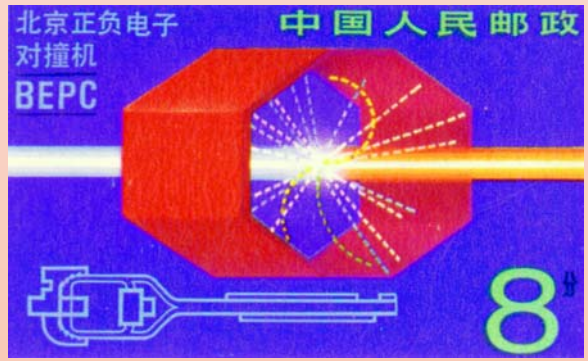
Recent $\psi(2s)$ and η_C Results from BES

Frederick A. Harris

Representing the BES Collaboration

ICHEP 2002



OUTLINE

- Introduction
- ψ(2S) Hadronic Decays
- ψ(2S) Scan Results
- η_c Results
- 2002 ψ(2S) Run
- Summary

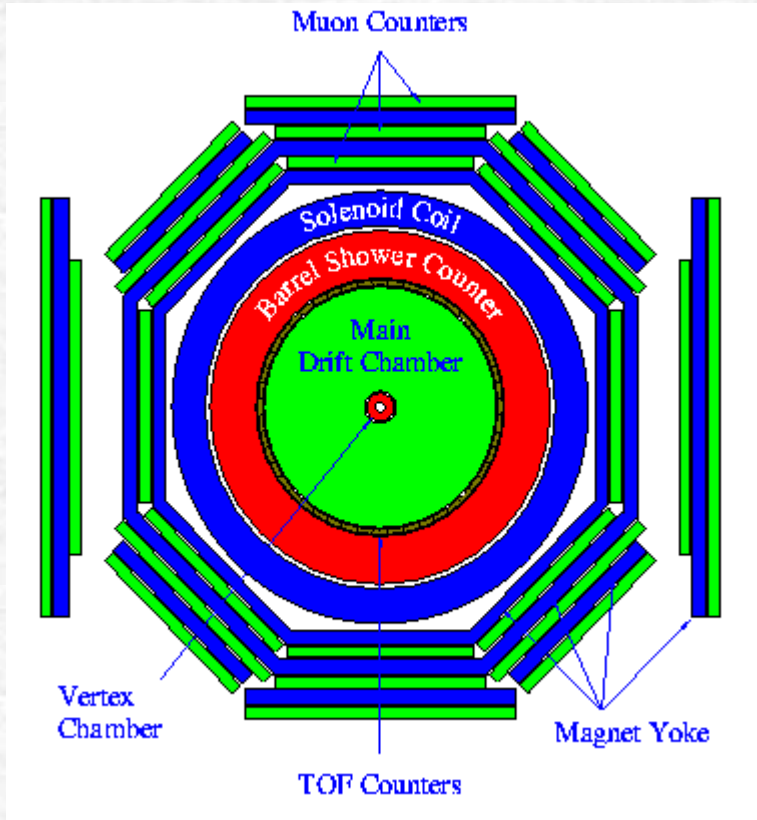
Introduction - BES

CM Energy ranges from 2 to 5 GeV

Luminosity at $J/\psi \sim 5 \times 10^{30}\ cm^{-2}\ s^{-1}$

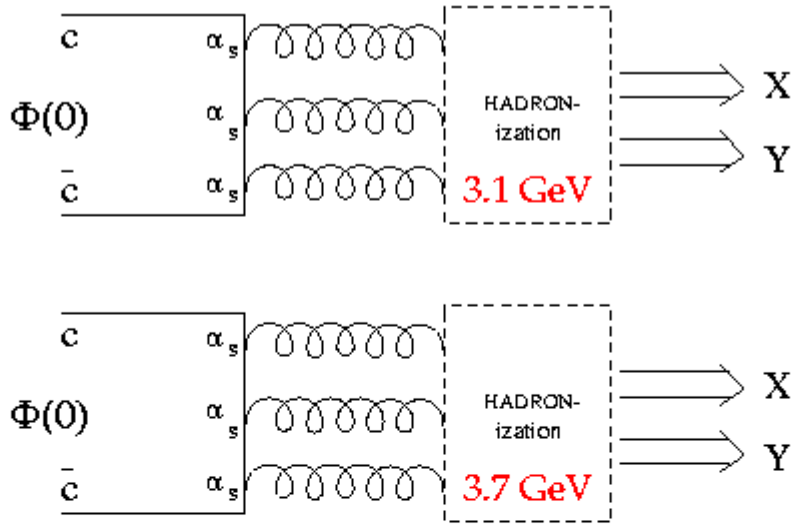
Detector Performance:

Detector	Major parameter	BESII
VC	$\sigma_{xy}(\mu m)$	100
MDC	$\sigma_{xy}(\mu m)$	190-220
	$\Delta p/p$ (%)	$1.78\sqrt{1+p^2}$
	$\sigma_{dE/dx}$ (%)	8.4
BTOF	σ_T (ps)	180
	L_{atten} (m)	3.5 - 5.5
ETOF	σ_T (ps)	720
BSC	$\Delta E/\sqrt{E}$ (%)	23%
	σ_z(cm)	2.3
ESC	$\Delta E/\sqrt{E}$ (%)	21%
μ counter	σ_z(cm)	5.5
DAQ	dead time (ms)	8



ψ(2S) Hadronic Decays

Expectations: *T. Applequist and D. Politzer, Phys. Rev. Lett.* ***51****, 43 (1975).*



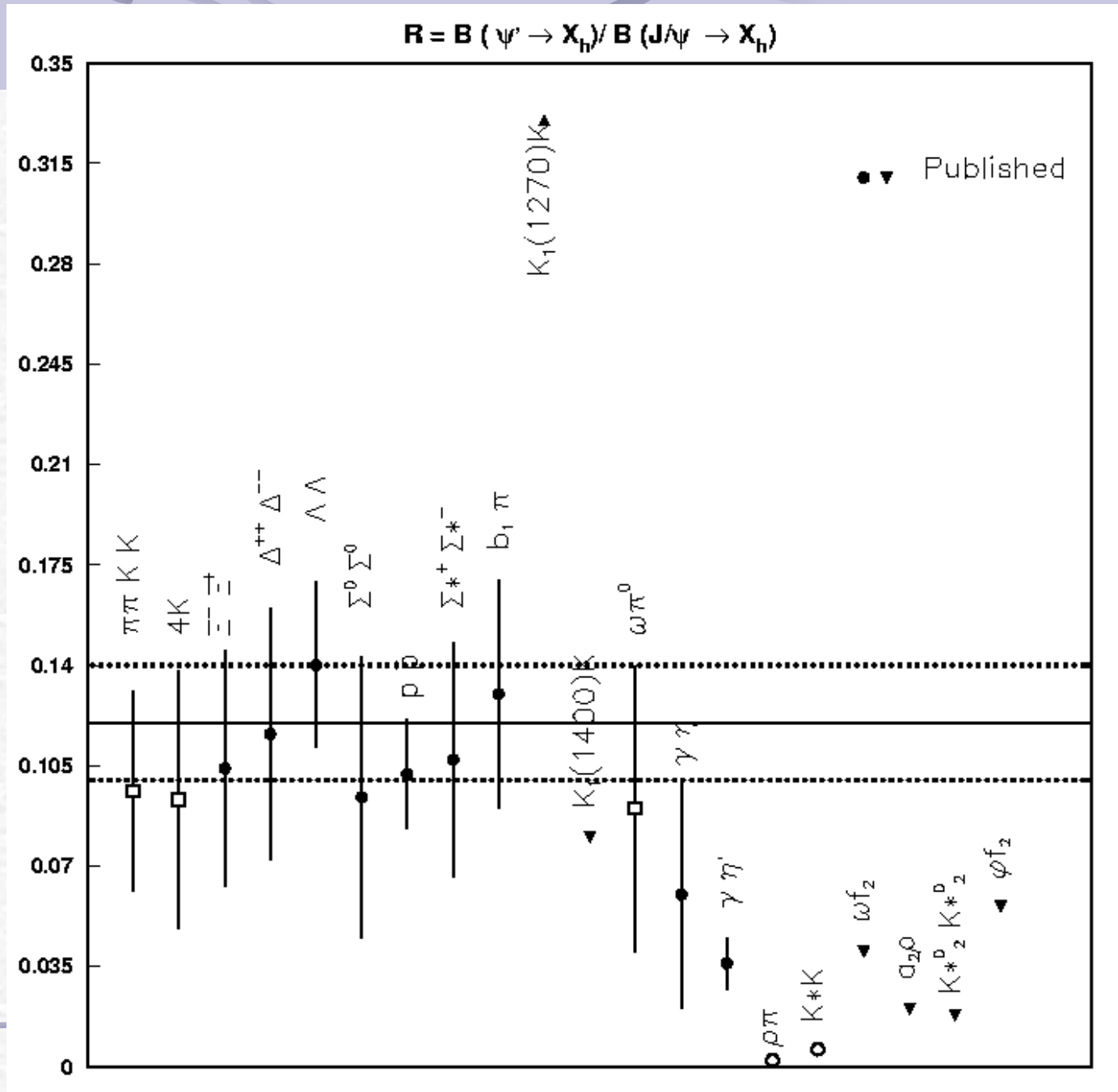
$$\mathcal{B}(\psi \to Final\ State) \propto \Gamma(\psi \to Final\ State)$$

$$\frac{\mathcal{B}[\psi(2S) \to X + Y]}{\mathcal{B}[J/\psi \to X + Y]} = \frac{\mathcal{B}[\psi(2S) \to \mu^+\mu^-]}{\mathcal{B}[J/\psi \to \mu^+\mu^-]} f(\alpha_s(s)) = (12.2 \pm 2.0)\%$$

Results

BESI :

4 M ψ(2s)



$\rho\pi$ Puzzle

VP states like $\rho\pi$ and $\bar{K}^* K$ are strongly suppressed.

- First seen by MarkII with suppression factor ~20.
- BES finds suppression ~60.
- BES also finds suppression in VT channels

New channels with ω's and ϕ's

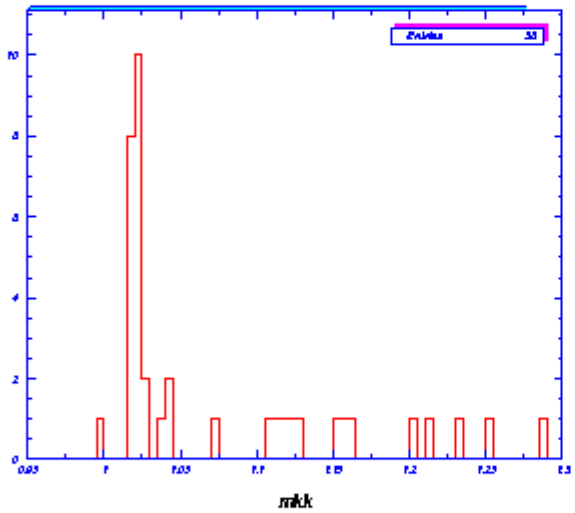
- $\psi' \to \omega\pi^+\pi^- \to \pi^0\pi^+\pi^-\pi^+\pi^-$
- $\psi' \to b_1^{\pm}\pi^{\mp} \to \omega\pi^+\pi^- \to \pi^0\pi^+\pi^-\pi^+\pi^-(*)$
- $\psi' \to \omega f_2(1270) \to \omega\pi^+\pi^- \to \pi^0\pi^+\pi^-\pi^+\pi^-(*)$
- $\psi' \to \omega K^+K^- \to \pi^0\pi^+\pi^-K^+K^-$
- $\psi' \to \omega p\bar{p} \to \pi^0\pi^+\pi^-p\bar{p}$
- $\psi' \to \phi\pi^+\pi^- \to K^+K^-\pi^+\pi^-$
- $\psi' \to \phi f_0(980) \to \phi\pi^+\pi^- \to K^+K^-\pi^+\pi^-$
- $\psi' \to \phi K^+K^- \to K^+K^-K^+K^-$
- $\psi' \to \phi p\bar{p} \to K^+K^-p\bar{p}$

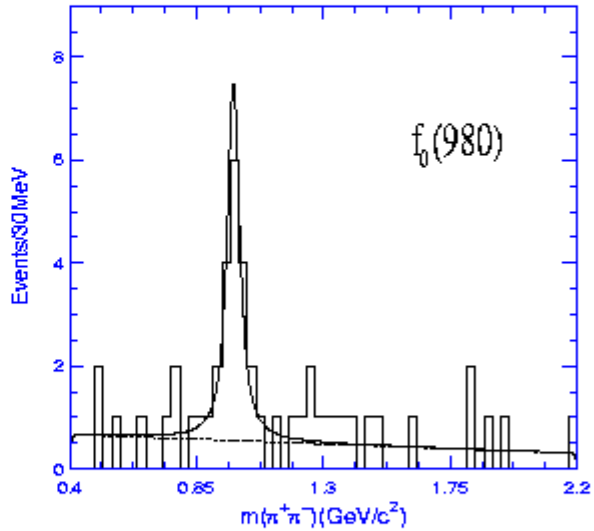
Cuts

- *Charged tracks*
  - *Good vertex*
  - *Sum charge = 0*
  - *cos θ < 0.8*
  - *PID (dE/dx & TOF): Prob > 1 %*
- *Neutral tracks*
  - *at least 2 photons*
  - *cos θ < 0.8*
  - *E_γ > 50 MeV*
- *Kinematic fit: Prob > 1 %*
- *$Prob_{comb}(signal) > Prob_{comb}(bg)$*
- *Cut J/ψ background from $\psi(2s) \rightarrow \pi\pi J/\psi$*

$\psi(2S) \to \phi f_0$

N events = 18 . 4 + 6.3
Mass = 0.980 + 0.009GeV
Width = 0.045 + 0.030 GeV

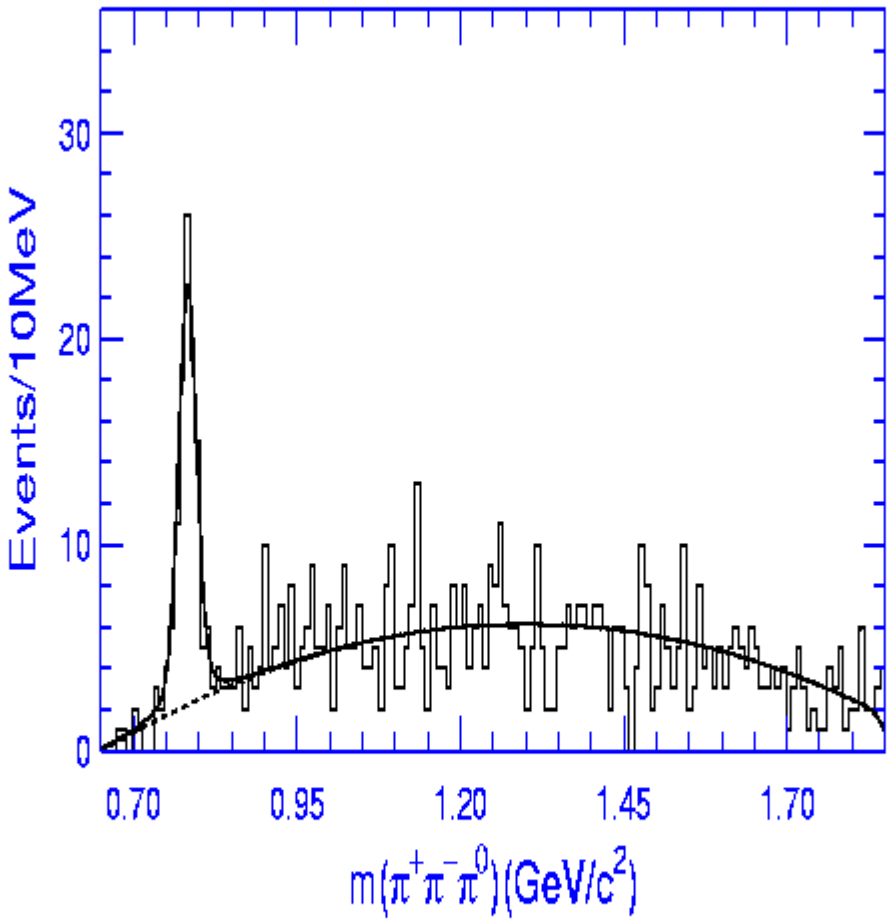




$$\mathcal{B}(\psi(2S) \to \phi f_0) = (1.1 \pm 0.4 \pm 0.2) \times 10^{-4}$$

using $B(f_0(980) \to \pi^+\pi^-) = 0.52$

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



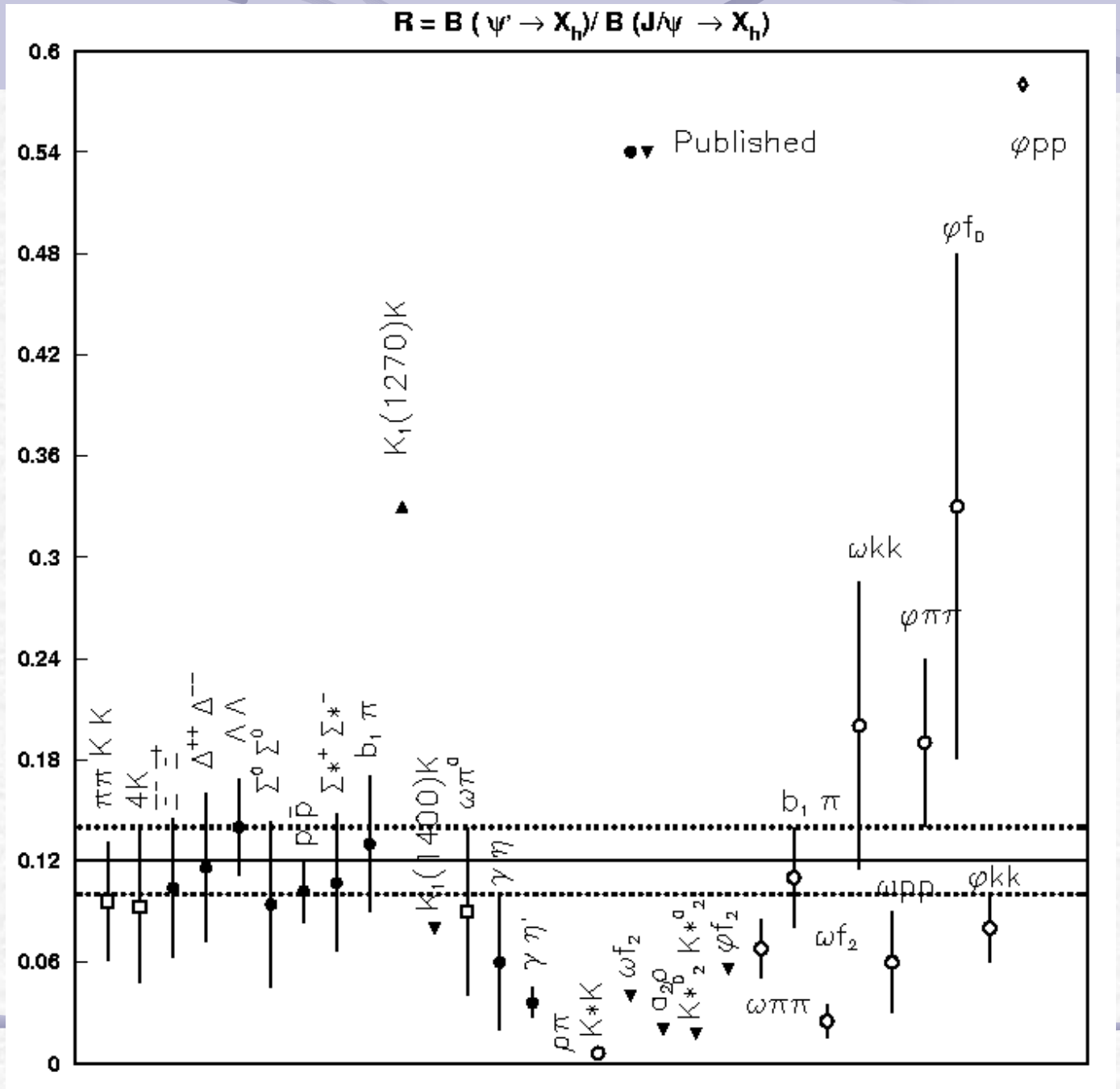
$$\mathcal{B}(\psi(2S) \to \omega\pi^+\pi^-) = (4.9 \pm 0.6 \pm 0.8) \times 10^{-4}$$

Results - Preliminary

Channels	$B_{\psi(2S)}(\times 10^{-4})$	$B_{J/\psi}(\times 10^{-4})$	$Q_h = \frac{B_{\psi(2S)}}{B_{J/\psi}}(\%)$
$\omega\pi^+\pi^-$	$4.9 \pm 0.6 \pm 0.8$	72.0 ± 10.0	6.8 ± 1.7
$b_1^{\pm}\pi^{\mp}$	$3.3 \pm 0.6 \pm 0.5$	30.0 ± 5.0	11.0 ± 3.3
$\omega f_2(1270)$	$1.2 \pm 0.4 \pm 0.2$	43.0 ± 6.0	2.7 ± 1.1
ωK^+K^-	$1.5 \pm 0.3 \pm 0.2$	7.4 ± 2.4	20.1 ± 8.5
$\omega p\bar{p}$	$0.8 \pm 0.3 \pm 0.1$	13.0 ± 2.5	6.0 ± 2.9
$\phi\pi\pi$	$1.5 \pm 0.2 \pm 0.2$	8.0 ± 1.2	19.1 ± 5.1
$\phi f_0(980)$	$1.1 \pm 0.4 \pm 0.2^*$	3.2 ± 0.9	33.7 ± 15.6
ϕK^+K^-	$0.6 \pm 0.2 \pm 0.1$	8.3 ± 1.3	7.7 ± 2.5
$\phi p\bar{p}$	$0.12 \pm 0.06 \pm 0.02$ < 0.3	0.45 ± 0.15	26.7 ± 16.2 < 57.8

$B(f_0(980) \to \pi^+\pi^-) = 0.52$

$$Q = B(\psi(2S) \to h)/B(J/\psi \to h)$$


R = B (ψ' → X_h)/ B (J/ψ → X_h)
Published
φpp
φf_D
K_1(1270)K
ωkk
φππ
b_1 π
ωpp
φkk
ωf_2
ωππ
0.6
0.54
0.48
0.42
0.36
0.3
0.24
0.18
0.12
0.06
0

ψ(2S) Scan

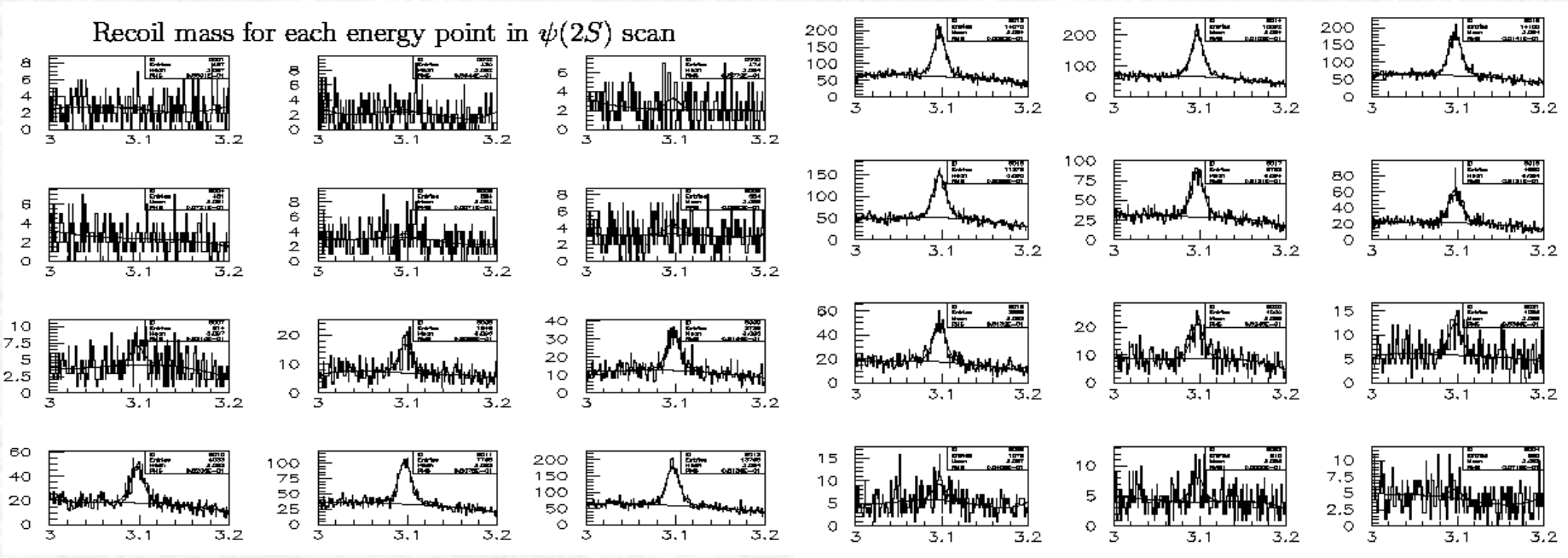
Purpose: Improve accuracies of ψ(2S) parameters: Γ, Γ_h, Γ_μ, $\Gamma_{\pi\pi\ J/\psi}$, B(h), B(μ), and B($\pi^+\ \pi^-\ J/\psi$)

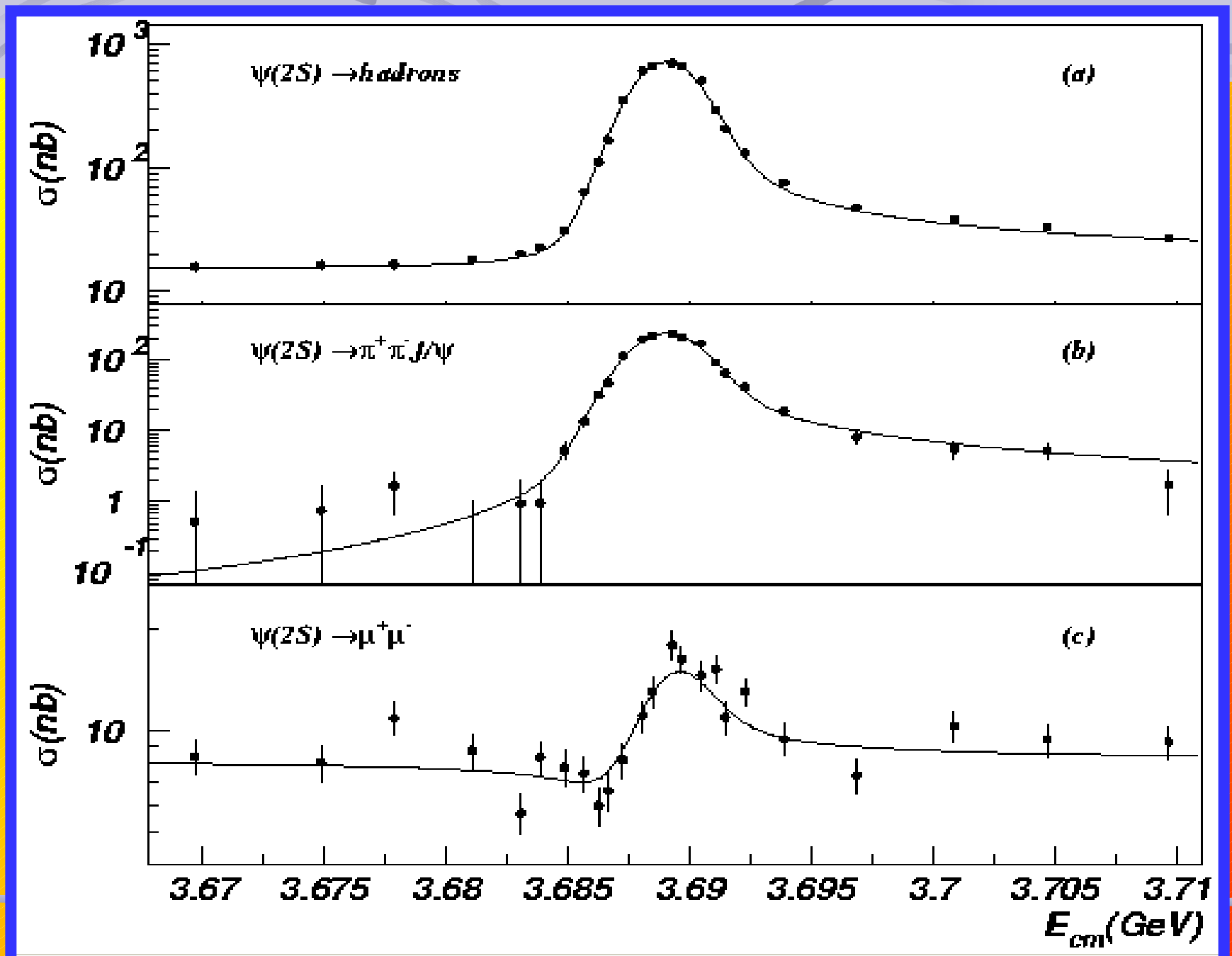
Group	yr	Γ(KeV)	Γ_h(KeV)	$B(\mu\mu)(10^{-3})$	$B(\pi^+\pi^- J/\psi)$ (%)
MARKI	75	228 ± 56	224 ± 56	9.3 ± 1.6	32 ± 4
SPEC	75			7.7 ± 1.7	
DASP	79	202 ± 57		9.9 ± 3.2	36 ± 6
E760	92	306 ± 39			
E760	97			8.3 ± 0.86	28.3 ± 2.9
E835	00			7.4 ± 0.53	
PDG	00	277 ± 31		10.3 ± 3.5	31.0 ± 2.8

Scanned 24 energy points from 3.67 and 3.71 GeV.

Integrated luminosity = 1150 nb^{-1}

For number of $\psi(2S)\rightarrow\pi^+\pi^-$ J/ψ, fit $\pi^+\pi^-$ recoil spectrum.




ψ(2S) →hadrons
(a)
σ(nb)
ψ(2S) →π+π-J/ψ
(b)
σ(nb)
ψ(2S) →μ+μ-
(c)
σ(nb)
3.67
3.675
3.68
3.685
3.69
3.695
3.7
3.705
3.71
Ecm(GeV)

Fitting

- Fit observed $\sigma_h(W)$, $\sigma_{\pi\pi\, J/\psi}(W)$, $\sigma_e(W)$, and $\sigma_\mu(W)$.
- Include resonance and continuum production plus interference, beam spread (Δ), ISR and FSR.
- Assume $\Gamma_e = \Gamma_\mu = \Gamma_\tau/0.3885$, $\Gamma_t = \Gamma_h + \Gamma_\mu + \Gamma_e + \Gamma_\tau$.
- Determine Γ_h, Γ_μ, $\Gamma_{\pi\pi\, J/\psi}$, M(ψ(2S)), Δ, and R.
- R = 2.29 $\pm$ 0.17 consistent with BES R meas. (R = 2.25 $\pm$ 0.06 $\pm$ 0.16 at 3.55 GeV).
- Δ = 1.298 $\pm$ 0.007. Agrees with expected beam spread.

Fitting Result

Preliminary

Param	BES	MARK I	PDG2002
Γ_t (keV)	264± 27(10.1 %)	228 ± 56 (24.6 %)	300 ± 25 (8.3 %)
Γ_h (keV)	258 ± 26(10.1 %)	224 ± 56 (25.0 %)	
$\Gamma_{\pi\pi\ J/\psi}$ (keV)	85.4 ± 8.7 (10.1 %)		
Γ_μ (keV)	2.44 ± 0.21 (8.8 %)	2.1 ± 0.3 (14.29 %)	2.19 ±0.15 (6.8 %)*
$\mathcal{B}_h$ (%)	97.8 ± 0.15 (0.16 %)	98.1±0.3 (0.31 %)	98.10 ±0.30(0.31 %)
$\mathcal{B}_{\pi\pi\ J/\psi}$ (%)	32.3 ± 1.4 (4.4 %)	32 ± 4 (12.5 %)	30.5 ± 1.6 (5.2 %)
$\mathcal{B}_\mu$ (%)	0.93 ± 0.08 (8.5 %)	0.93 ±0.16(17.2 %)	0.7 ±0.09(12.9 %)

* Γ_e(keV)

Discussion

- Width variation

Γ_t(keV) :300 ⟶ 264.5(12%)

- **Improved precision**

$\mathbf{B_h}$ (%) : 0.31 ⟶ 0.2

$\mathbf{B_{\pi\pi\ J/\psi}}$(%) : 5.2 ⟶ 4.4

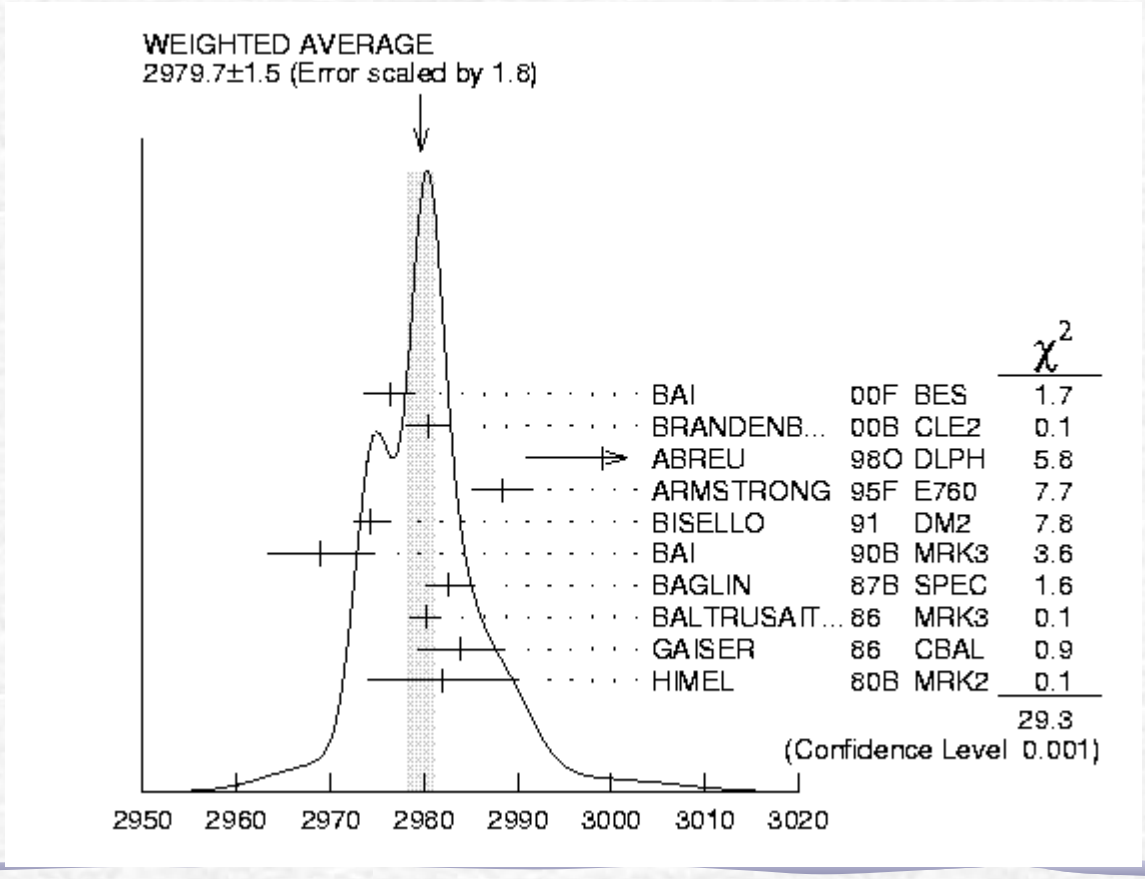
$\mathbf{B_\mu}$ (%) : 13 ⟶ 8.5

- **First measurement of $\Gamma_{\pi\pi\ J/\psi}$**

η_c Parameters

Precise ($m_{J/\psi}$ - $m_{\eta c}$) needed for potential models.

But η_c mass not well determined: PDG02 CL = 0.001



Previous BES Results

- *4 M ψ(2S) Sample: Phys. Rev. D60 72001 (1999)*
- *7.8 M J/ψ Sample: Phys Rev.D62 72001 (2000)*

Data Sample	7.8×10^6 J/ψ	$3.79 \times 10^6 \psi(2S)$
Studied channels	$\gamma\pi^+\pi^-\pi^+\pi^-$ $\gamma\pi^+\pi^-K^+K^-$ $\gamma K_S^o K^\pm\pi^\mp$ $\gamma\phi\phi(\to \gamma K^+K^-K^+K^-)$ $\gamma K^+K^-\pi^o$	$\gamma\pi^+\pi^-\pi^+\pi^-$ $\gamma\pi^+\pi^-K^+K^-$ $\gamma K_S^o K^\pm\pi^\mp$ $\gamma K^+K^-K^+K^-$
$M_{\eta C}$ (MeV)	$2976.6 \pm 2.9 \pm 1.3$	$2975.8 \pm 3.9 \pm 1.2$
	$2976.3 \pm 2.3 \pm 1.2$	
$\Gamma_{\eta C}$ (MeV)	$11.0 \pm 8.1 \pm 4.1$	

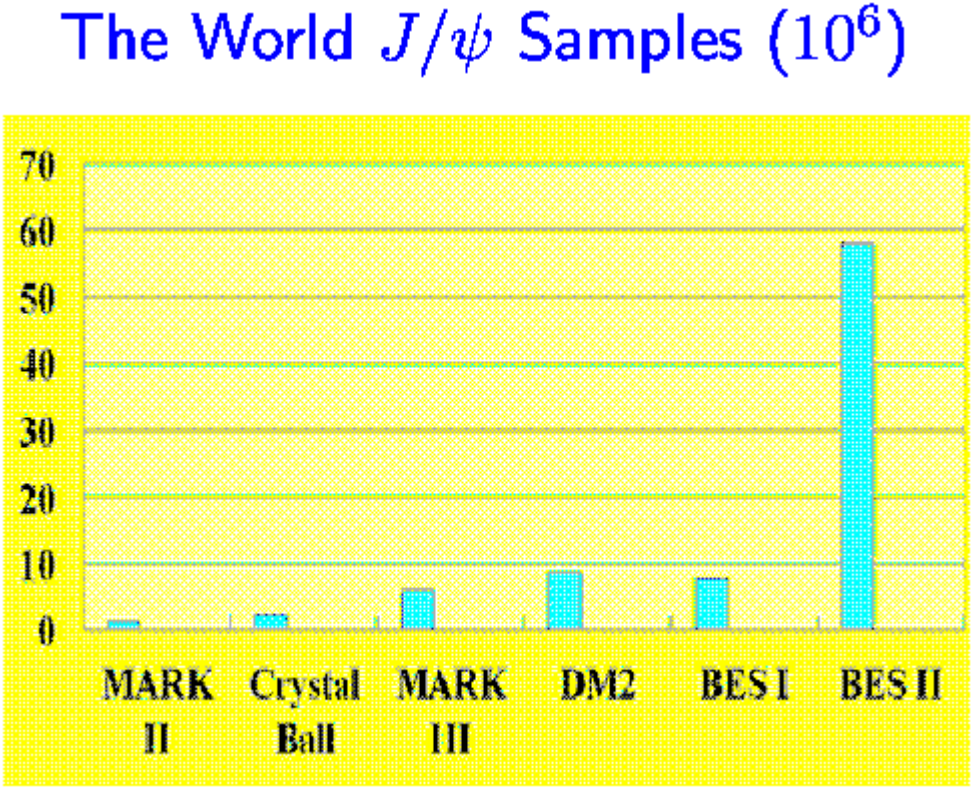
Width Measurements

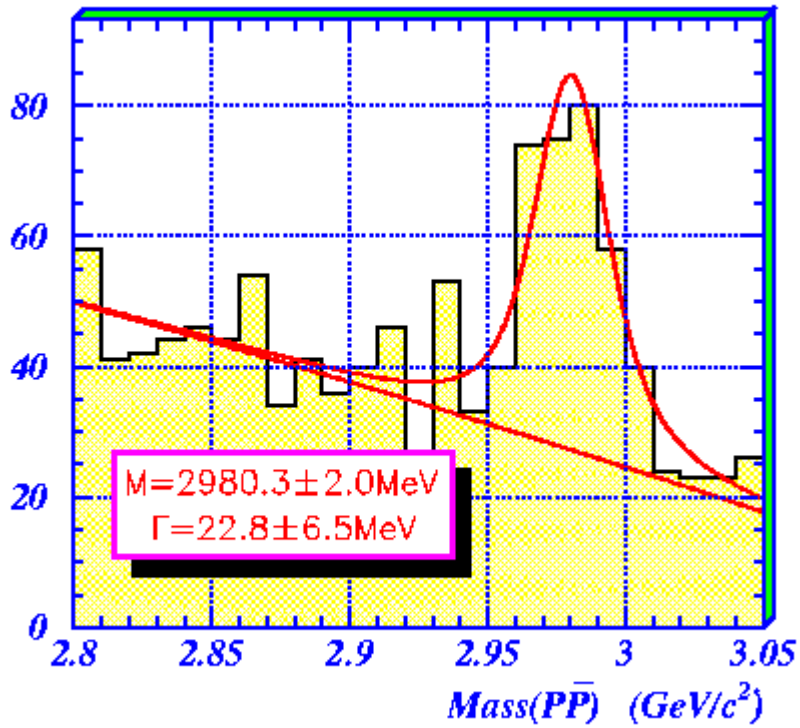
Exp.	Type	Year	Value (MeV)
Crys. Ball	$J/\psi, \psi(2S) \to \gamma X$	1986	11.5 ± 4.5
MARKIII	$J/\psi \to \gamma p\bar{p}$	1986	$10.1^{+33.0}_{-8.2}$
SPEC	$\bar{p}p \to \gamma\gamma$	1987	$7.0^{+7.5}_{-7.0}$
E760	$\bar{p}p \to \gamma\gamma$	1995	$23.9^{+12.6}_{-7.1}$
BESI	$J/\psi, \psi(2S) \to \gamma X$	2000	$11.0 \pm 8.1 \pm 4.1$
CLEO	$e^+e^- \to \gamma\gamma$	2000	$27.0 \pm 5.8 \pm 1.4$
PDG2002		2002	$16.0^{+3.6}_{-3.2}$

η_C measurements with BESII 58 M J/ψ *sample*

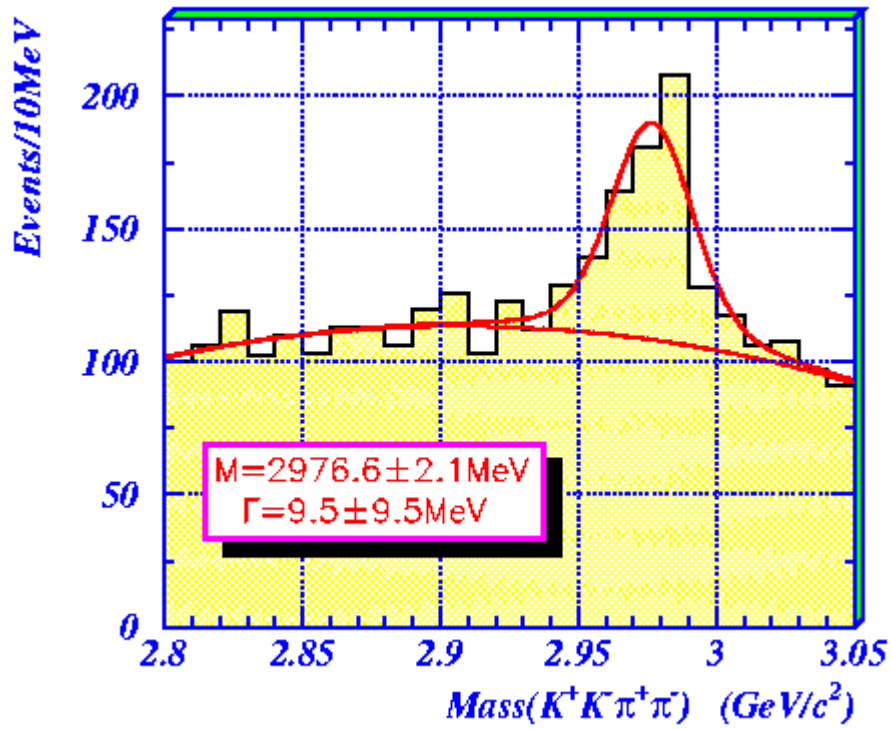
- Channels: $J/\psi \to \gamma\ \eta_C$, $\eta_C \to K^+K^-\pi^+\pi^-$, $\pi^+\pi^-\pi^+\pi^-$, $K^{+/-}\ K^0_S\pi^{-/+}$, $\phi\phi$, and $p\bar{p}$.
- Use PID for π/K/p separation.
- Select events based on chisquare from kinematic fit.
- Use $U_{miss} = E_{miss} - p_{miss}$ and $P^2_{t\gamma}$ (transverse momentum relative to γ) to remove π^0 background.

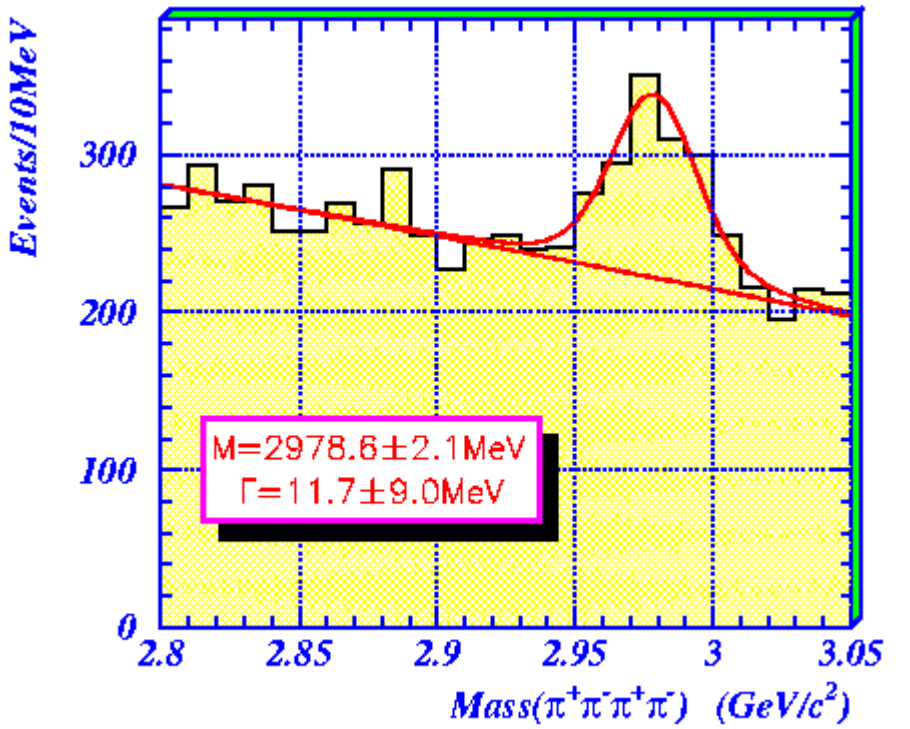
Preliminary





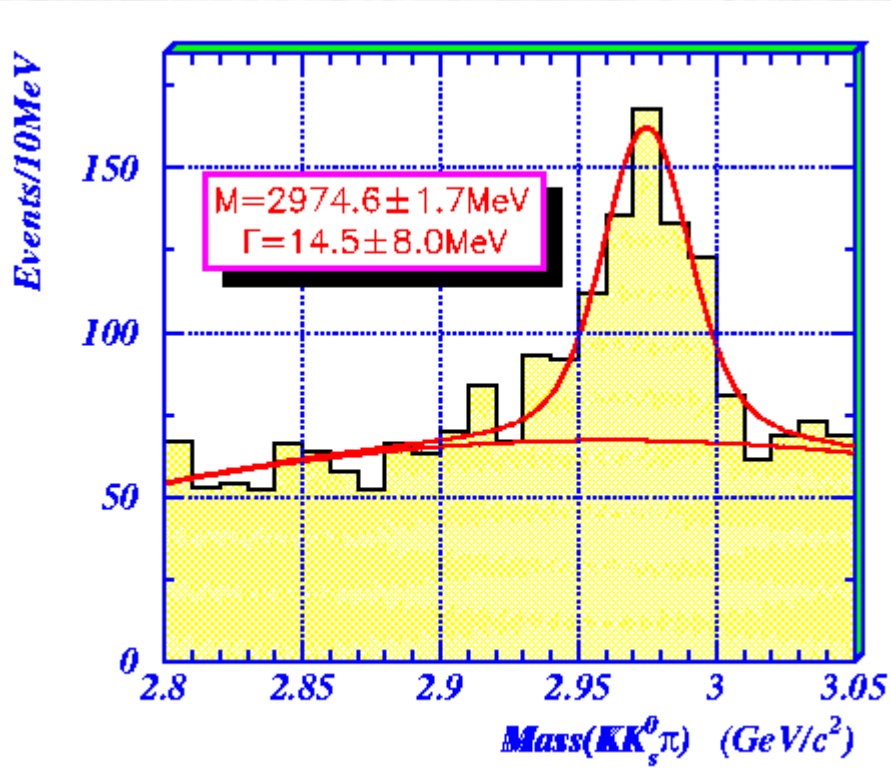
$M(\mathrm{p\bar{p}})$

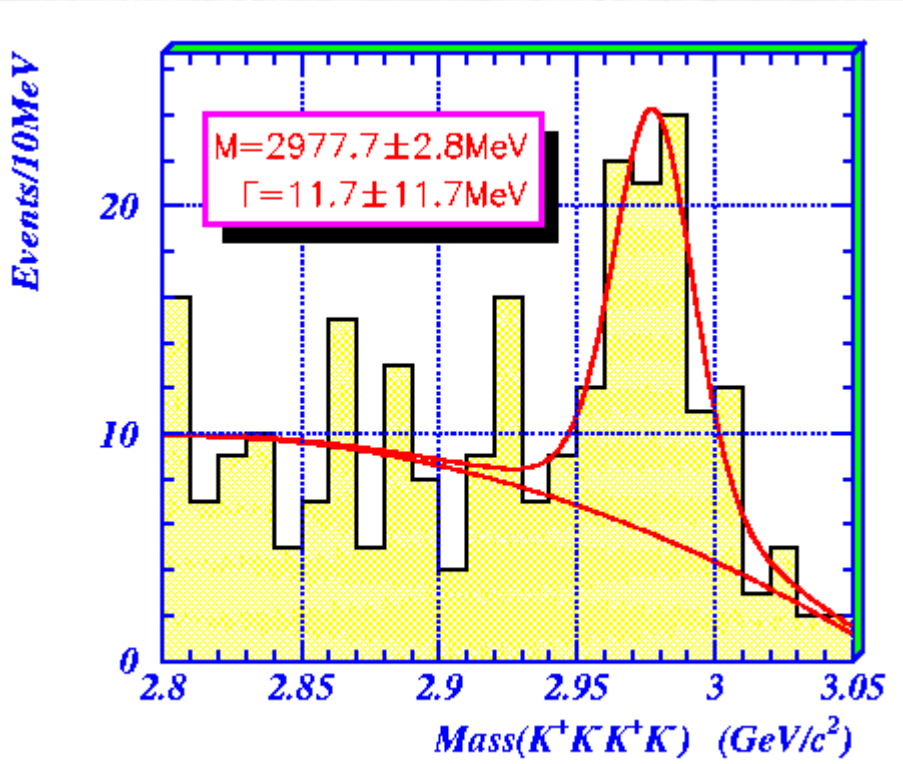




$M(K^+K^-\pi^+\pi^-)$

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





M($K^{+/-}$ $K^0_S\pi^{-/+}$)

M($\phi\phi$)

Results Preliminary

Combining channels

$M(\eta_C) = 2977.4 \pm 0.9 \pm 2.6\ MeV$

chisquare/dof = 5.3/4

$\Gamma(\eta_C) = 15.7 \pm 3.8 \pm 10.0\ MeV$

chisquare/dof = 2.0/4

PDG

$M(\eta_C) = 2979.7 \pm 1.5\ MeV$

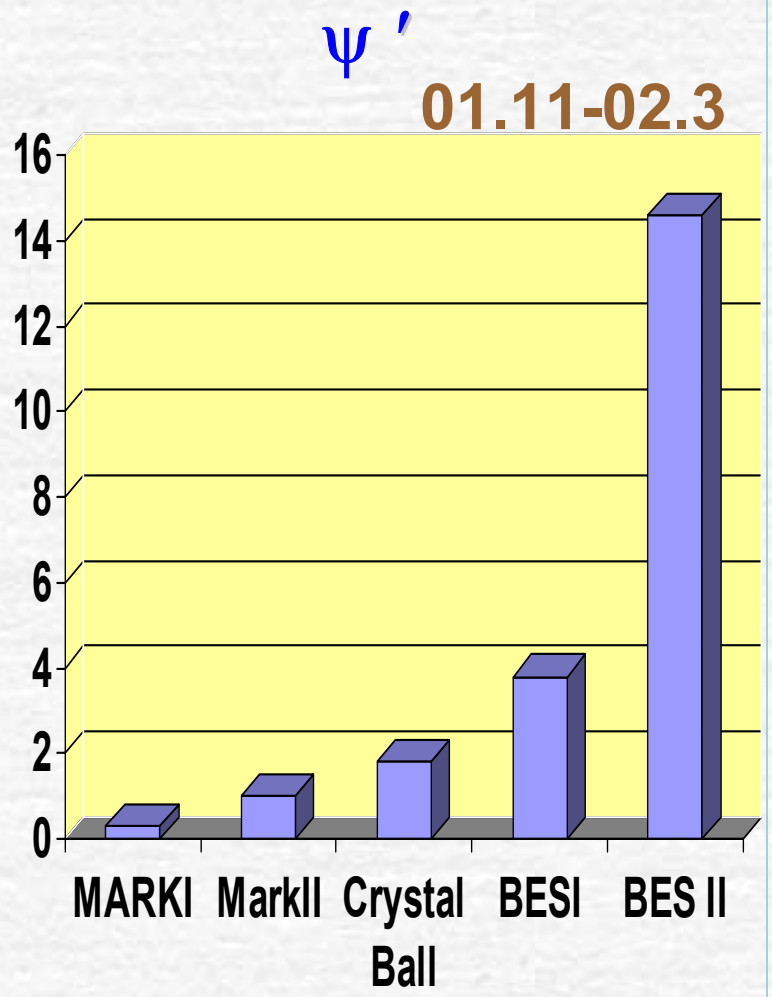
$\Gamma(\eta_C) = 16.0\ ^{+3.6}_{-3.2}\ MeV$

Year 2002 ψ(2S) run

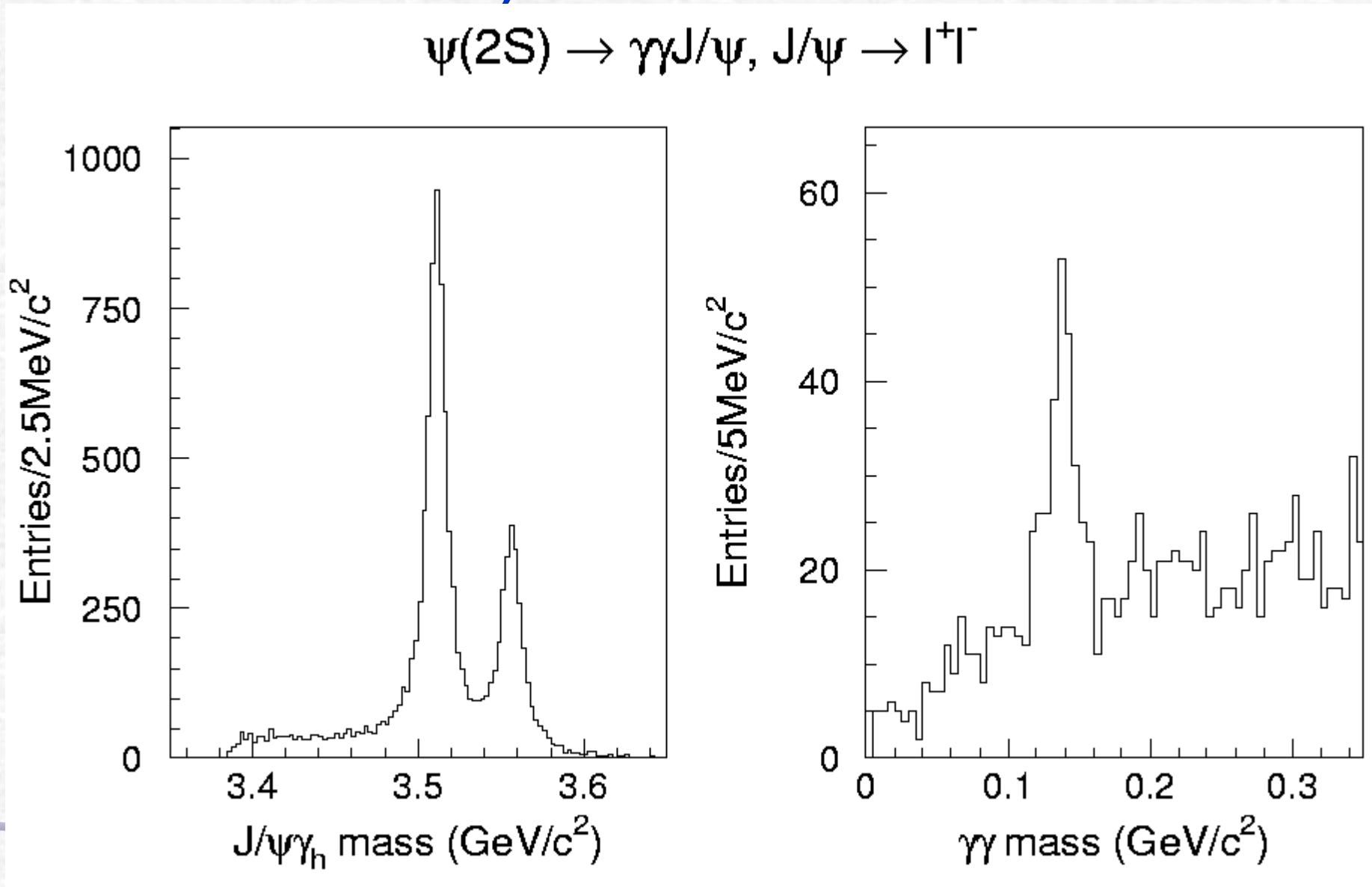
BES obtained 14 M

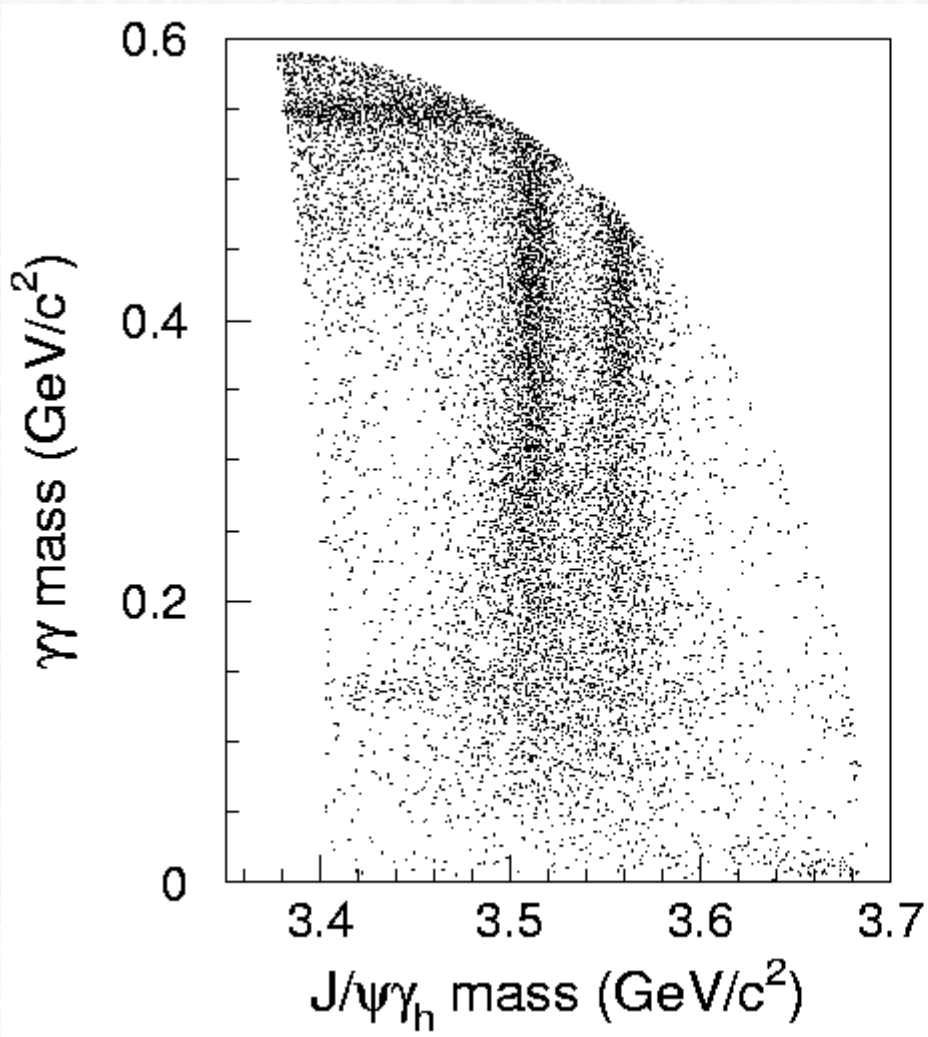
ψ(2S) events.

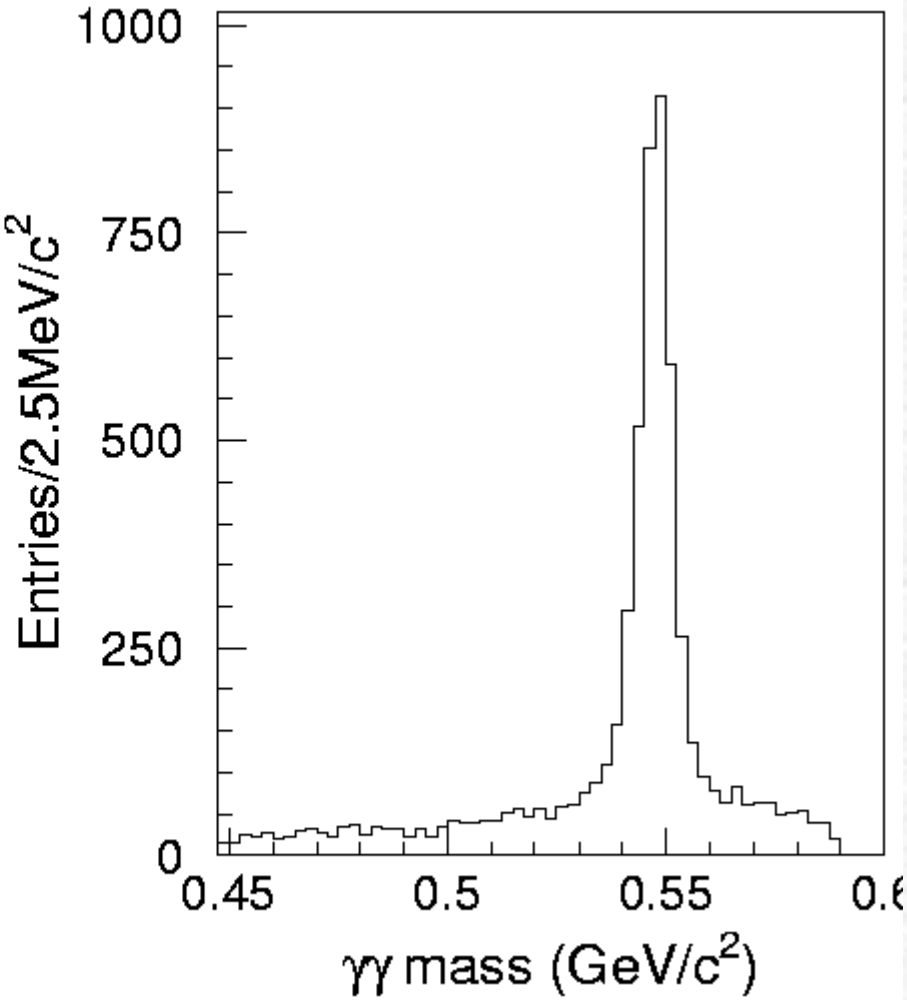
Plan to obtain 24 M events total.



Preliminary look:




0.6
0.4
0.2
0
γγ mass (GeV/c²)
3.4
3.5
3.6
3.7
J/ψγ_h mass (GeV/c²)


1000
750
500
250
0
Entries/2.5MeV/c²
0.45
0.5
0.55
γγ mass (GeV/c²)

Summary

- *Measured $\psi(2s)$ decay modes containing ω's and ϕ's. These provide more information on 12 % Rule.*
- *Scan results improve on $\psi(2s)$ resonance parameters. First measurement of $\Gamma_{\pi\pi J/\psi}$.*
- 58 M J/ψ *sample gives improved η_C results:*

  $M(\eta_C) = 2977.4 \pm 0.9 \pm 2.6$ *MeV*

  $\Gamma(\eta_C) = 15.7 \pm 3.8 \pm 10.0$ *MeV*
- New 14 M $\psi(2s)$ $(\rightarrow 24\ M)$ *will provide many new results.*