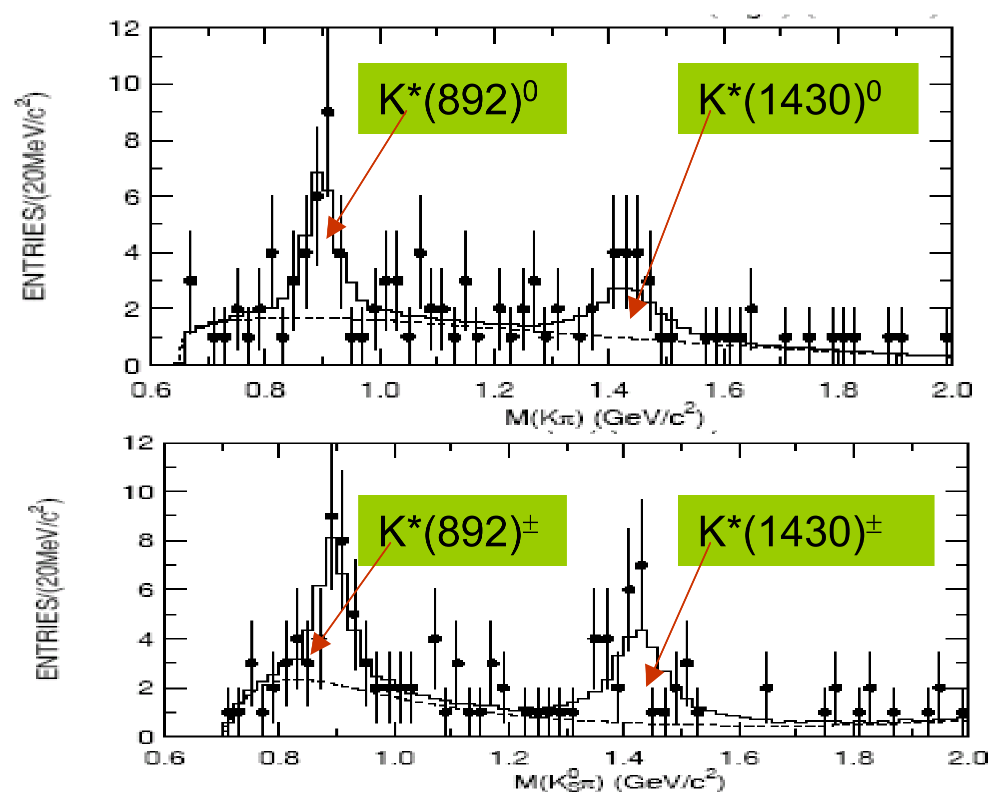
$\eta(1440)$ are not found in $\psi(2S)$ decay



$\chi_{cJ} \rightarrow K_S^0 K^+ \pi^- + c.c$



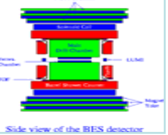
State	n^{obs}	$\epsilon(\%)$	$\mathcal{B}(\times 10^{-3})$
χ_{c0}	3.9 ± 4.6	6.24	< 0.3
χ_{c1}	220.1 ± 15.9	6.80	$4.1 \pm 0.3 \pm 0.7$
χ_{c2}	28.4 ± 7.6	5.82	$0.8 \pm 0.3 \pm 0.2$



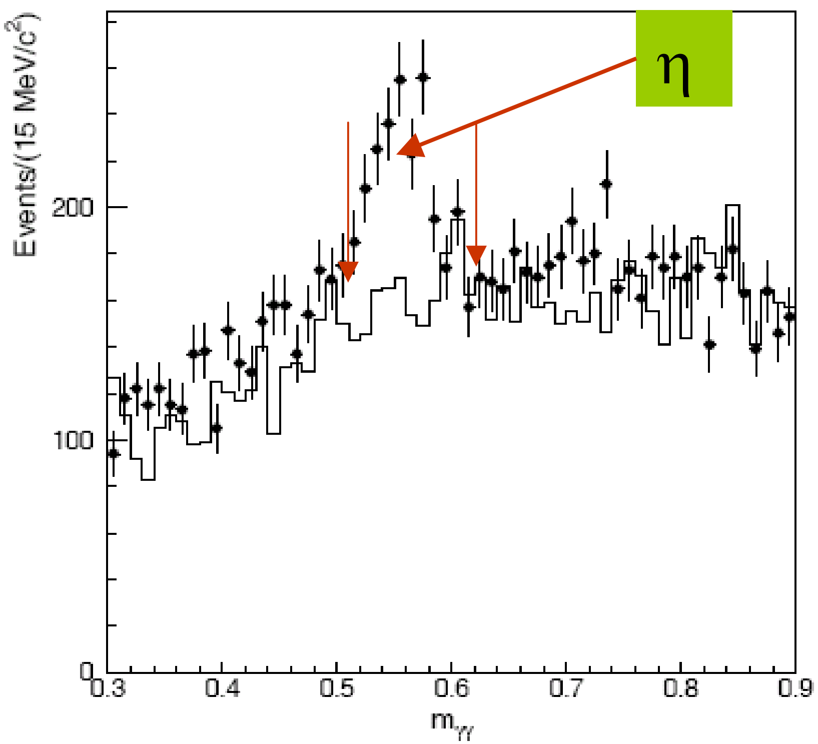
$\chi_{c1} \rightarrow K_S^0 K^+ \pi^- + c.c$

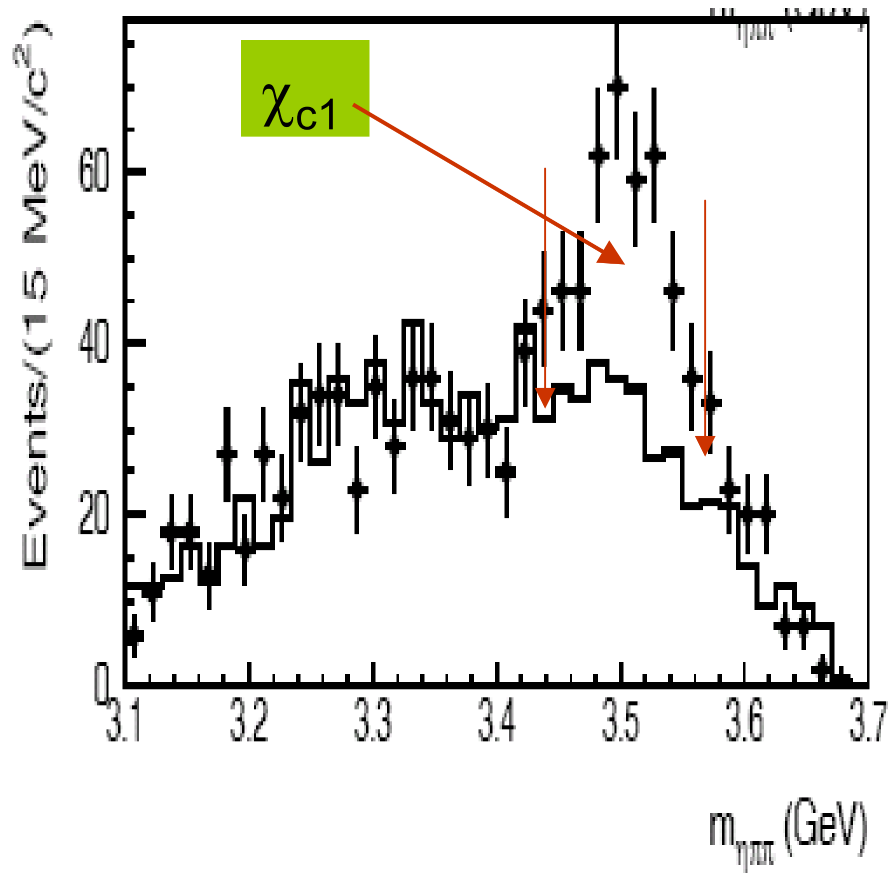
$\chi_{c1} \rightarrow$	n^{obs}	$\varepsilon(\%)$	$\mathcal{B}(\times 10^{-3})$
$K^*(892)^0 \overline{K}^0 + c.c.$	22.5 ± 7.3	7.67	$1.1 \pm 0.4 \pm 0.2$
$K^*(892)^+ K^- + c.c.$	26.7 ± 11.0	6.20	$1.6 \pm 0.7 \pm 0.3$
$K_J^*(1430)^0 \overline{K}^0 + c.c. \rightarrow K_S^0 K^+ \pi^- + c.c.$	21.8 ± 14.7	6.28	< 0.6
$K_J^*(1430)^+ K^- + c.c. \rightarrow K_S^0 K^+ \pi^- + c.c.$	45.0 ± 26.1	5.00	< 1.4

BES preliminary

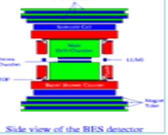


$\chi_{c1} \to a_0^{\pm}\pi^{\pm}, f_2\eta \to \pi^+\pi^- \eta$

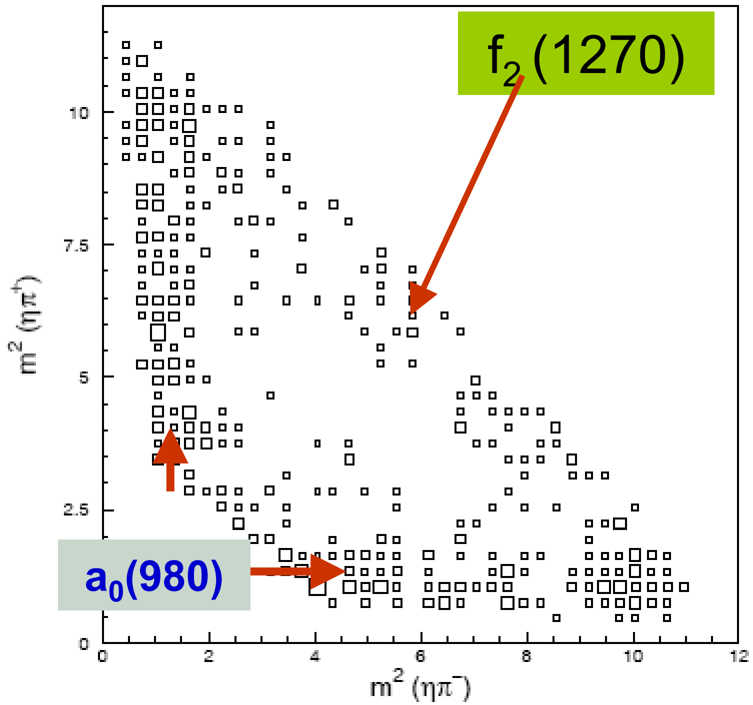




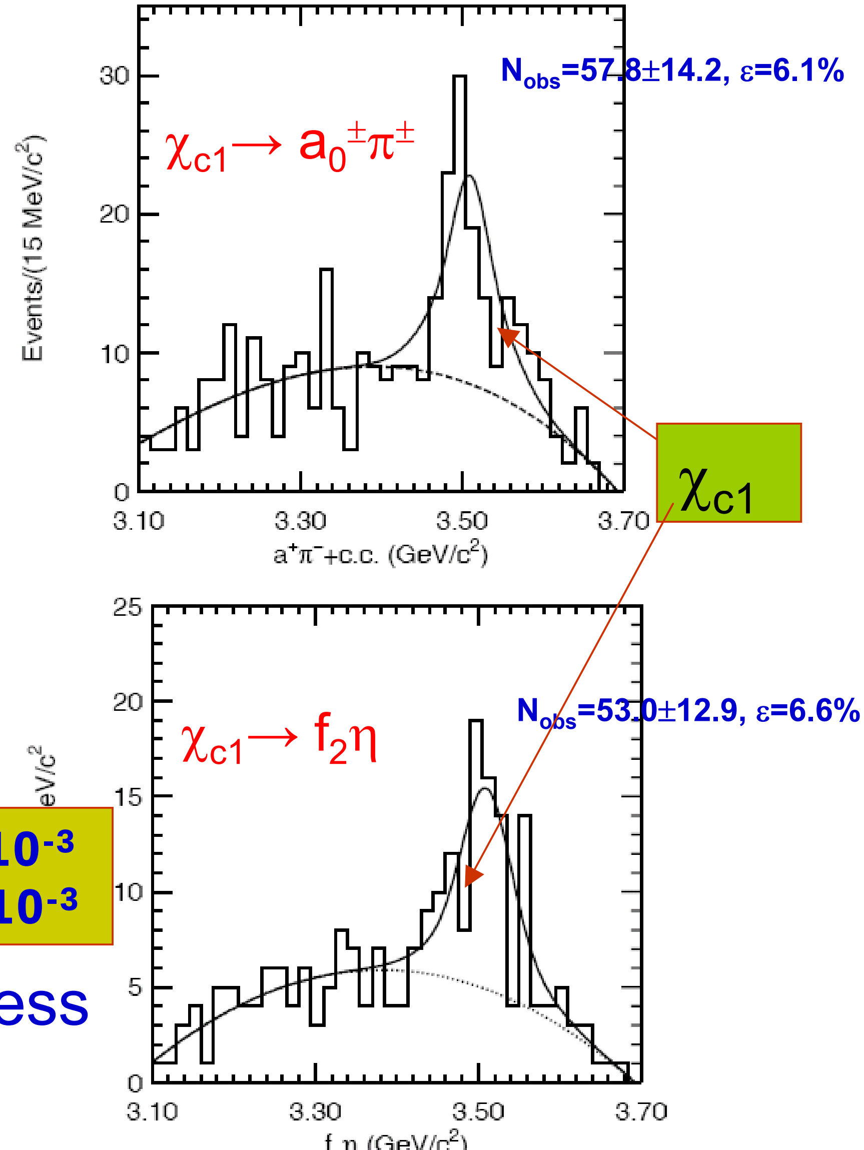
In $\psi(2S)\to\gamma\chi_{c1}\to\gamma\eta\pi^+\pi^-\to\gamma\gamma\gamma\pi^+\pi^-$ process



$\chi_{c1}\rightarrow a_0^{\pm}\pi^{\pm}, f_2\eta\rightarrow\pi^+\pi^-\eta$



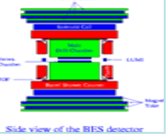
Daliz plot for $\chi_{c1}\rightarrow\eta\pi^+\pi^-$



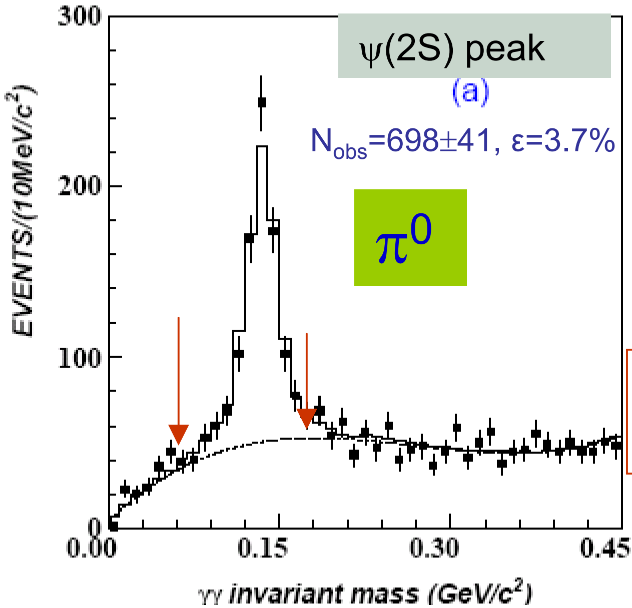
Br($\chi_{c1}\rightarrow a_0^{\pm}\pi^{\pm}\rightarrow\pi^+\pi^-\eta$) = $(2.1\pm0.5\pm0.5)\times10^{-3}$
Br($\chi_{c1}\rightarrow f_2\eta\rightarrow\pi^+\pi^-\eta$) = $(2.1\pm0.5\pm0.4)\times10^{-3}$

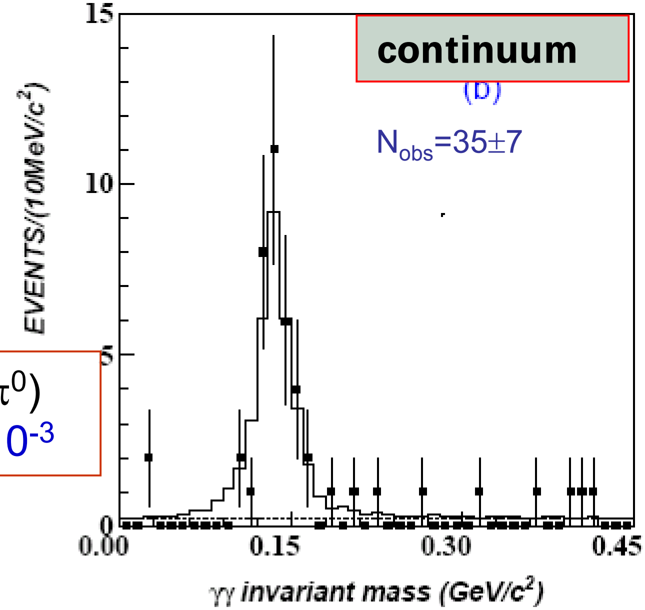
$\psi(2S)\rightarrow\gamma\chi_{c1}\rightarrow\gamma\eta\pi^+\pi^-\rightarrow\gamma\gamma\gamma\pi^+\pi^-$ process

BES preliminary

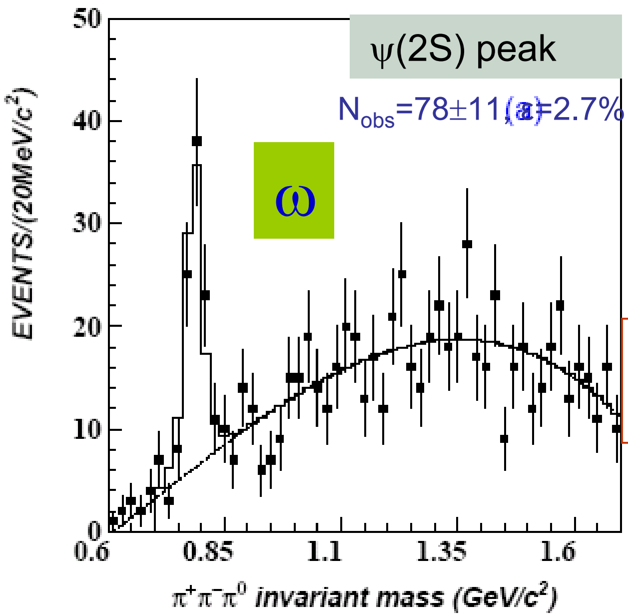


$\psi(2S) \to K^+K^-\pi^+\pi^-\pi^0$

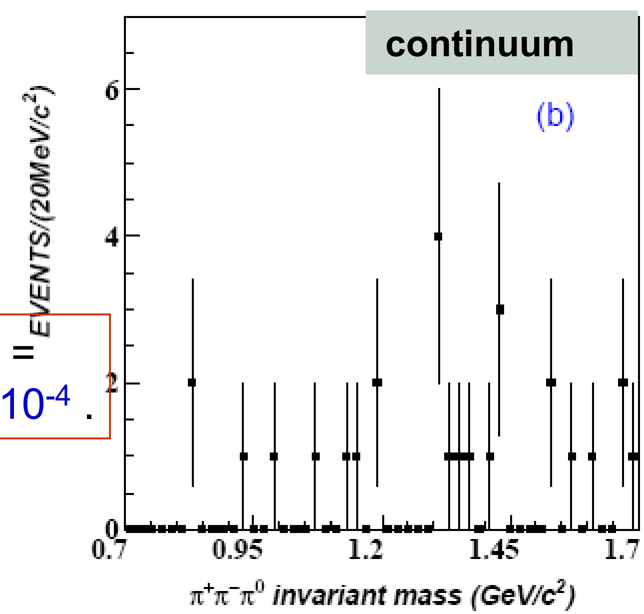




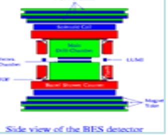
$Br(\psi(2S) \to K^+K^-\pi^+\pi^-\pi^0)$
$=(1.17\pm0.10\pm0.15)\times10^{-3}$



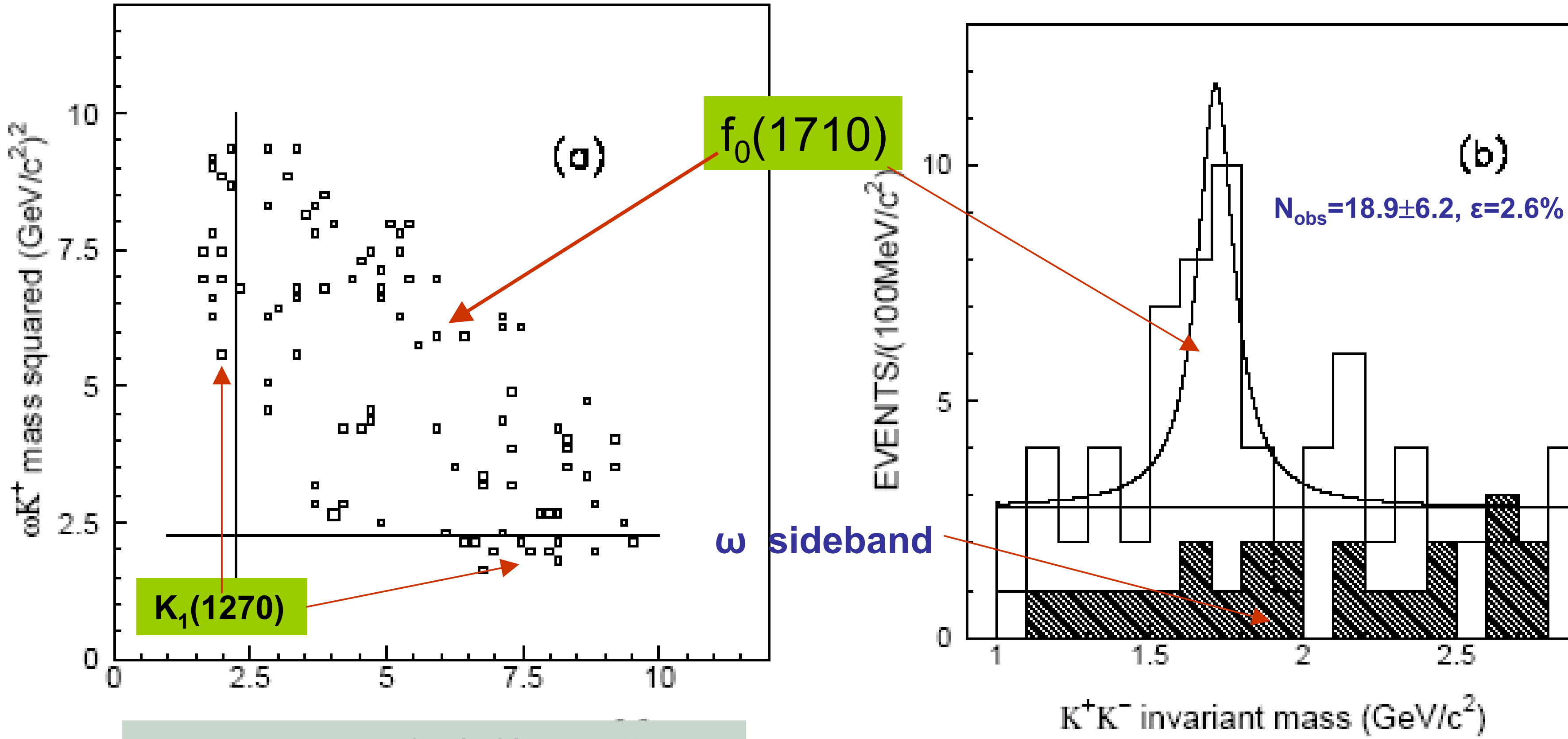
$Br(\psi(2S) \to K^+K^-\omega) =$
$(2.38\pm0.37\pm0.29)\times10^{-4}$.



Hep-ex/0512025 accepted by PRD.



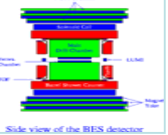
Br(ψ(2S)→ $\omega f_0(1710)$)



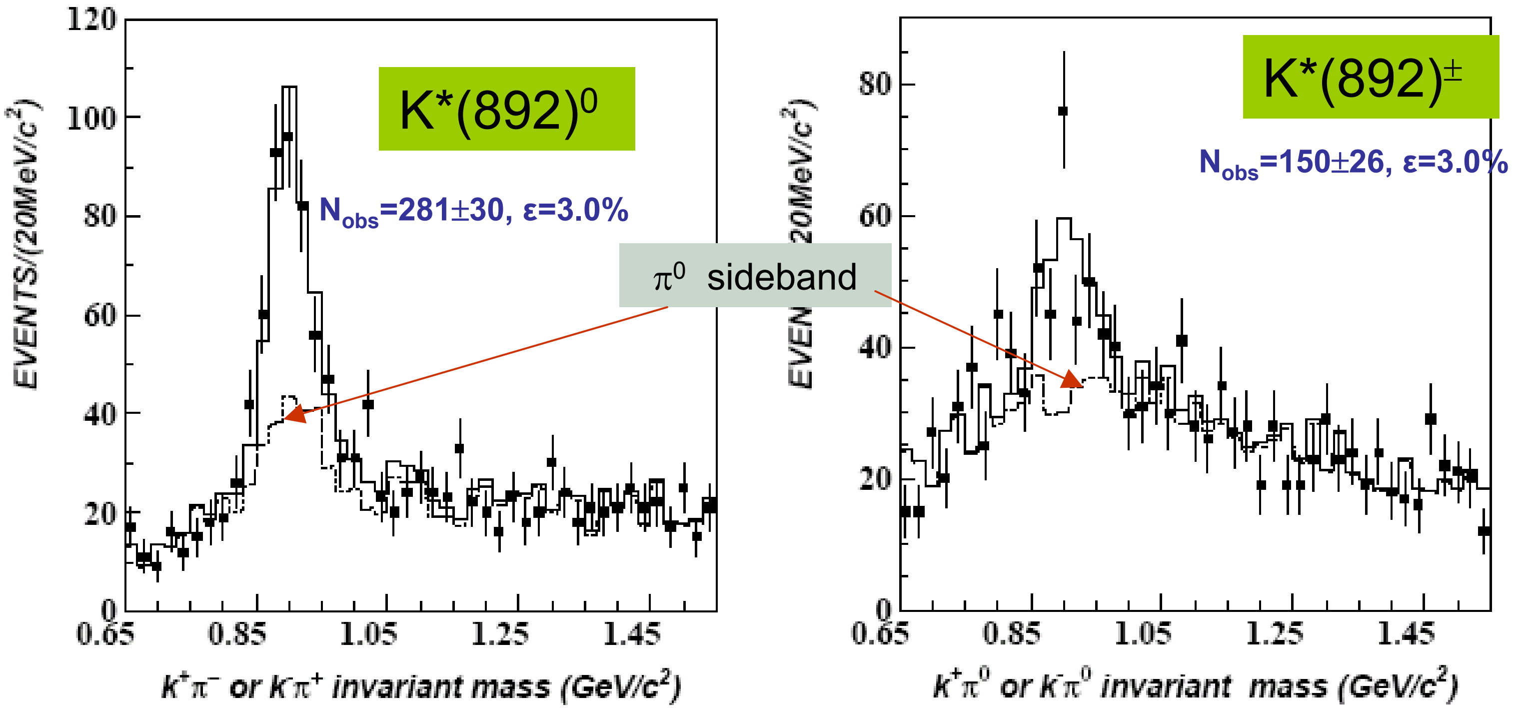
Dalitz plot of ψ(2S)→ ωK^+K^-

$Br(\psi(2S)\to\omega f_0(1710),\ f_0(1710)\to K^+K^-)=(5.9\pm2.0\pm0.9)\times10^{-5}$

Hep-ex/0512025 accepted by PRD.



$Br(\psi(2S)\rightarrow K^{*}(892)K\pi\pi)$

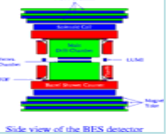


$Br(\psi(2S)\rightarrow K^{*}(892)^{0}K^{-}\pi^{+}\pi^{0} + c.c.) = (8.6\pm1.3\pm1.8)\times10^{-4}$

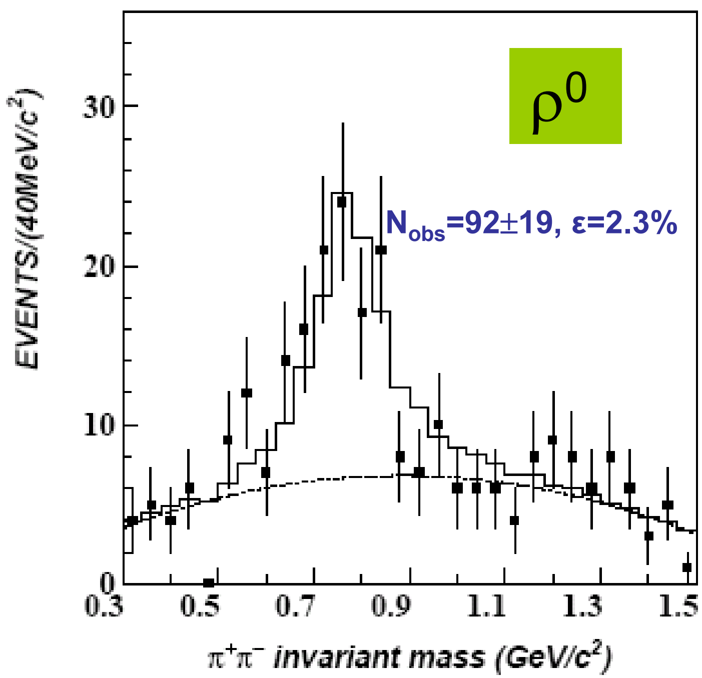
$Br(\psi(2S)\rightarrow K^{*}(892)^{+}K^{-}\pi^{+}\pi^{-} + c.c.) = (9.6\pm2.2\pm1.7)\times10^{-4}$

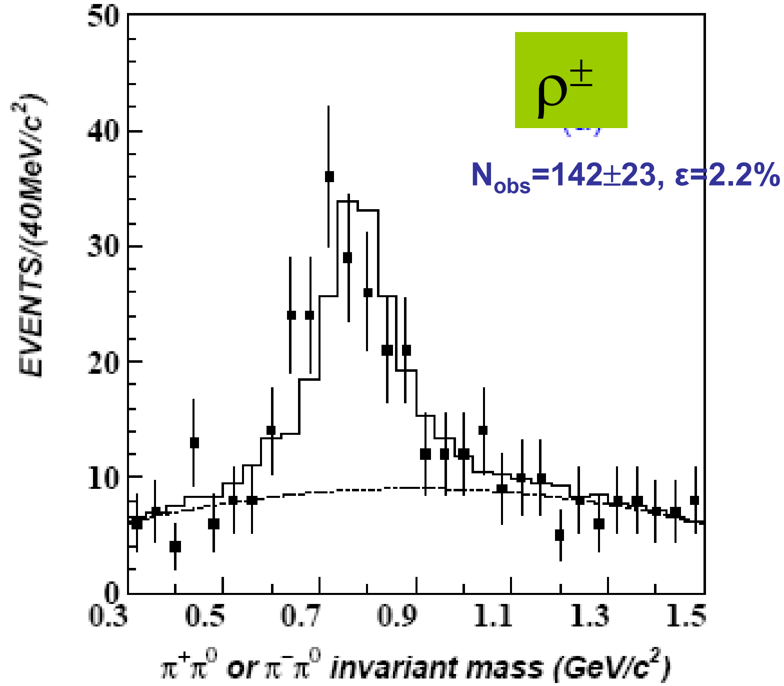
Continuum contribution subtracted incoherently.

Hep-ex/0512025 accepted by PRD.



Br(ψ(2S)→ K*(892)Kρ)



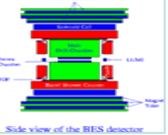


$Br(\psi(2S) \to K^*(892)^+ K^- \rho^0 + c.c.) = (7.3 \pm 2.2 \pm 1.4) \times 10^{-4}$

$Br(\psi(2S) \to K^*(892)^0 K^- \rho^+ + c.c.) = (6.1 \pm 1.3 \pm 1.2) \times 10^{-4}$

Continuum contribution subtracted incoherently.

Hep-ex/0512025 accepted by PRD.



Summary

Using 14M $\psi(2S)$ data taken with the BESII detector at the BEPC,

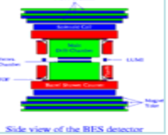
- PWA for the $\chi_{c0} \to \pi^+\pi^-K^+K^-$.

- Analyzed $\psi(2S) \to \gamma K\overline{K}\pi$ and $\gamma\eta\pi^+\pi^-$ processes, $\eta(1440)$ is not found.

- $Br(\chi_{c0,2} \to \omega\omega)$, $Br(\chi_{cJ} \to 2(K^+K^-), \phi K^+K^-, \phi\phi)$ are measured.

- Analyzed the $\psi(2S) \to K^+K^-\pi^+\pi^-\pi^0$, $\chi_{cJ} \to 2(\pi^+\pi^-)p\overline{p}$ and $\chi_{c1} \to K_S^0K^+\pi^- + c.c.$ $\eta\pi^+\pi^-$ processes and their possible intermediate states.

Thanks a lot !



Mixing of the $K_1(1270)$-$K_1(1400)$

Two lowest-lying Axial-Vector meson octets:

Spin singlet ($^1P_1$)	Spin triplet ($^3P_1$)
K_B (b_1)	K_A (a_1)

$K_1(1270)$: $K\rho$;
$K_1(1400)$: $K^*\pi$

$$K_A = \cos\theta K_1(1400) + \sin\theta K_1(1270)$$
$$K_B = \cos\theta K_1(1270) - \sin\theta K_1(1400)$$

$a_1\pi$: fobidden by G parity, SU(3) symmetry→

K_AKbar disallowed, pure K_BKbar

meanwhile, $\theta \approx 45^0$

→ roughly equal of $K_1(1270)$-$K_1(1400)$

Here $\theta > 57^0$ is requirement.