# Recent Physics Results from BES

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For the BES collaboration

24/08/1999

- ☞ The Upgrade of BEPC/BES
- ☞ Recent Physics Results
- ☞ Future Plan
- ☞ Summary

## ☞ The Upgrade of BEPC/BES (1995-1997)

**BEPC:**

- Luminosity 1.5-2 × increase
- Reduced beam associated background
- Full energy injection @ J/ψ

**BES:**

- New luminosity monitor
- Refurbished MarkIII VC+Be beam pipe
- New drift chamber
- New barrel TOF system

# Table 1. The BESII Performance

| | | |
|---|---|---|
| VC | $\sigma_{x,y}$ (μm)<br>$\varepsilon_{trk}$ (%) | 100<br>97 |
| MDC | $\varepsilon_{wire}$ (%)<br>$\sigma_{xy}$ (μm)<br>$\Delta p/p$ (%)<br>$\sigma_{dE/dx}$ (%) | 96<br>200<br>$1.78\sqrt{(1+p^2)}$<br>8.4 |
| BTOF | $\sigma_T$ (ps)<br>$L_{atten}$ (m) | 180<br>3.5-5.5 |
| ETOF | $\sigma_T$ (ps) | 720 |
| BSC | $\Delta E/\sqrt{E}$ (%)<br>$\sigma_z$ (cm) | 20.3<br>2.3 |
| ESC | $\Delta E/\sqrt{E}$ (%) | 22.1 |
| μ counter | $\varepsilon_{trk}$ (%)<br>$\sigma_z$ (cm) | 95<br>5.5 |

# ☞ Recent Physics Results

## Data sets

Table 2. Data collected with BESI-BESII and the corresponding physics

| $E_{cm}$ (GeV) | Physics | BES Data | Other Lab. Data |
|---|---|---|---|
| 3.10 | J/ψ, light hadron Spectroscopy | $7.8\times10^6$ | $8.6\times10^6$ |
| 3.69 | ψ(2S) | $3.7\times10^6$ | $1.8\times10^6$ |
| 4.03 | τ | $1.0\times10^5$ | LEP |
| 4.03 | $D_S$, D | 22.3 $pb^{-1}$ | CLEO |
| 3.55<br>$m_\tau$ scan | $m_\tau$ | 5 $pb^{-1}$ | |
| 2-5<br>R scan | R, hadron production mechanism | | γγ2, MarkI Crystal Ball Pluto…… |

- An unique laboratory to systematically study the charmonium family members and test of QCD from different angles

- Study the interplay of the strong and weak interaction

- Glueball, bound states of interacting glues, is an entire new form of hadrons

- confirmation of the existence of glueball $\rightarrow$ directly test of QCD

- study of glueball properties $\rightarrow$ help understand the strong interaction

# R scan:

March-May, 1998:

- 6 energy points
(2.6, 3.2, 3.4, 3.55, 4.6, 5.0 GeV)

-Repeated 3.4 GeV
-Separated beam operation for all points
-Single beam and separated beam at 3.55 GeV

Feb.- June, 1999:

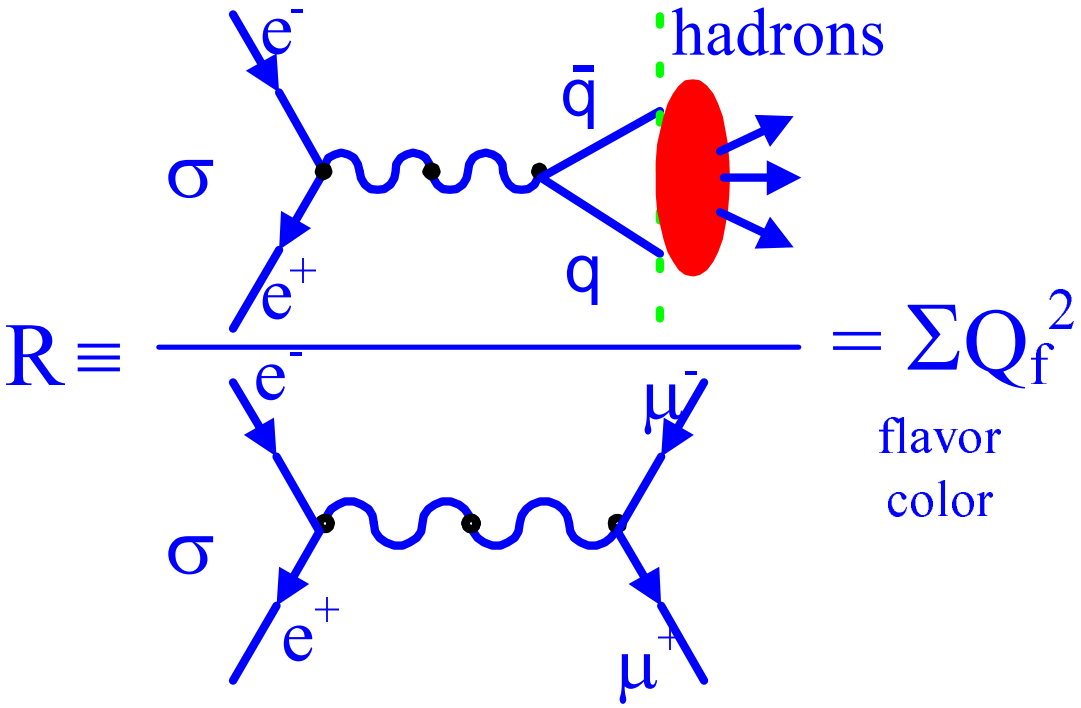
- 85 energy points (2-4.8 GeV)
+ detailed scan of ψ(2S) (24 points)

- repeated 2.6, 4.6 GeV

-Separated beam at 37 points

-Single ($e^+$ and $e^-$)+separated beam at 7 points

# Definition of R




Experimentally,

$$R = \frac{1}{\sigma^{0}_{\mu^+\mu^-}} \cdot \frac{N_{had} - N_{bg}}{L \cdot \varepsilon_{had} \cdot (1+\delta)}$$

$N_{had}$: observed hadronic events
L: integrated luminosity
δ: radiative correction
$N_{bg}$: background events

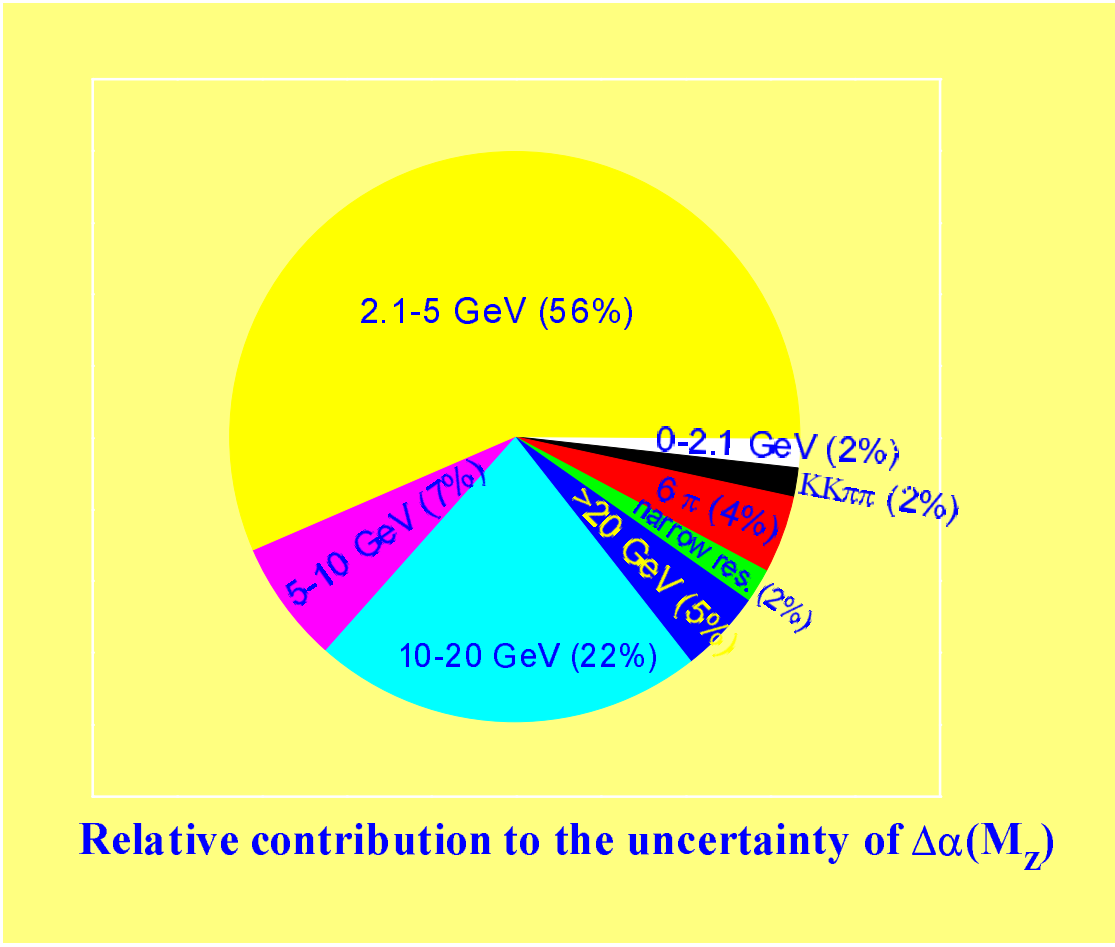
- Reducing the uncertainty of $\alpha(M_Z^2)$ → essential for precision tests of the SM

$$\alpha(s) \equiv \frac{\alpha(0)}{1-\Delta\alpha(s)}$$

with $$\Delta\alpha(s) = \Delta\alpha(s)_{lep} + \Delta\alpha(s)_{had}$$

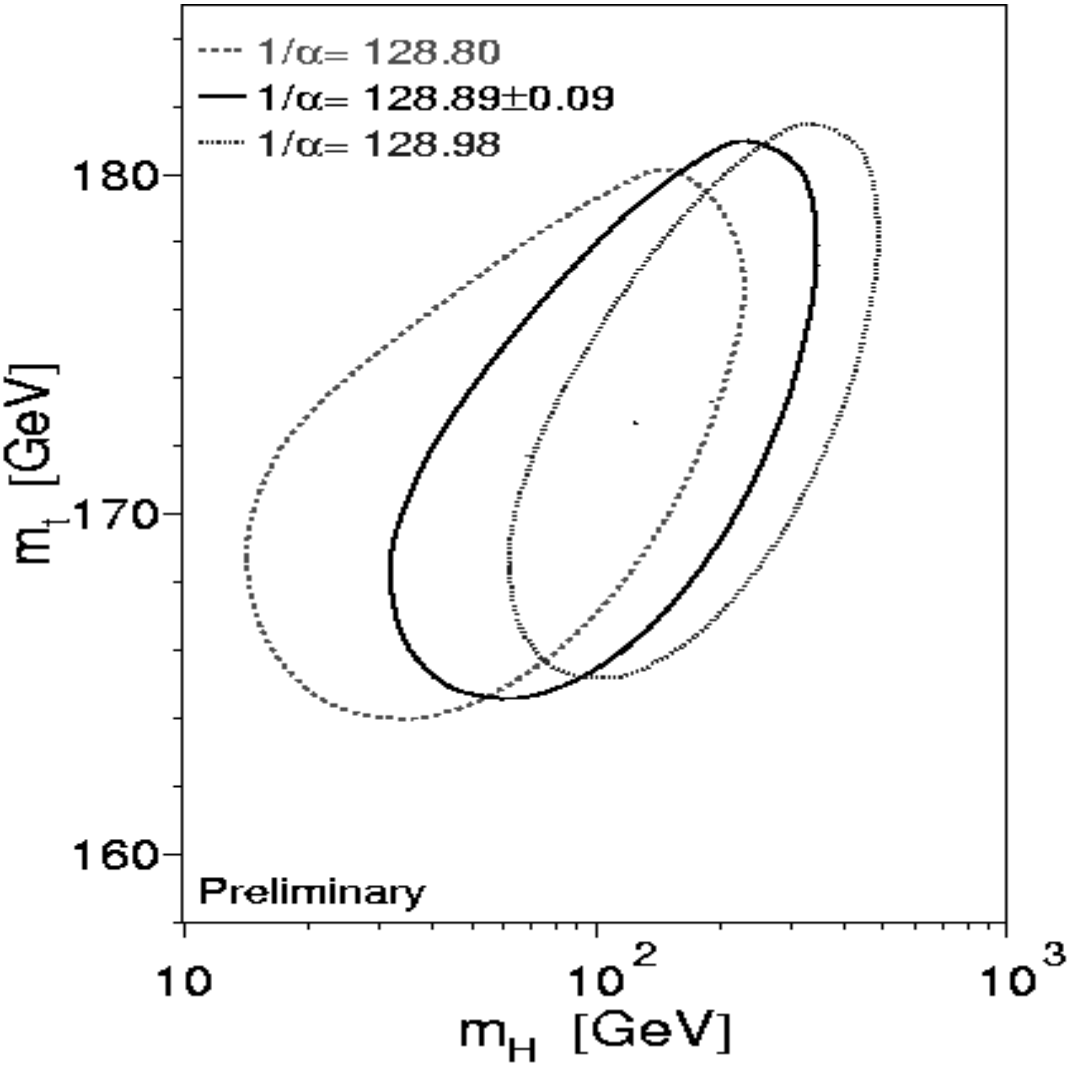
| | calculated | measured |
|---|---|---|
| at $M_Z^2$ | 0.03142 | 0.0280±0.0009 |

$$\Delta\alpha_{had}(M_Z^2) = -\frac{\alpha(0)M_Z^2}{3\pi}\,\mathrm{Re}\int_{4m_\pi^2}^{\infty} ds\,\frac{R(s)}{s(s-M_Z^2)-i\varepsilon}$$




**Relative contribution to the uncertainty of $\Delta\alpha(M_Z)$**

The indirect determination of $m_H$ depends critically on the precision of $\alpha(M_Z^2)$



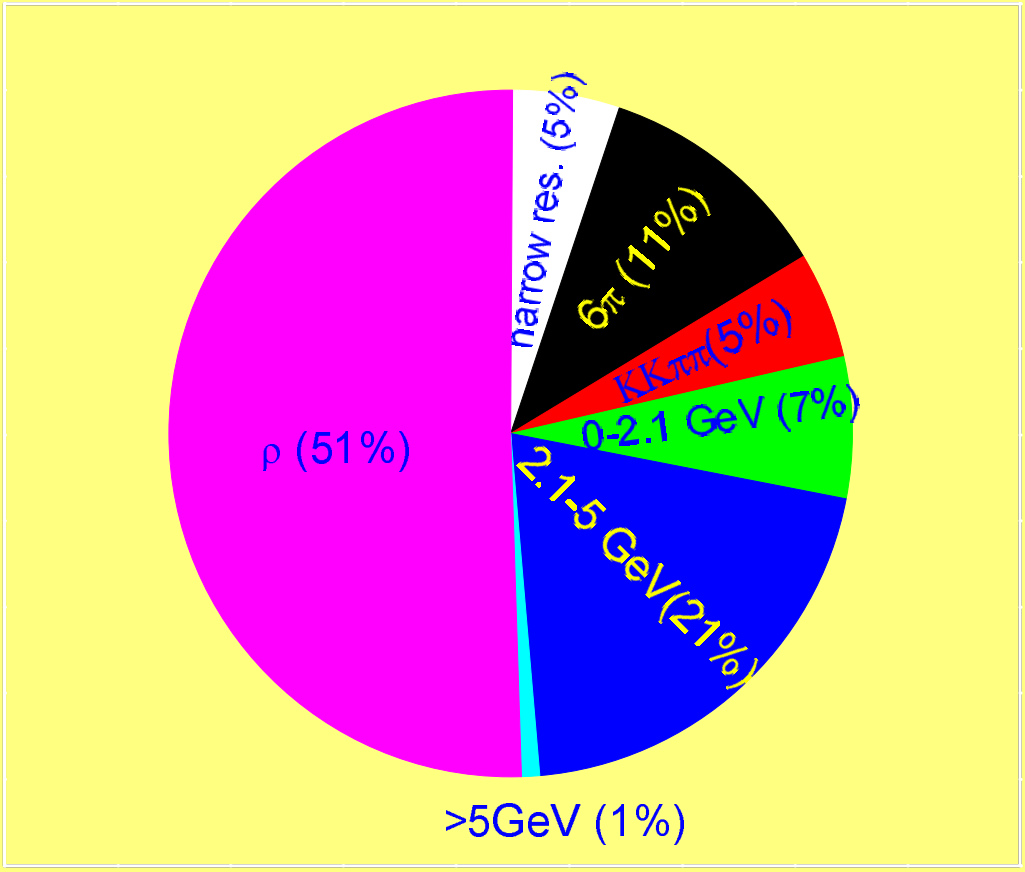

SM fit to $m_t$ and $m_H$ with $\alpha(M_Z^2)$ varying by $\pm\sigma$ (B. Pietrzyk and H. Burkhard)

- Hunting for new physics from $a_\mu \equiv (g-2)/2$

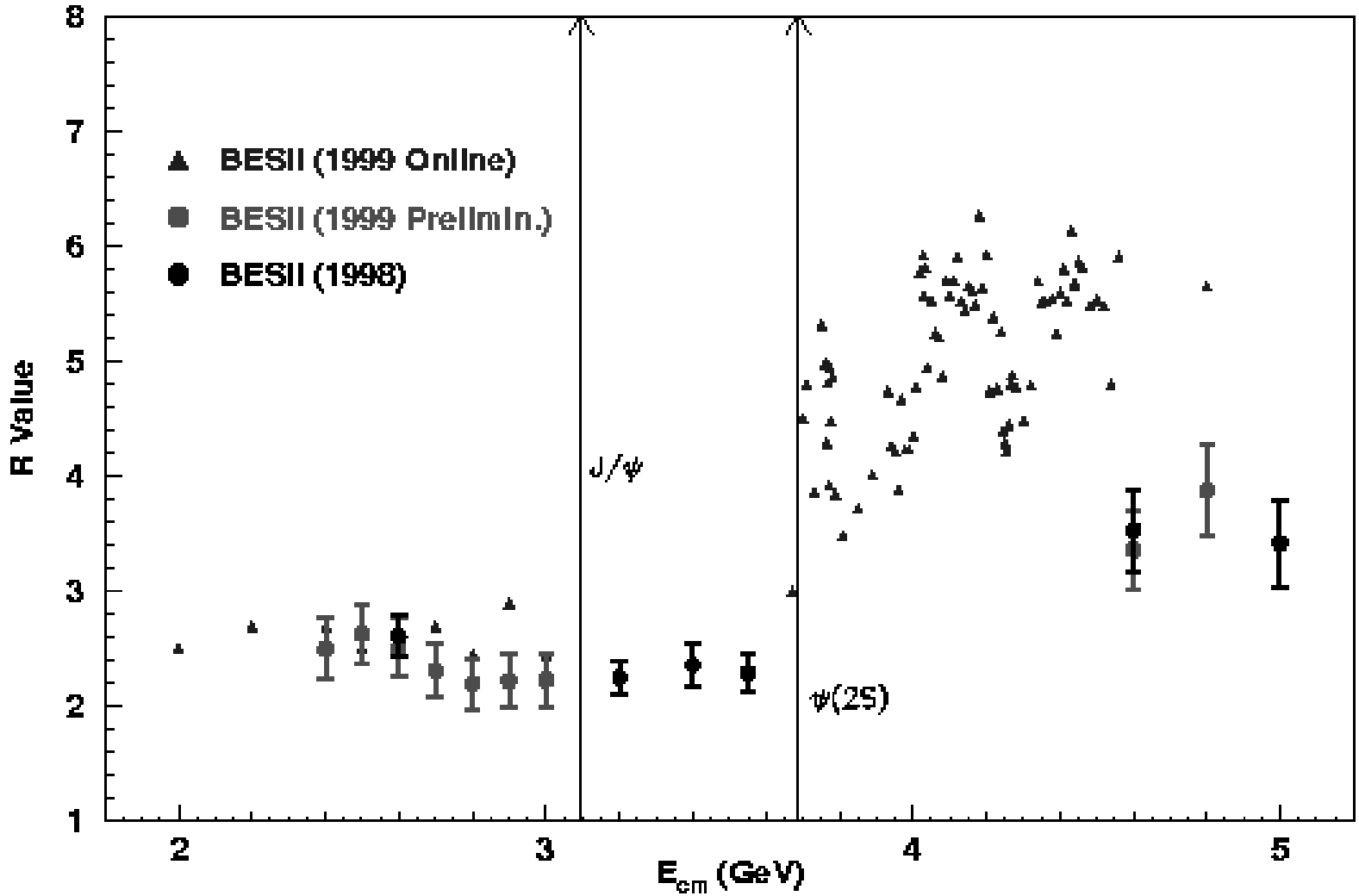
  $\rightarrow$Interpretation of E821 at BNL

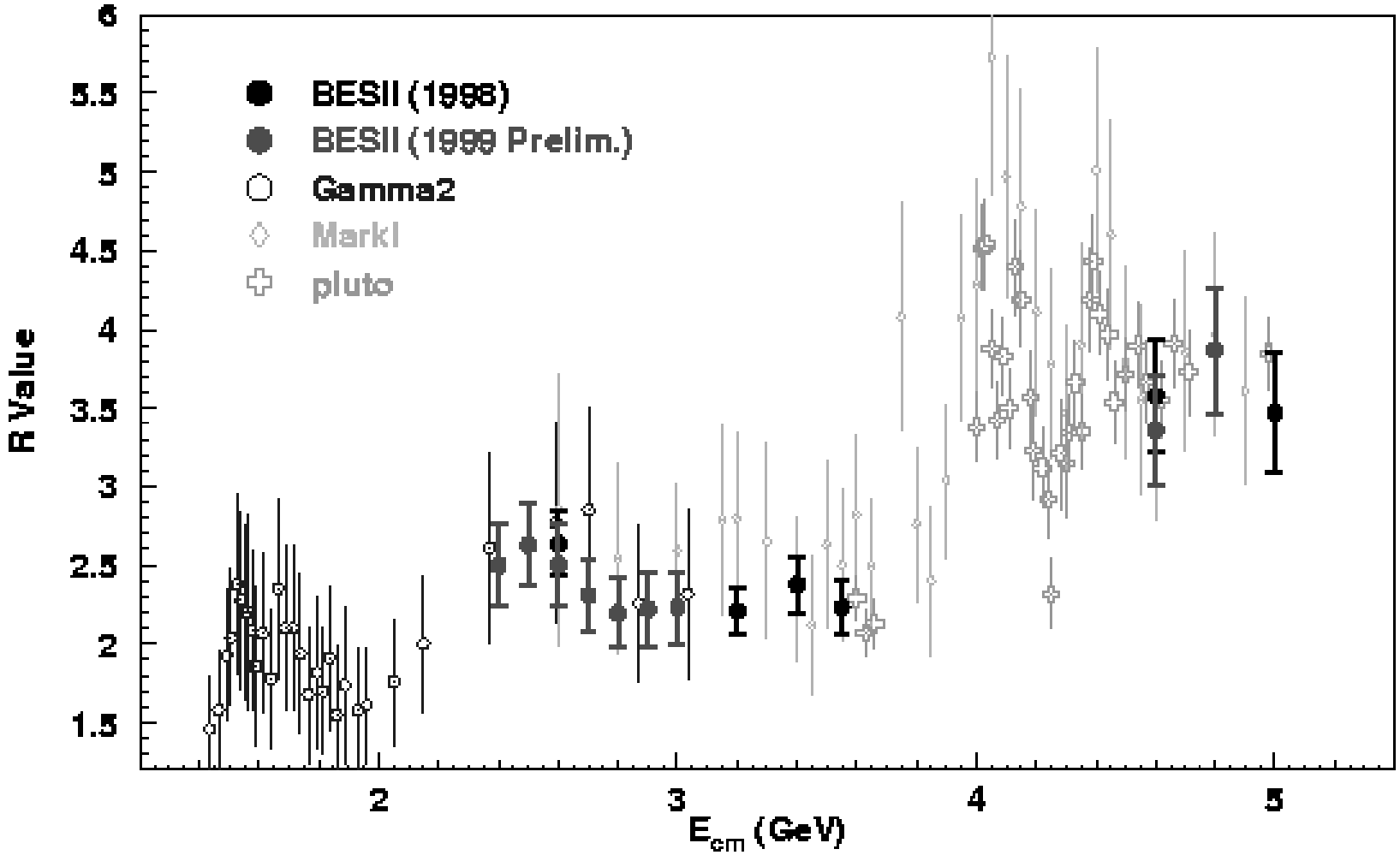
$$a_\mu^{SM} = a_\mu^{QED} + a_\mu^{had} + a_\mu^{weak}$$

$$a_\mu^{had} = \frac{\alpha^2(0)}{3\pi^2} \int_{4m_\pi^2}^{\infty} ds \frac{K(s)}{s^2} R(s)$$




**Retative contribution to the uncertainty of $a_\mu$(had)**


BESII (1999 Online)
BESII (1999 Preliminn.)
BESII (1998)
J/ψ
ψ(2S)
R Value
E_cm (GeV)
1
2
3
4
5
6
7
8


BESII (1998)
BESII (1999 Prelim.)
Gamma2
Mark I
pluto
R Value
$E_{cm}$ (GeV)
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
2
3
4
5

**Physics on ψ(2S) :** (preliminary)

(talk to be given by F. Liu)

ψ(2S) is an important laboratory to study

- charmonium family members
- non-relativistic perturbative QCD

According to non relativistic perturbative QCD:

BES has measured many decay channels - many for the first time.

Fill up the PDG and improve the precision

- Dynamics of $\psi(2S)\rightarrow\pi^+\pi^-J/\psi$

- Largest decay mode [Br=(30.2±1.9)%]
- Very clean and high statistics

$\psi(2S)\rightarrow \pi^+\pi^-J/\psi$

$\hookrightarrow \ell^+\ell^-$ (23K)

Found:
$\pi^+\pi^-$ system contains a D-wave contribution in addition to the S-wave $\rightarrow$ consistent with some heavy quark model, e.g Novikov-Shifman.

# ψ(2S) hadronic and radiative decay (Preliminary)

- ψ(2S) →VP (ρπ, $K^* \overline{K}$)

-Final states are strongly suppressed → ρπ-puzzle

-BES find a suppression factor of ~60

-B(ψ(2S)→ωπ$^0$) > B(ψ(2S)→ρπ

isospin violating isosping-conserving, SU(3)-allowed

-Large isospin violatings between branching fractions for charged and neutral ψ(2S)→$K^* \overline{K}$ decays

$\psi(2S) \to \overline{K}^{*0} K^0$ (↱ $\pi^+\pi^-$; ↳ $K^-\pi^+$)

$\psi(2S) \to K^{*0} K^-$ (↳ $K^0\pi^+$; ↳ $\pi^+\pi^-$)

• $\psi(2S) \rightarrow AP$ ($b_1^+\pi^-$, $K_1^+(1270)K^-$)

-Relatively strong decay channels

-$\psi(2S) \rightarrow b_1^+\pi^-$ consistent with ~15% rule

Rules out explanations for the $\rho\pi$ puzzle that suppress all $\psi(2S)$ decays to lowest lying two-body mesons final states.

• $\psi(2S) \rightarrow \gamma\, f_2(1270)$ $\quad\quad$ $,\gamma\, f_J(1710)$

$\quad\quad\quad

- Decays involving ω and ϕ

| $\psi(2S)\rightarrow$ | $N_{obs}$ | $Br(\times 10^{-5})$ | Q(%) |
|---|---|---|---|
| $\omega\pi^+\pi^-$ | 79.3±10.2 | 44.7±5.7±5.4 | 6.3±1.4 |
| $\omega K^+K^-$ | 16.2±5.5 | 12.6±4.3±3.9 | 17.0±9.6 |
| $\phi\pi^+\pi^-$ | 57.4±7.2 | 17.6±2.2±2.4 | 22.0±5.3 |
| $\phi K^+K^-$ | 18.1±5.3 | 6.10±1.79±1.51 | 7.3±3.0 |
| $\phi f_0$ | 20.3±5.2 | 6.57±1.68±0.76 | 20.5±8.1 |
| $\omega p\bar{p}$ | 11.0±4.3 | 6.00±2.34±1.41 | 4.6±2.2 |
| $\phi p\bar{p}$ | 3.0±1.7 | 0.86±0.50±0.20 | 18.9±13.4 |
| $\pi^+\pi^-\pi^0 p\bar{p}$ | 112.4±11.0 | 38.5±3.7±5.5 | 16.7±7.1 |
| $\eta\pi^+\pi^- p\bar{p}$ | 35.0±9.2 | 25.8±6.8±7.3 | ? |
| $\eta p\bar{p}$ | 3±1.7 | 8.36±4.8±4.8 | 4.0±4.0 |

Some satisfy "15%" rule, some do not

- Study of Charmonium $\chi_{cj}$(j=0,1,2)

-$\psi(2S)\rightarrow\gamma\chi_{cJ}$ (J=0, 1, 2)

↳34 decay channels

- 34 decay channels studied). Many for the first time

-Improved measured values of $M\chi_{c0}$ and $\Gamma_{\chi 0}$

| | $M\chi_{c0}$ | $\Gamma_{\chi 0}$ |
|---|---|---|
| PDG | 3417±2.8 | 14±5 |
| BES | 3414.1±0.6±0.8 | 14.3±3.6 |

- $\eta_c$ mass (not well determined, 0.1%CL in PDG)

$\psi(2S)\rightarrow\gamma\eta_c$

↳$\pi^+\pi^-\pi^+\pi^-$, $\pi^+\pi^-K^+K^-$

$K^+K^-K^+K^-$, $\pi^{\mp}K_SK^{\pm}$

Preliminary: $M\eta_c$=2975.8±3.9±1.2 MeV

- $Br(\psi(2S)\rightarrow\tau^+\tau^-)$

The first measurement

$Br(\psi(2S)\rightarrow\tau^+\tau^-)=2.82 \pm 0.45 \pm 0.56$

$Br(\psi(2S)\rightarrow\tau^+\tau^-)/0.3885=7.26\pm1.16\pm1.44$

PDG: $Br(\psi(2S)\rightarrow e^+e^-) = 8.5 \pm 0.7$

$Br(\psi(2S)\rightarrow\mu^+\mu^-) = 7.7 \pm 1.7$

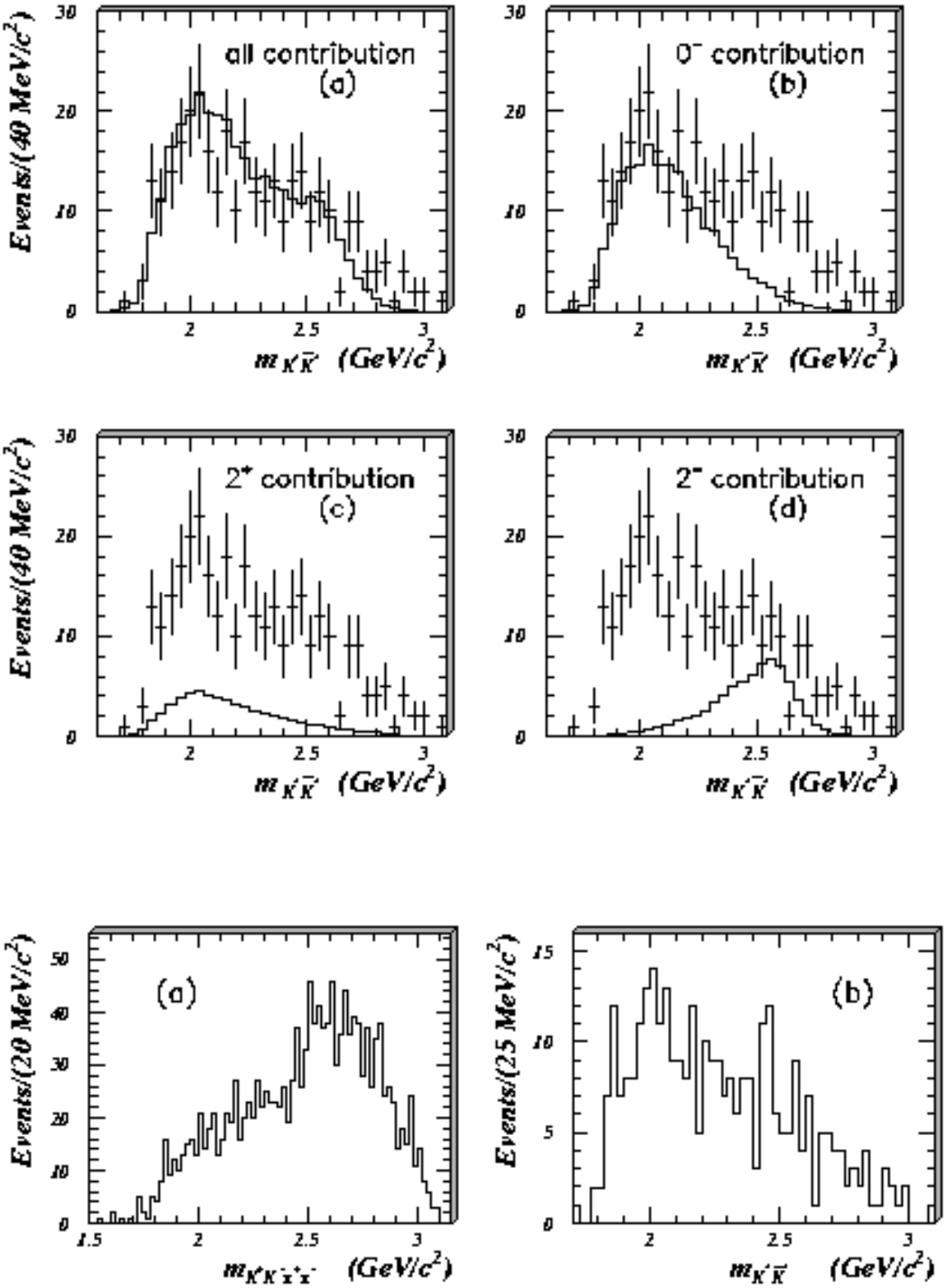
# J/ψ Physics

BEPC:
The only $e^+e^-$ machine running at J/ψ

BES:
Continuous effort to search for glueball, study light hadron spectroscopy with the data collected

Many decay channels have been studied using invariant mass spectrum BW fit and partial wave analysis(PWA)

- PWA of $J/\psi \to \gamma K^+K^-\pi^+\pi^-$



- $K^*\overline{K}^*$ contribution peaks strongly near threshold
- $0^{-+}$ (M=1800±100 MeV, Γ=500±200 MeV) dominant partial wave for $K^*\overline{K}^*$
- Requiring $2^{++}$ (M~2020 MeV, Γ~500 MeV)
- Evidence for $2^{-+}$ component at 2.55 GeV
- No distinctive $0^{++}$, $1^{++}$ and $4^{++}$

Submitted to PRL

- Study of $N^*$ from J/ψ decay
  (talk to be given by H.B. Li)

$J/\psi \to \bar{p} N^*(1535, 1650, 1834)$

$\hookrightarrow p\eta$

Preliminary results:

| State | Mass (MeV) | Width (MeV0 | Spin-parity |
|---|---|---|---|
| $N^*(1535)$ | $1540^{+15}_{-17}$ | $178^{+20}_{-22}$ | $(1/2)^-$ |
| $N^*(1650)$ | $1648^{+18}_{-16}$ | 150 fixed | $(1/2)^-$ |

$Br(J/\psi \to \bar{p} N^*(1535) \times Br(N^*(1535) \to p\eta)$
$= (3.89 \pm 0.78)\ \% \times 10^{-4}$

$Br(J/\psi \to \bar{p} N^*(1650) \times Br(N^*(1650) \to p\eta)$
$= (1.10 \pm 0.21)\ \% \times 10^{-4}$

$Br(J/\psi \to \bar{p} N^*(1535) \times Br(N^*(1535) \to p\eta)$
$= (0.49 \pm 0.08)\ \% \times 10^{-4}$

- Measurement of $M\eta_c$ and $\Gamma\eta_c$

$J/\psi \rightarrow \gamma\eta_c$

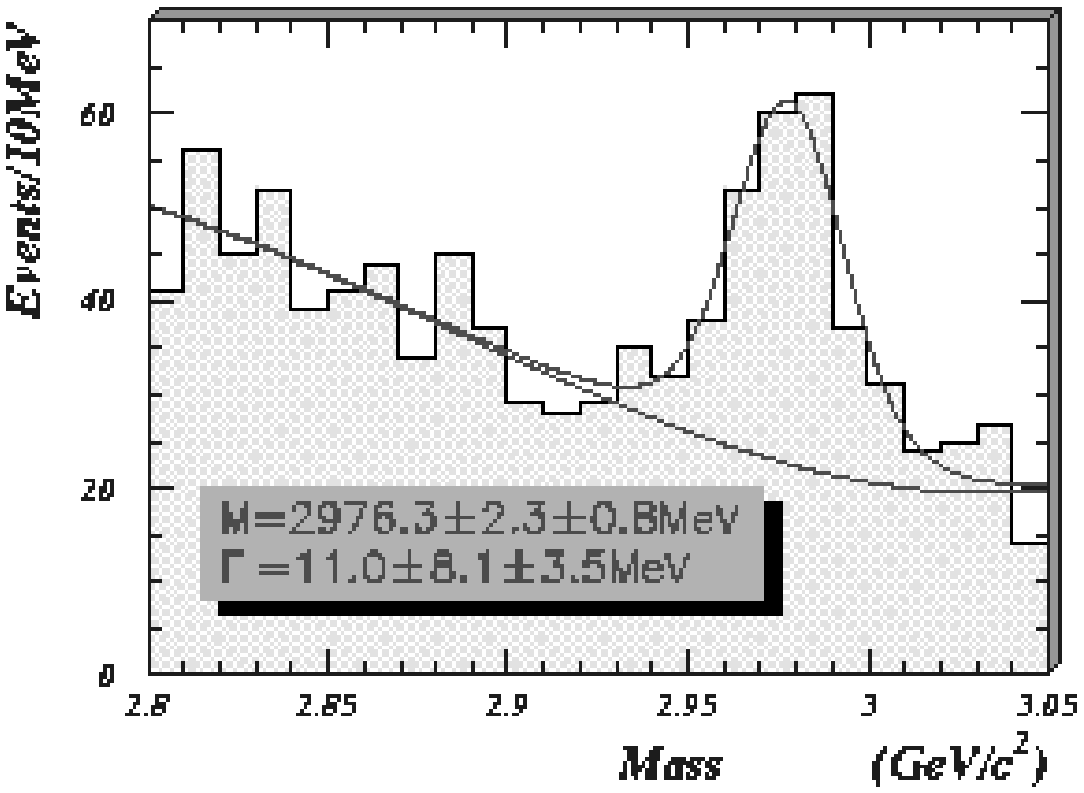
$\hookrightarrow \pi^+\pi^-\pi^+\pi^-$, $\pi^+\pi^-K^+K^-$, $K^+K^-\pi^0$

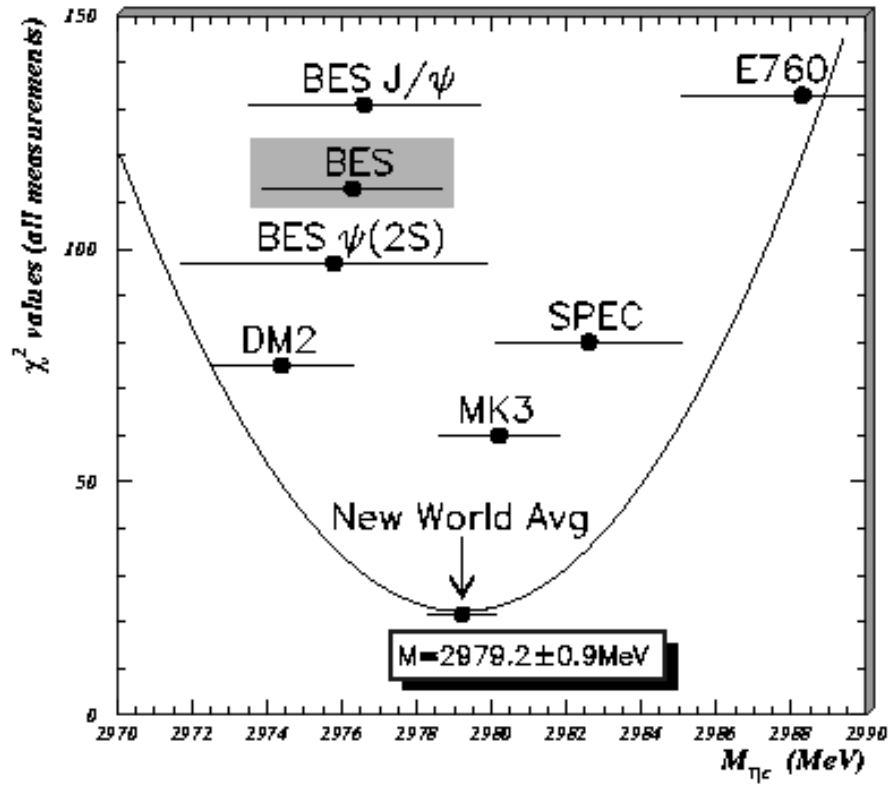
$K^{\pm}K^0_S\pi^{\mp}(K^0_S \rightarrow \pi^+\pi^-)$, $\phi\phi(\phi \rightarrow K^+K^-)$

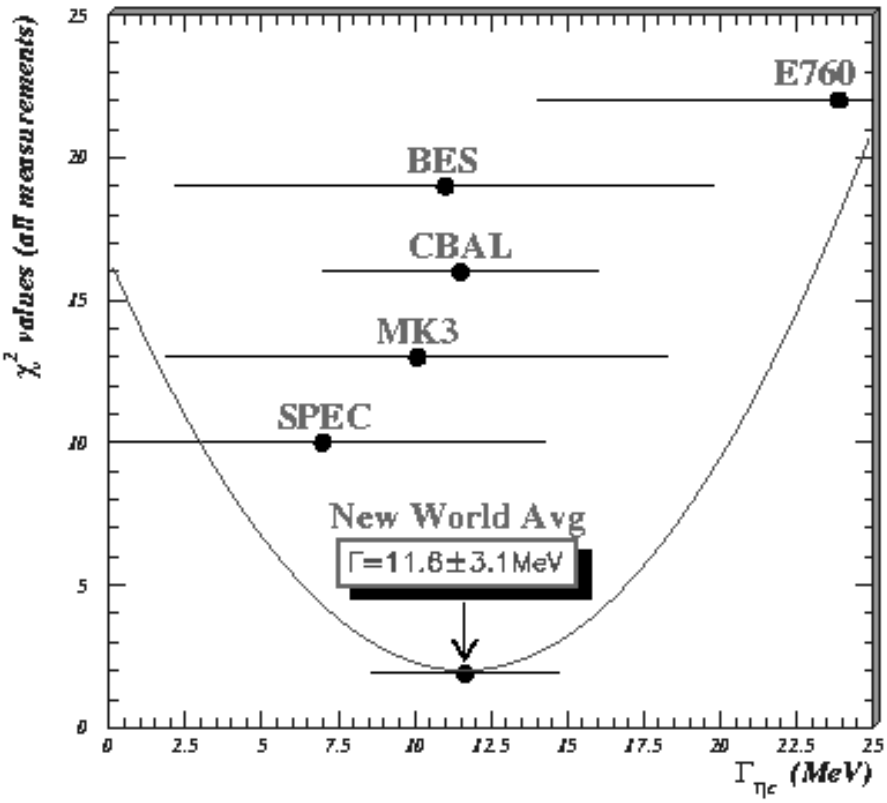
$M\eta_c$=2976.6±2.9±1.0 MeV

Combining the results from $\psi(2S) \rightarrow \gamma\eta_c$

Preliminary




BES J/ψ
E760
BES
BES ψ(2S)
SPEC
DM2
MK3
New World Avg
M=2979.2±0.9MeV
χ² values (all measurements)
M_ηc (MeV)


E760
BES
CBAL
MK3
SPEC
New World Avg
Γ=11.6±3.1MeV
χ² values (all measurements)
Γ_ηc (MeV)

## $D_S$ physics : (Talk to be given by G. Rong)

The first measurement. Preliminary

$Br(D_S^+ \to \overline{K}^{*0} X) = (20.3 \pm 11.9 \pm 1.8)\ \%$

$Br(D_S^+ \to K^{*0} X) < 7.5\%$ at 90% C.L.

## ☞ Future Plan

- Collect ~50 M J/ψ events in 2000-2001

  ~5 times higher than the current world largest sample

- ~10 M $US approved for R&D

## ☞Summary

- BESII has improved $\Delta R/R$ to ~7% $E_{cm}$ $\lesssim$ 3.55 GeV, similar improvement are expected in 3.5-5.0 GeV region from the data being analyzed at present
- Based on the data collected with BESI, BES has been producing physics results in charmonium physics. Many improved the precision and many for the first time
- BES is going to collect ~50 M J/ψ evnets→world largest sample to systematically study light hadron spectroscopy
- A τ-charm factory or further upgrade has been under discussing. ~10 M$US for R&D has been approved