New J/ψ Physics Results from BES

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Outline

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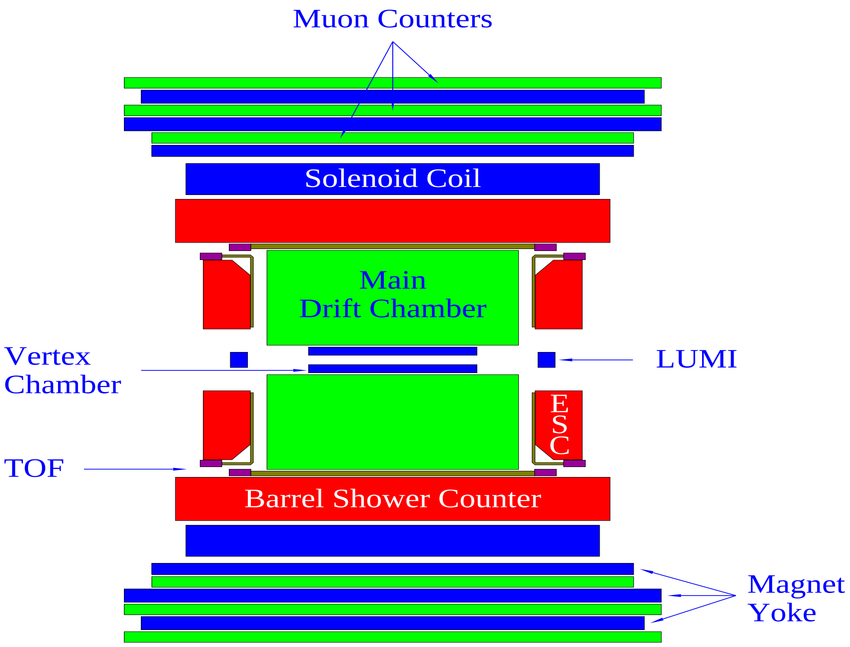
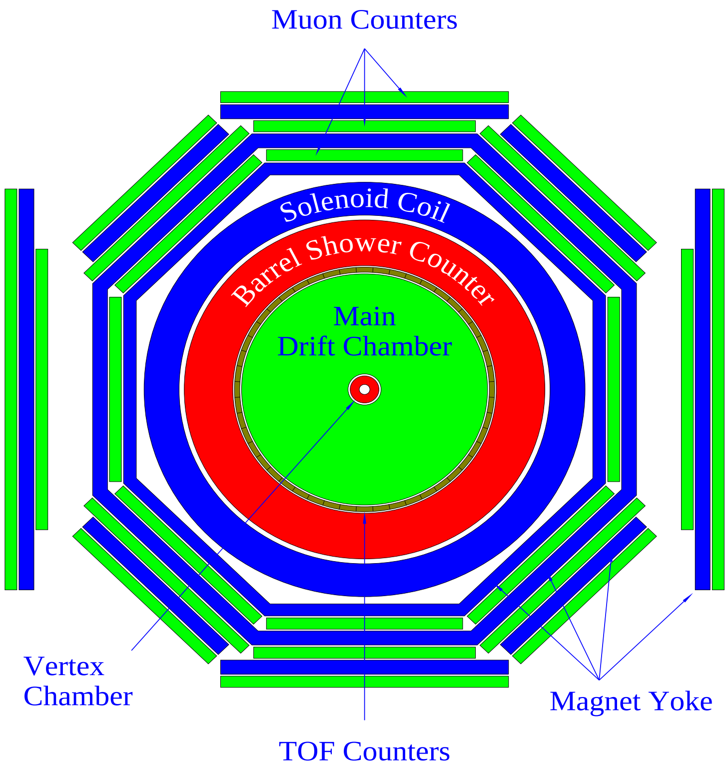
- Mesurement of the mass of η_c meson
- Other results
  - Study of Excited Baryon States
  - 3-body J/ψ Decay
- Summary

Introduction

- BES (Beijing Spectrometer) is a large general purpose solenoidal detector at Beijing Electron Positron Collider (BEPC)
- Beam energy range from 1.0 to 2.8 GeV
- Luminosity at J/ψ peak
  $\sim 5 \times 10^{30} cm^{-2} s^{-1}$
- e^+e^- physics in the $\tau - c$ energy region, only BES running



Side view of the BES detector



End view of the BES detector

Table 1: Performance of BES I and BES II

Detector	Parameter	BES I	BES II
VC(CDC)	$\sigma_{xy}(\mu)$	200	100
MDC	$\sigma_{xy}(\mu)$	200-250	198-224
	$\Delta p/p(\%)$	$1.76\sqrt{1+p^2}$	$1.78\sqrt{1+p^2}$
	$\sigma_{dE/dx}(\%)$	7.8	8.0
BTOF	$\sigma_T(ps)$	375	180
	$L_{atten}(m)$	1.0-1.2	3.5-5.5
ETOF	$\sigma_T(ps)$		720
BSC	$\Delta E/\sqrt{E}(\%)$	23.8	22
ESC	$\Delta E/\sqrt{E}(\%)$	24	22
MUON	$\sigma_z(cm)$	5.5	5.5
DAQ	Dead time(ms)	20	8

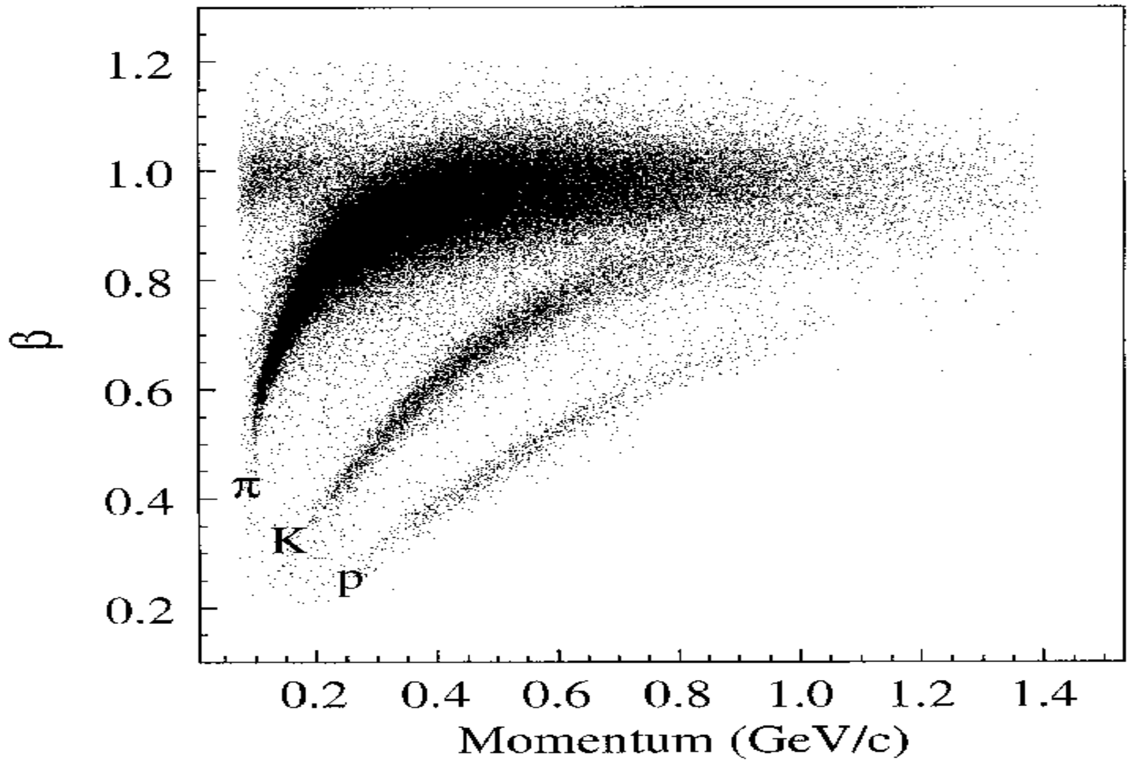


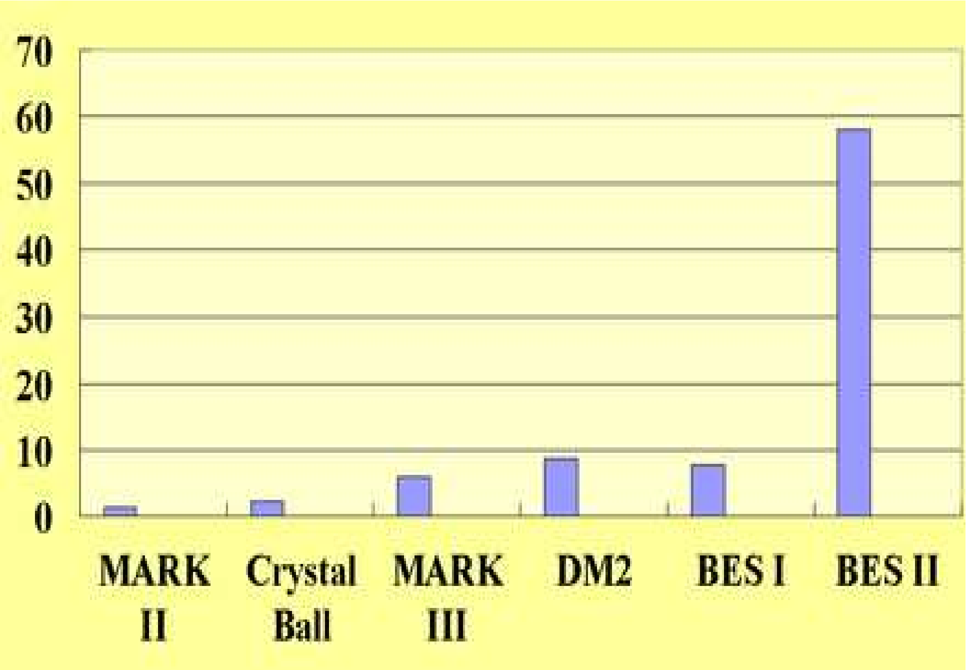
Table 2: Data Collected with BES I and BES II

Detector	$E_{CM}(GeV)$	Physics	Data Sample
BES I	3.097	J/ψ	7.8×10^6
	3.686	$\psi(2S)$	3.96×10^6
	4.03	D_S, D	$22.3pb^{-1}$
	3.55, m_τ scan	m_τ	$5pb^{-1}$
BES II	2-5 R scan	R, α_{QED}, g-2	6+85 points
	$\psi(2S)$ scan	res. para.	24 points
	3.097	J/ψ	58×10^6
	ψ'' scan	res. para.	24 points

- e^+e^- experiments for study of J/ψ.
  Mark I, II, III, Crystal Ball, DM2, BES

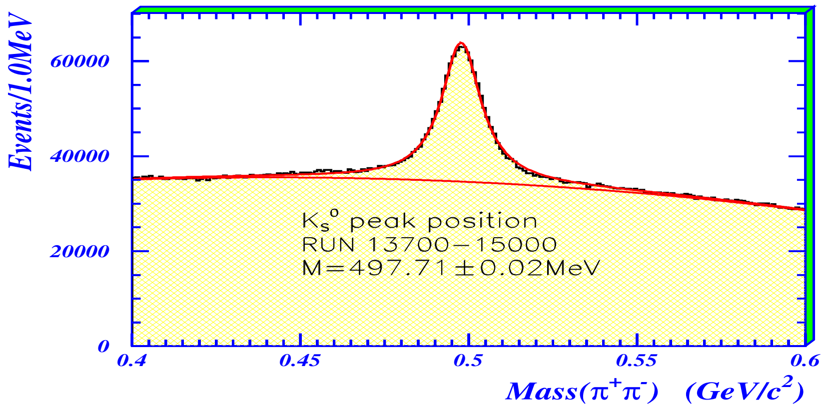
Exp.	Total J/ψ number
Mark II	1.3×10^6
Crystal Ball	2.2×10^6
Mark III	5.8×10^6
DM2	8.6×10^6
BES I	7.8×10^6
BES II	58×10^6

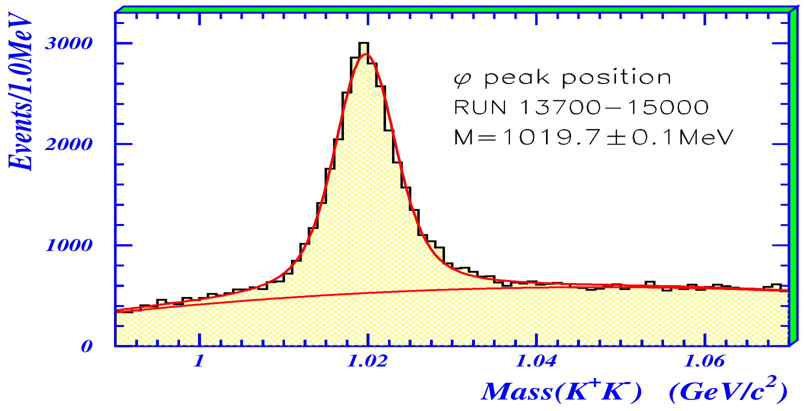
The World J/ψ Samples (10^6)



- At the end of April, 2001 BES completed J/ψ run: 58×10^6 events which is the largest J/ψ sample in the world

- High statistics and good data quality

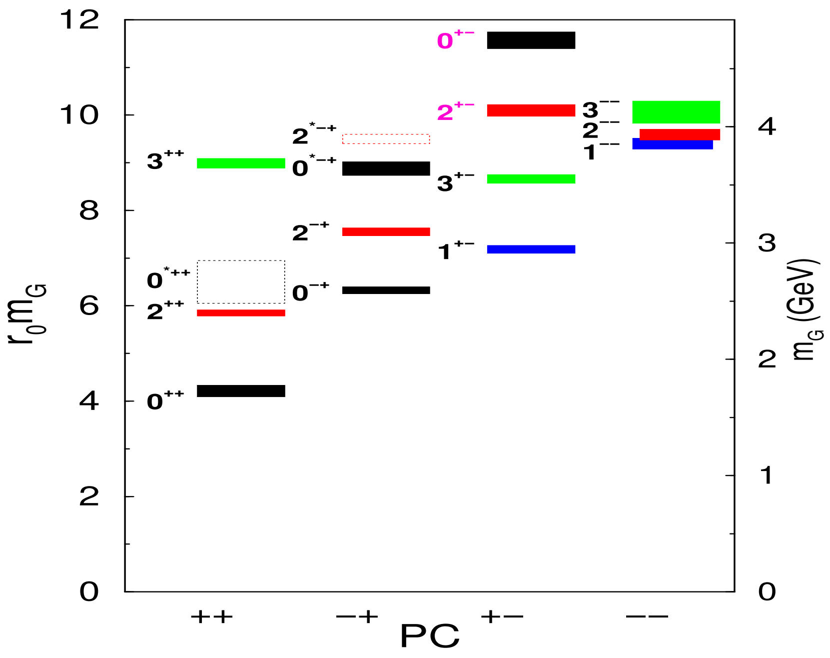




- Plenty of physics topics based on 58M J/ψ events: glueball search, study of excited baryon states, rare decay ...

Partial Wave Analysis of $J/\psi \to \gamma K^+K^-$ and $\gamma K_S^0 K_S^0$

- QCD Lattice   the ground scalar glueball should be in the mass range 1.5-1.7 GeV



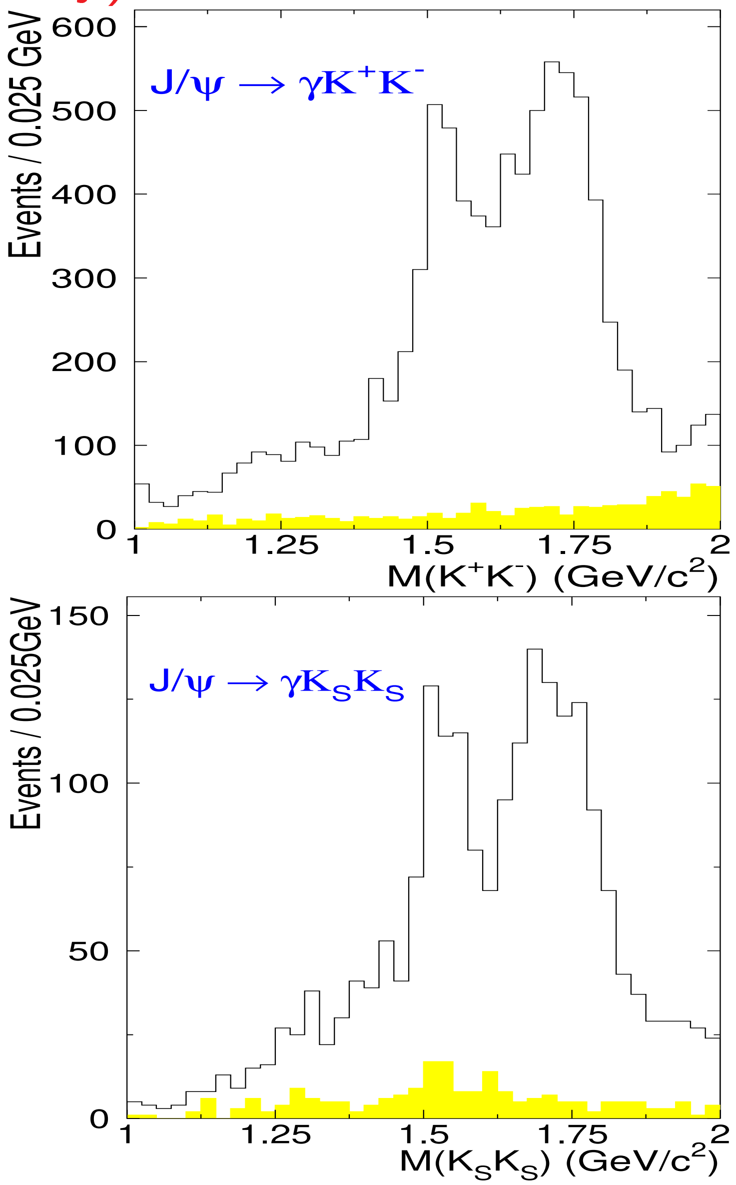
C.Morningstar and M.Peardon, PR D60(1999)

- Long history of uncertainty about $f_0(1710)$

Process	Collaboration	M(MeV)	Γ(MeV)	J^{PC}
$J/\psi \rightarrow \gamma\eta\eta$	CBAL(82)	1640 ± 50	220^{+100}_{-70}	2^{++}
$\pi^- p \rightarrow K_s^0 K_s^0 n$	BNL(82)	1771^{+77}_{-53}	200^{+156}_{-9}	0^{++}
$\pi^- N \rightarrow K_s^0 K_s^0 n$	FNAL(84)	1742 ± 15	57 ± 38	——
$\pi^- p \rightarrow \eta\eta N$	GAMS(86)	1755 ± 8	< 50	0^{++}
$J/\psi \rightarrow \gamma K^+ K^-$	MARKIII(87)	1720 ± 14	130 ± 20	2^{++}
$J/\psi \rightarrow \gamma K\bar{K}$ $\gamma\pi^+\pi^-$	DM2(88)	1707 ± 10 1698 ± 15	166 ± 33 136 ± 28	——
$pp \rightarrow ppK^+K^-$ $ppK_S^0 K_S^0$	WA76(89)	1713 ± 10 1706 ± 10	181 ± 30 104 ± 30	2^{++}
$J/\psi \rightarrow \gamma K\bar{K}$	MARKIII(91)	1710 ± 20	186 ± 30	0^{++}
$p\bar{p} \rightarrow \pi^0\eta\eta$	E760(93)	1748 ± 10	264 ± 25	$(even)^{++}$
$J/\psi \rightarrow \gamma 4\pi$	MARKIII data D. Bugg *et al.*(95)	1750 ± 15	160 ± 40	0^{++}
$J/\psi \rightarrow \gamma K^+ K^-$	BES(96)	$1696 \pm 5^{+9}_{-34}$ $1781 \pm 8^{+10}_{-31}$	$103 \pm 18^{+30}_{-11}$ $85 \pm 24^{+22}_{-19}$	2^{++} 0^{++}
$J/\psi \rightarrow \gamma K\bar{K}$	MARKIII data W. Dunwoodie(97)	1704^{+16}_{-23}	124^{+52}_{-44}	0^{++}
$pp \rightarrow p_f(K^+K^-)p_s$	WA102(99)	1730 ± 15	100 ± 25	0^{++}
$pp \rightarrow p_f(\pi^+\pi^-)p_s$	WA102(99)	1750 ± 25	105 ± 34	0^{++}
$pp \rightarrow K^+K^-\pi^+\pi^-$	WA102(99)	1710 ± 16	126 ± 24	0^{++}
$pp \rightarrow p_f(K^+K^-)p_s$	WA76(99)	1710 ± 25	105 ± 34	0^{++}
$pp \rightarrow p_f\eta\eta p_s$	WA102(00)	1698 ± 18	120 ± 26	0^{++}
$J/\psi \rightarrow \gamma 4\pi$	BES(00)	1740^{+20}_{-25}	135^{+40}_{-25}	0^{++}

- $J/\psi \to \gamma K\bar{K}$ would be a very important channel to investigate the $f_0(1710)$

(Preliminary)



- Amplitudes are fitted to relativistic covariant tensor expressions (Under 2.0GeV)

- Both global fit and bin-by-bin fit are done for $J/\psi \to \gamma K^+K^-$ and $\gamma K_S^0 K_S^0$

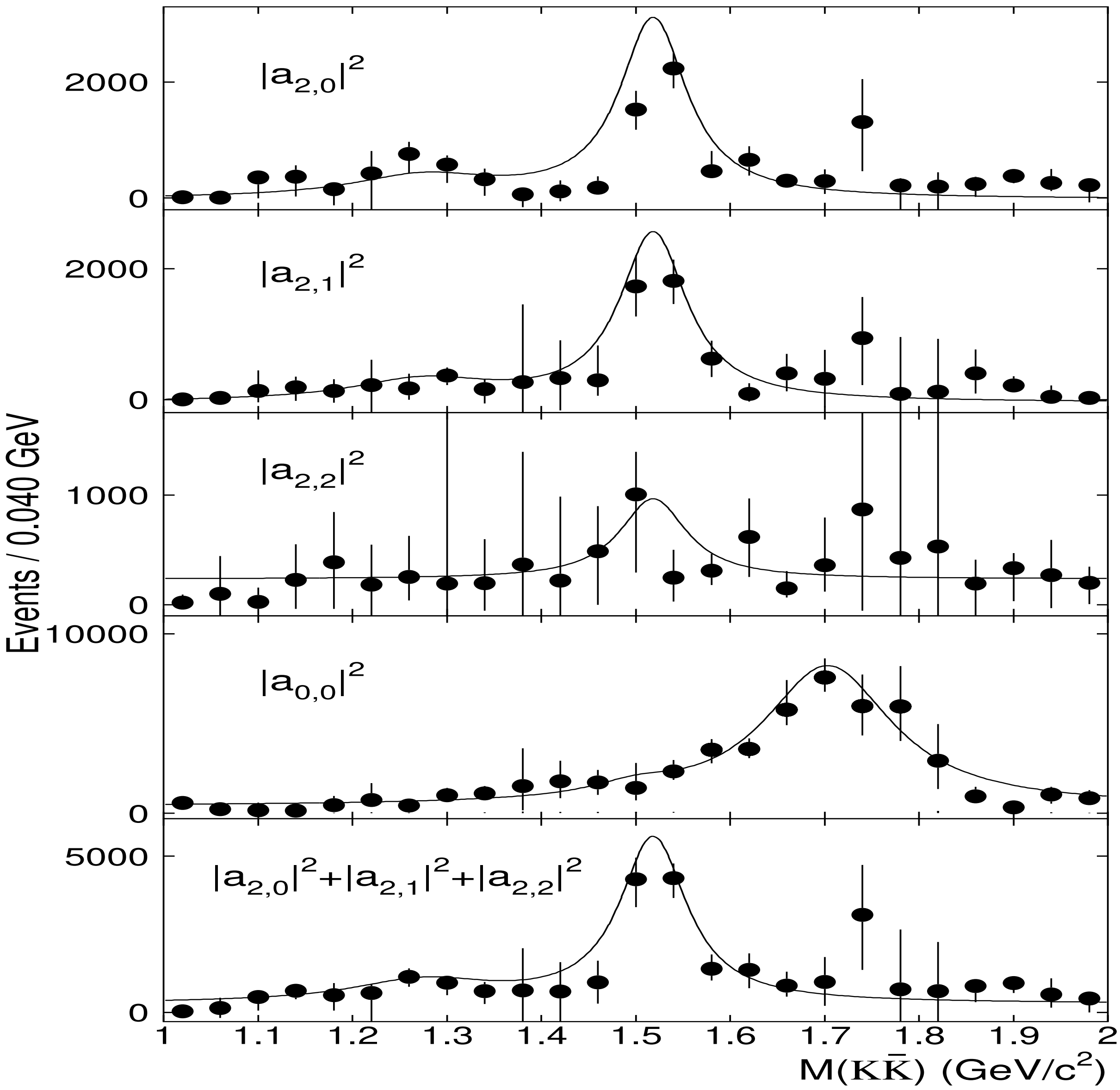
- The Maximum Likelihood method is employed in the fit

- For global fit, partial waves have been fitted to the data for the following channels:

$$\begin{aligned} J/\psi \quad \to \quad & \gamma {f_2}'(1525) \\ & \gamma f_0(1710) \\ & \gamma f_2(1270) \\ & \gamma f_0(1500) \end{aligned}$$

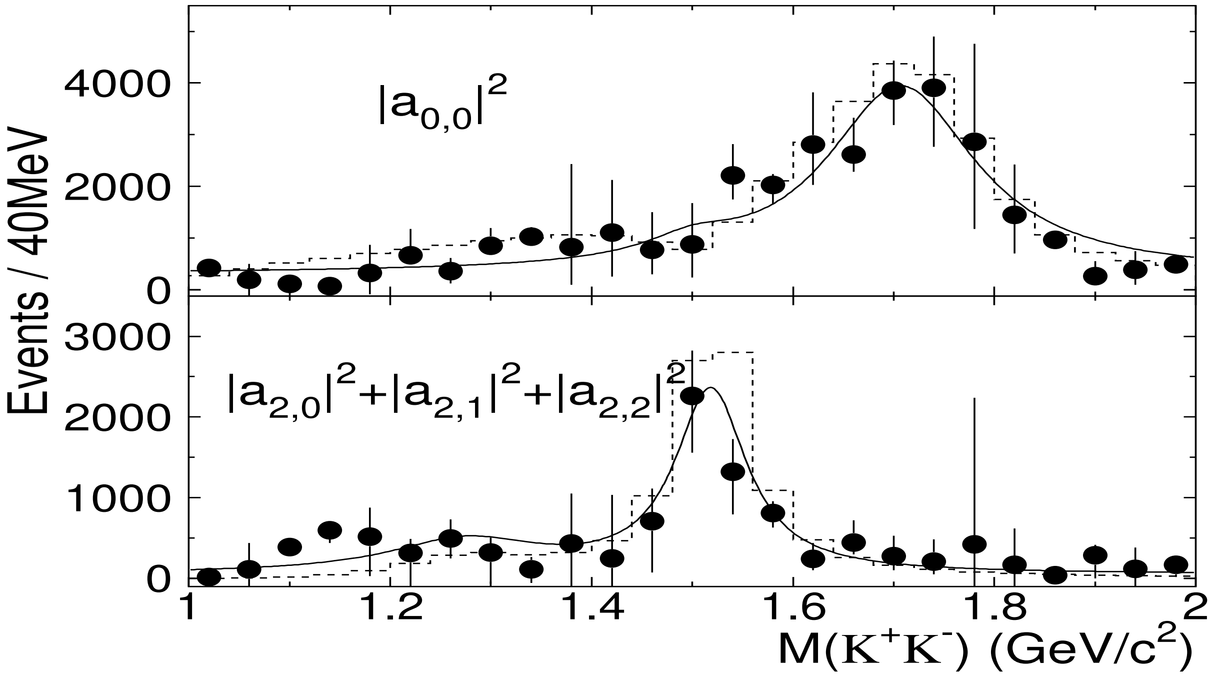
with a broader 0^{++} background

$J/\psi \to \gamma K\bar{K}$ (Preliminary)

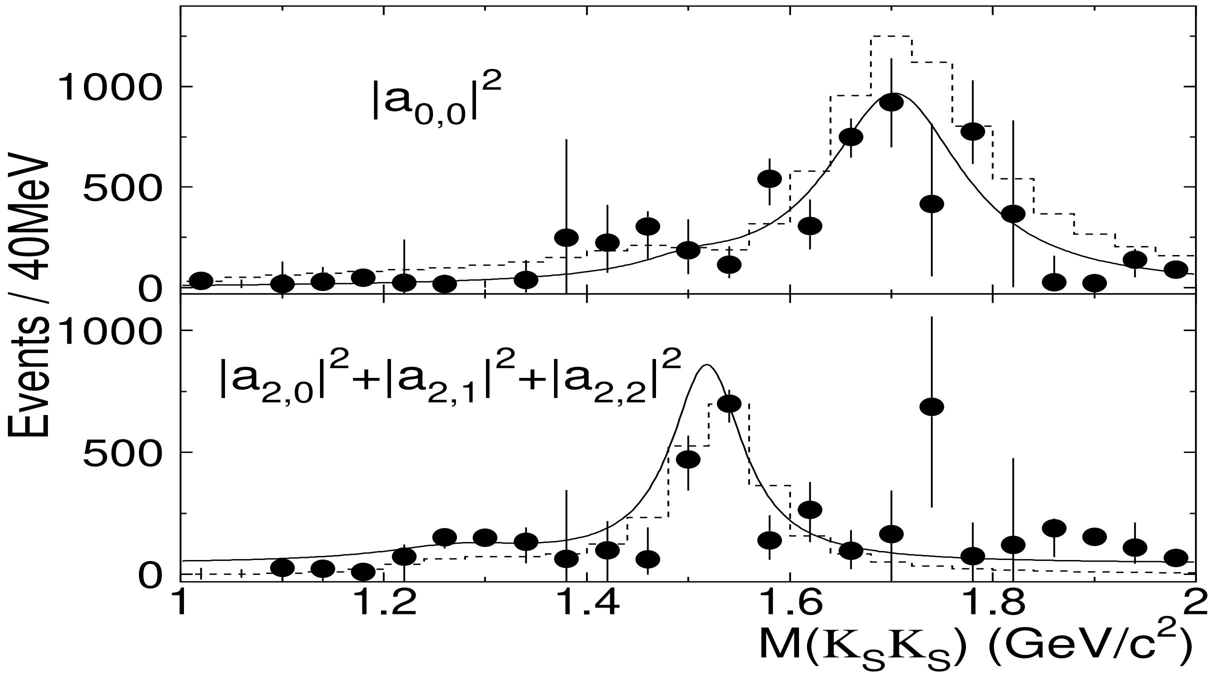


The results of fitting Breit-Wigner line shapes to the amplitude intensity distributions of combined $J/\psi \to \gamma K^+K^-$ and $J/\psi \to \gamma K_S^0 K_S^0$ data.
The solid curves correspond to the coherent superposition of the individual Breit-Wigner resonances fit the efficiency-corrected data points.

$J/\psi \to \gamma K^+ K^-$ (Preliminary)



$J/\psi \to \gamma K^0_S K^0_S$ (Preliminary)



- The 2^{++} distribution shows a clear signal corresponding to the $f_2'(1525)$, and also evidence of $f_2(1270)$; there is some 2^{++} contribution at about 1.7Gev, but the region is predominantly 0^{++}

- Mass and Width (Statistical only)

	Mass(MeV/c^2)	Γ(MeV/c^2)
$f_2{}'(1525)$	1518 ± 6	84^{+28}_{-24}
$f_0(1710)$	1703^{+8}_{-10}	163^{+27}_{-22}

- The ratio of the amplitudes intensities of the $f_2{}'(1525)$ (Statistical only)

	BES	Mark III[1]	Mark III[2]
$x^2 = \frac{\lvert a_{2,1}\rvert^2}{\lvert a_{2,0}\rvert^2}$	0.94 ± 0.08	1.08 ± 0.31	$1.66^{+1.10}_{-0.57}$
$y^2 = \frac{\lvert a_{2,2}\rvert^2}{\lvert a_{2,0}\rvert^2}$	0.26 ± 0.10	0.25 ± 0.24	$0.28^{+0.36}_{-0.21}$

Measurement of the mass of η_c meson

Table 3: η_c mass and width

Process	Exp.	Mass (MeV)	Width (MeV)
e^+e^-	MRK2(80)	2982 ± 8	
$J/\psi, \psi' \to \gamma X$	CBAL(86)	$2984 \pm 2 \pm 4$	11.5 ± 4.5
$J/\psi \to \gamma\eta_c$	MRK3(86)	2980.2 ± 1.6	
$J/\psi \to \gamma p\bar{p}$	MRK3(86)		$10.1^{+37.0}_{-8.2}$
$p\bar{p} \to \gamma\gamma$	SPEC(87)	$2982.6^{+1.7}_{-2.3}$	$7.0^{+7.5}_{-7.0}$
$J/\psi \to \gamma 4K$	MRK3(90)	$2969 \pm 4 \pm 4$	
$J/\psi \to \gamma\eta_c$	DM2(91)	2979.4 ± 1.9	
$p\bar{p} \to \gamma\gamma$	E760(92)	$2988.3^{+3.3}_{-3.1}$	$23.9^{+12.6}_{-7.1}$
e^+e^-	DLPH(98)	2999 ± 8	
$\psi' \to \gamma\eta_c$	BES(99)	$2975.8 \pm 3.9 \pm 1.2$	
PDG2000		2979.8 ± 1.8	$13.2^{+3.8}_{-3.2}$

- L3(1999) measured η_c parameters.
- E835 $p\bar{p} \to \gamma\gamma$ data.

  $M = 2985^{+1.7}_{-1.8} MeV$, $\Gamma = 17.8^{+7.2}_{-6.9} MeV$.

- BESI(2000) $J/\psi \to \gamma\eta_c$, $\eta_c \to K^+K^-\pi^+\pi^-$, 4π, $KK\pi$ and $\phi\phi$. $M = 2976.3 \pm 2.3 \pm 1.2 MeV$, $\Gamma = 11.0 \pm 8.1 \pm 4.1 MeV$.

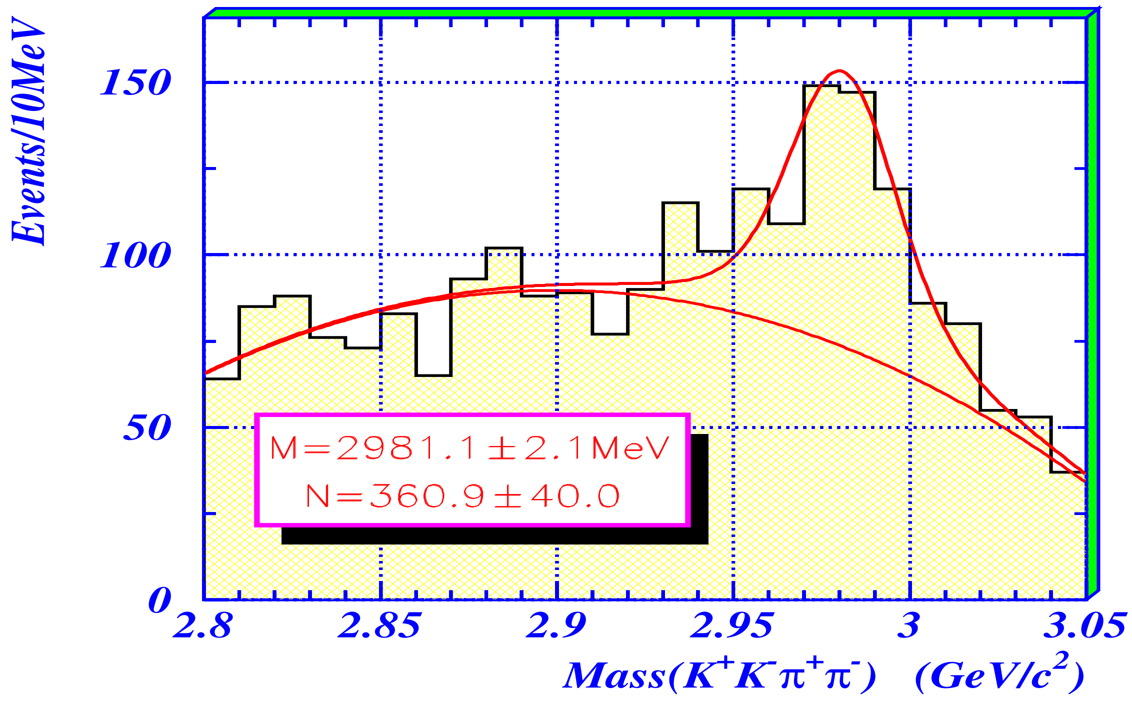
- CLEO(2000) 2-photon collision.

  $M = 2980.4 \pm 2.3 \pm 0.6 MeV$, $\Gamma = 27.0 \pm 5.8 \pm 1.4 MeV$.

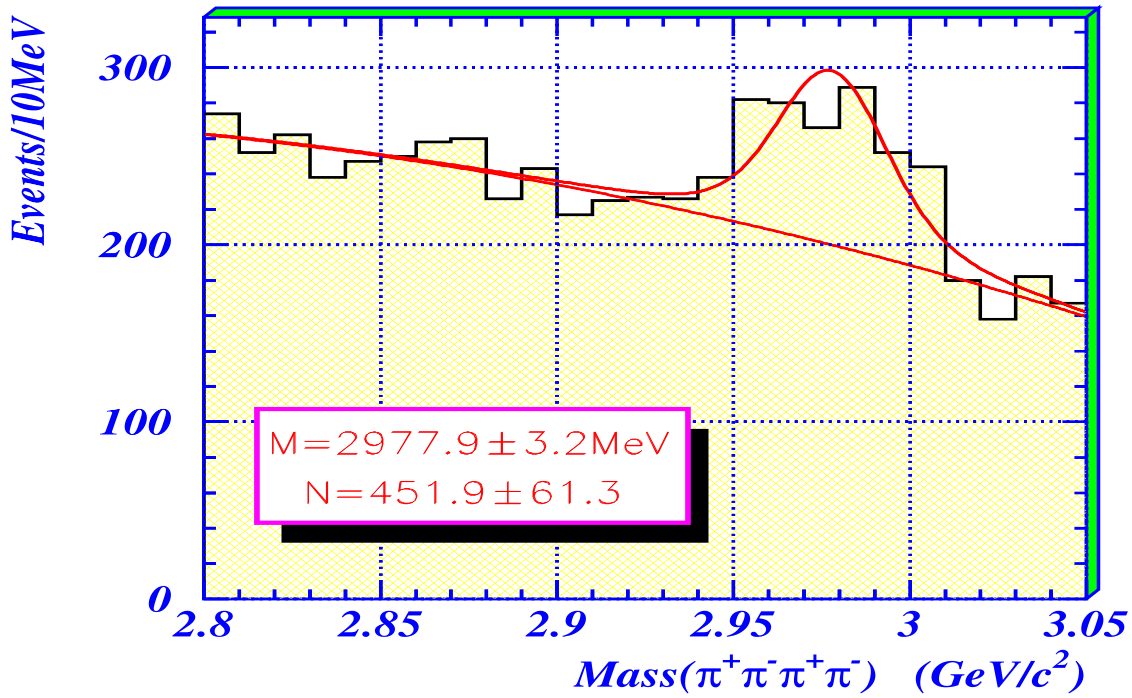
- SIX radiative decay channels were analyzed using BES II J/ψ data

$$
\begin{array}{lcl}
J/\psi & \to & \gamma\eta_c \\
\eta_c & \to & K^+K^-\pi^+\pi^- \\
 & & \pi^+\pi^-\pi^+\pi^- \\
 & & K^\pm K^0_S\pi^\mp \to K^\pm\pi^\mp\pi^+\pi^- \\
 & & \phi\phi \to K^+K^-K^+K^- \\
 & & K^+K^-\pi^0 \\
 & & p\bar{p}
\end{array}
$$

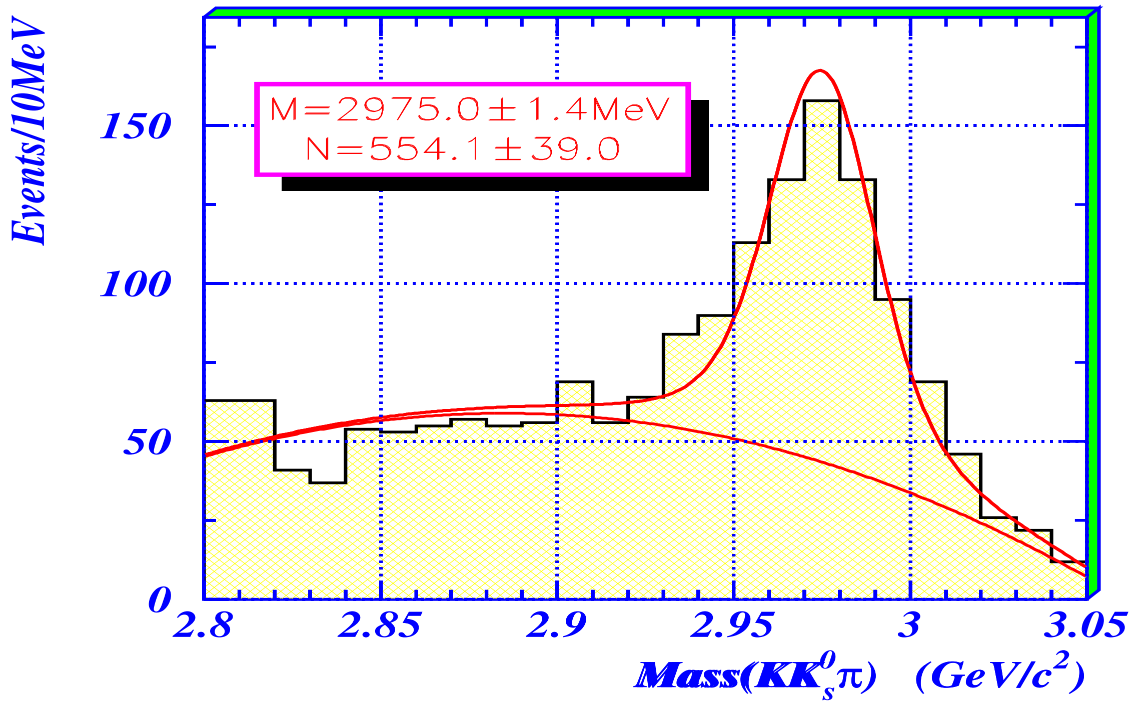
$J/\psi \to \gamma K^+ K^- \pi^+ \pi^-$ (Preliminary)



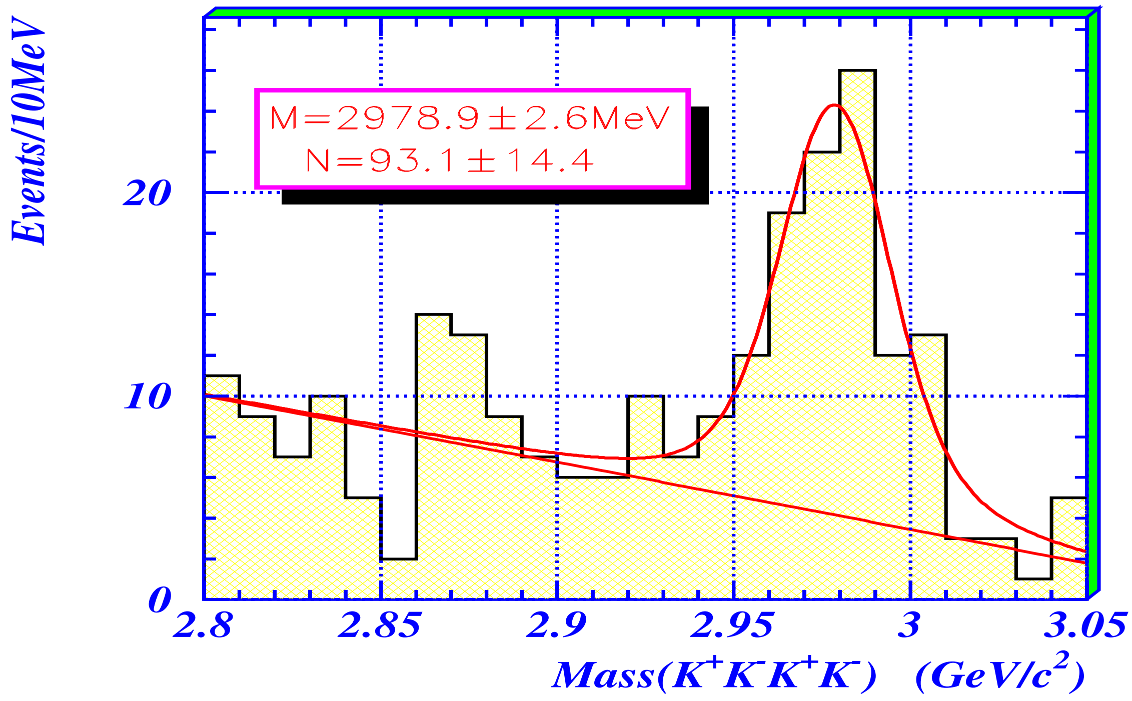
$J/\psi \to \gamma \pi^+ \pi^- \pi^+ \pi^-$ (Preliminary)



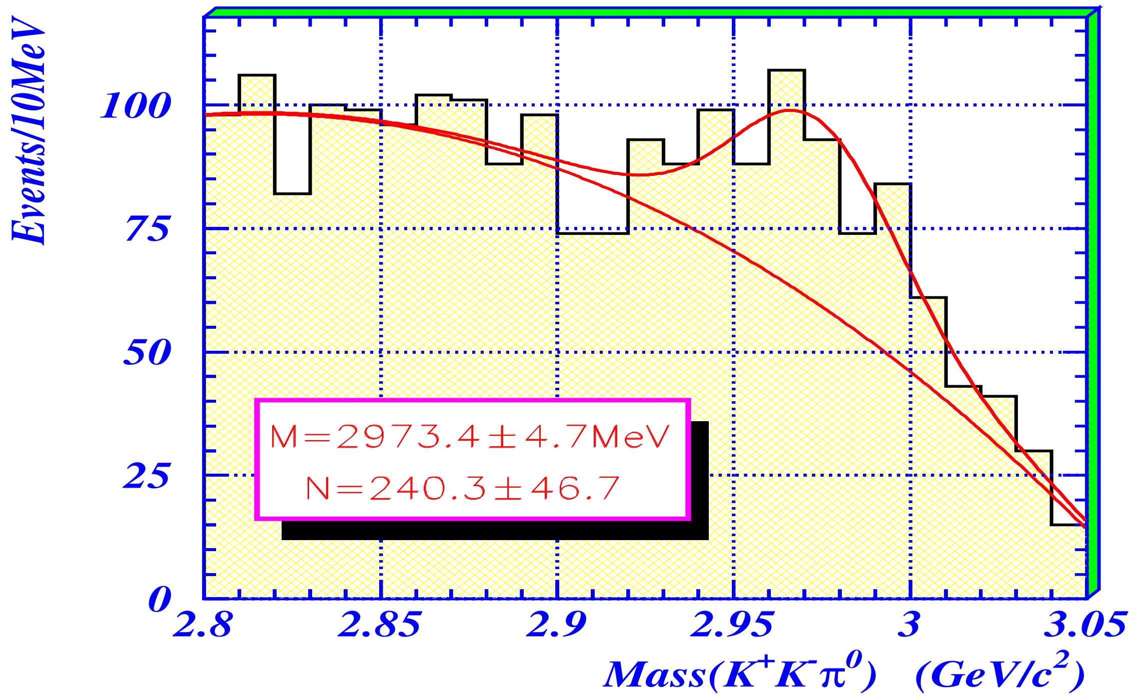
$J/\psi \to \gamma K^{\pm} K^0_S \pi^{\mp}$(Preliminary)



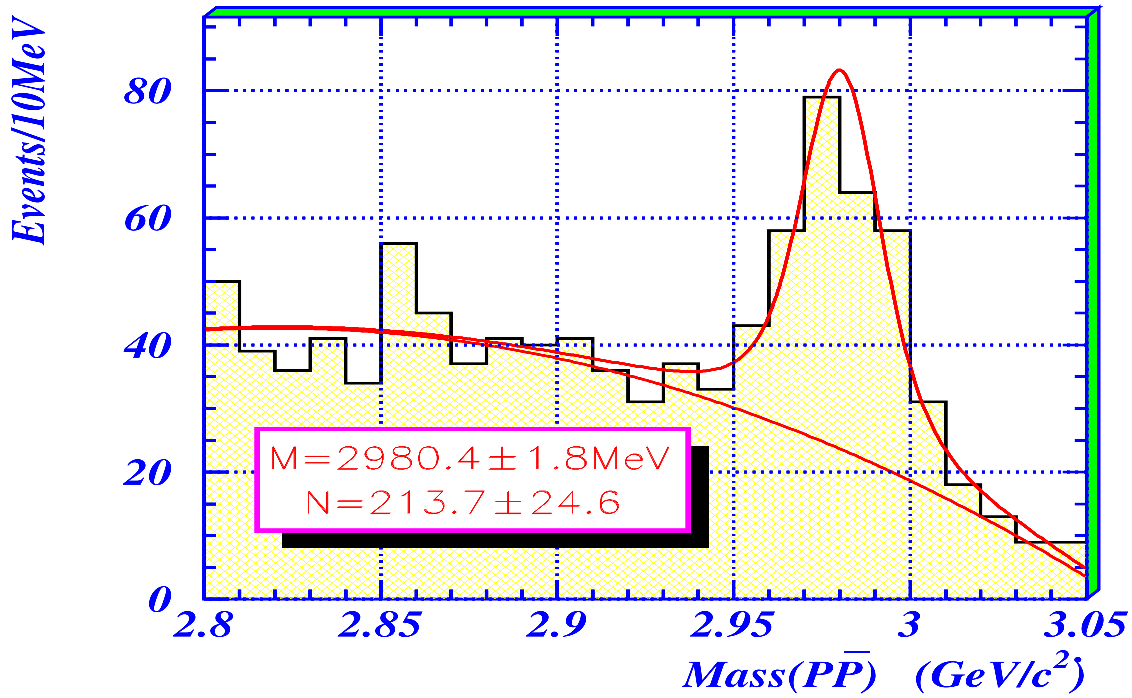
$J/\psi \to \gamma \phi\phi$(Preliminary)



$J/\psi \to \gamma K^+ K^- \pi^0$(Preliminary)



$J/\psi \to \gamma p\bar{p}$(Preliminary)



- The fit values of number of events and mass for the individual channels (Γ fixed at $16.5 MeV$, the weighted average of PDG, BES I and CLEO values, errors are statistical only)

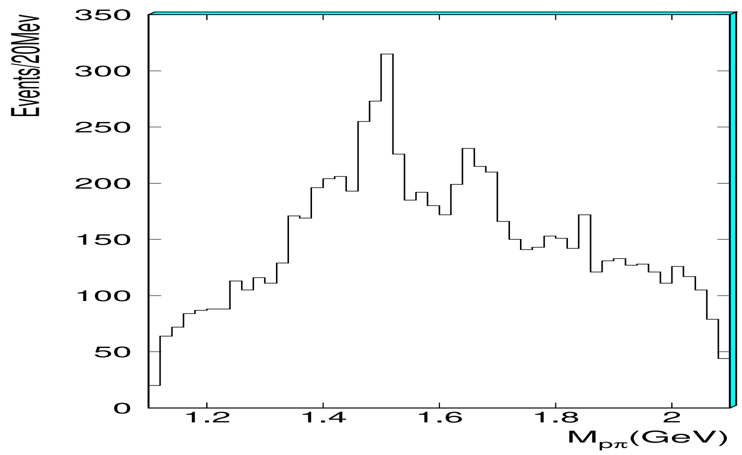
Channel	No. of events	mass(MeV)
$K^+K^-\pi^+\pi^-$	360.9 ± 40.0	2981.1 ± 2.1
$\pi^+\pi^-\pi^+\pi^-$	451.9 ± 61.3	2977.9 ± 3.2
$K^\pm K^0_S\pi^\mp$	554.1 ± 39.0	2975.0 ± 1.4
$\phi\phi$	93.1 ± 14.4	2978.9 ± 2.6
$K^+K^-\pi^0$	240.3 ± 46.7	2973.4 ± 4.7
$p\bar{p}$	213.7 ± 24.6	2980.4 ± 1.8

- Combining the weighted average with the results for the six channels, we obtain

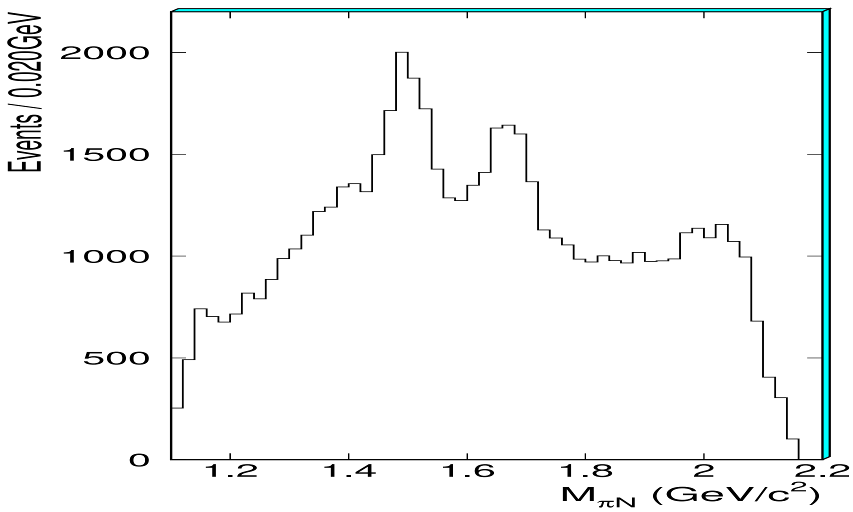
$$m_{\eta_c} = 2977.9 \pm 0.9(stat)\text{MeV}$$

Study of Excited Baryon States

$\underline{J/\psi \to p\bar{p}\pi^0}$(Preliminary)

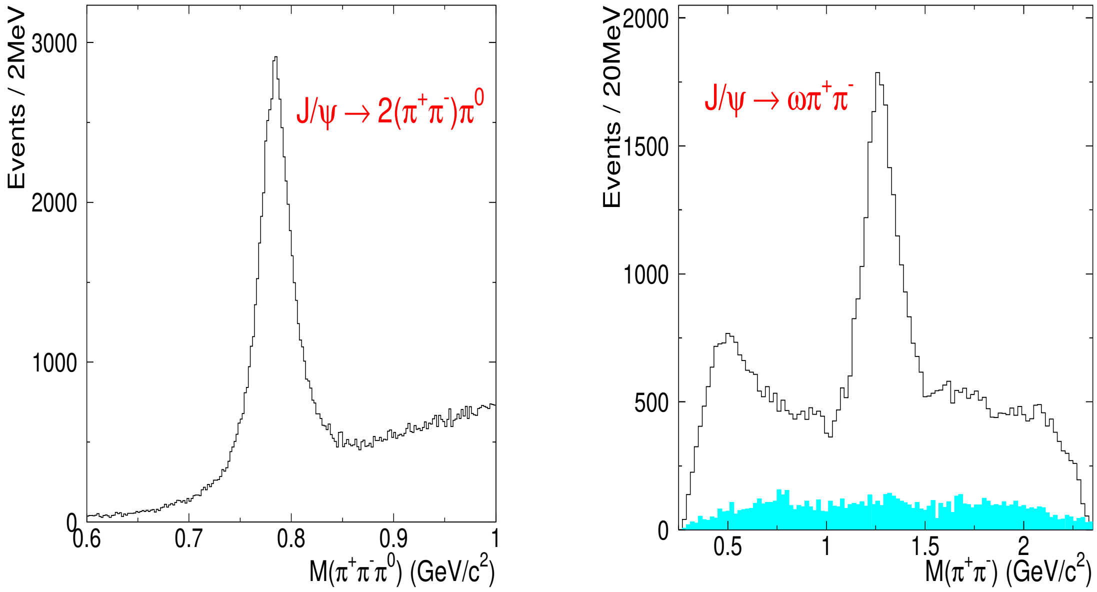


$\underline{J/\psi \to p\bar{n}\pi^-}$(Preliminary)

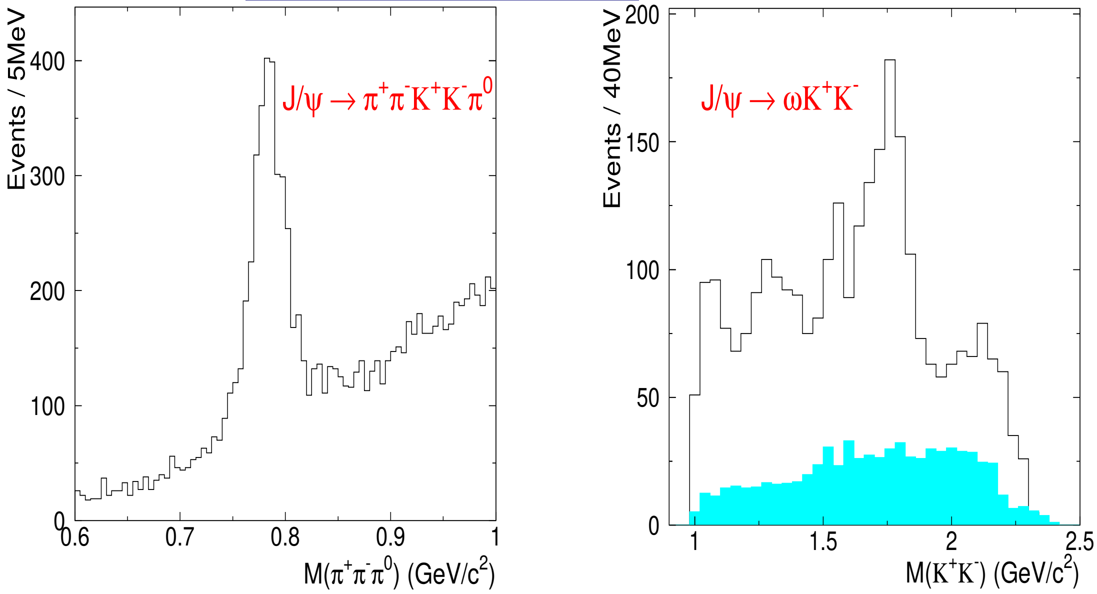


J/ψ's 3-body decay

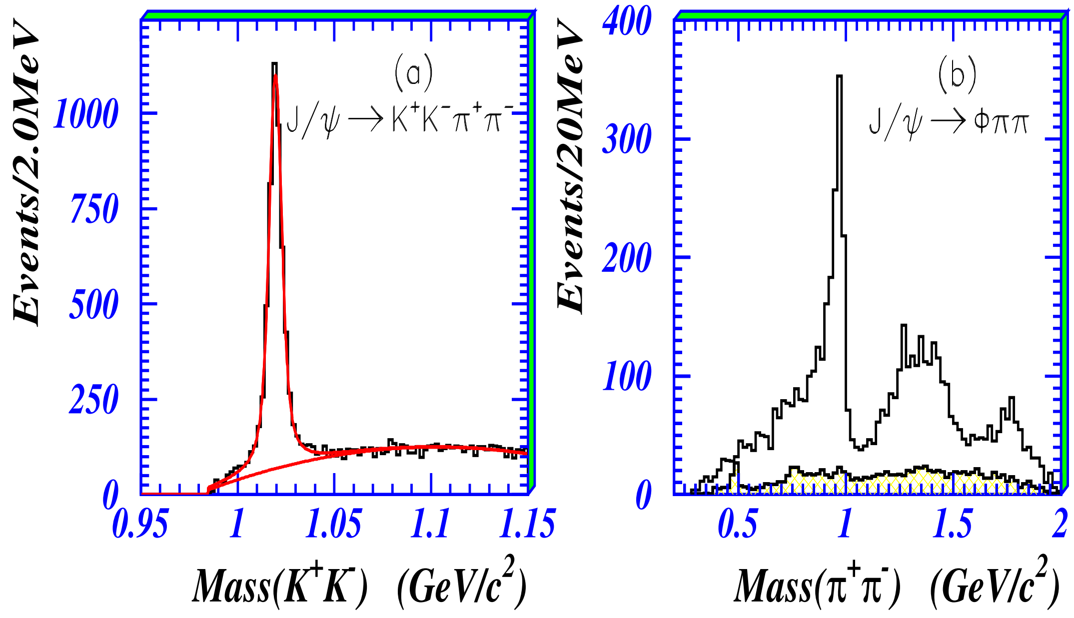
$J/\psi \rightarrow \omega\pi^+\pi^-$(Preliminary)



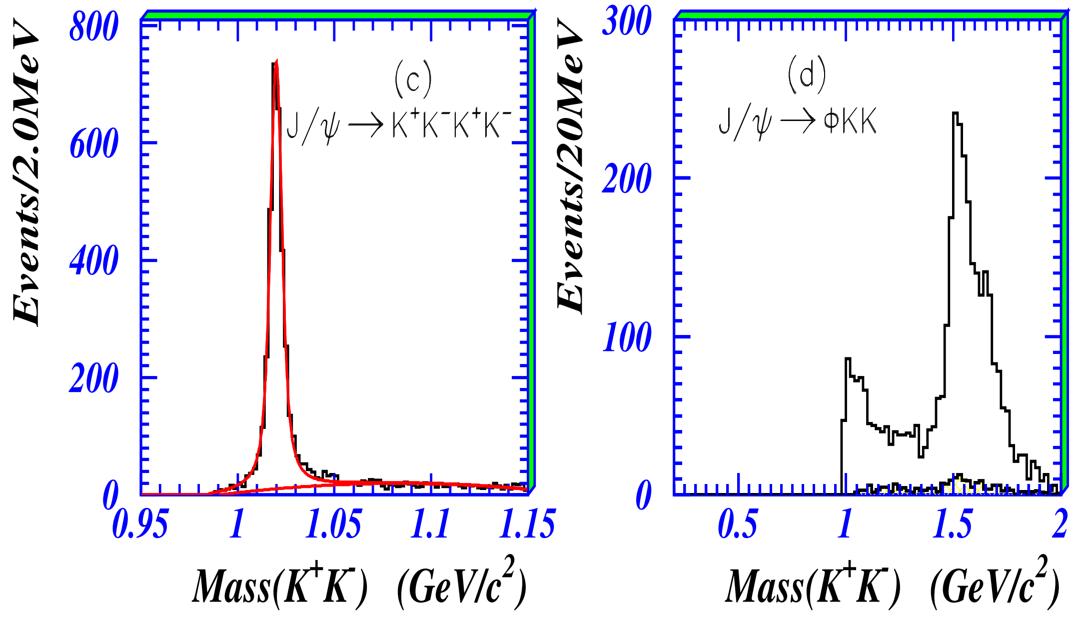
$J/\psi \rightarrow \omega K^+K^-$(Preliminary)



$\underline{J/\psi \to \phi\pi^+\pi^-}$(Preliminary)



$\underline{J/\psi \to \phi K^+K^-}$(Preliminary)



Summary

- BES has accumulated 58M J/ψ events until 2001, the largest data sample

- Partial Wave Analysis of $J/\psi \to \gamma K^+K^-$ and $\gamma K_S^0 K_S^0$ using total BES II J/ψ data set

  0^{++} dominant in the $f_0(1710)$ region

$f_2^{'}(1525)$	M=1518 ± 6MeV	$\Gamma = 84^{+28}_{-24}$MeV
$f_0(1710)$	M=1703^{+8}_{-10}MeV	$\Gamma = 163^{+27}_{-22}$MeV

- The process $J/\psi \to \gamma\eta_c$ is observed in six decay channels. η_c mass is

$$m_{\eta_c} = 2977.9 \pm 0.9(stat)MeV$$

  which is in good agreement with the PDG value 2979.8 ± 1.8 MeV.

- Expect many new results in the future