Recent results from the BES collaboration

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The status of the upgraded BEijing Spectrometer(BESII) and the measurement of the R values in the center-of-mass (cm) energy region of 2-5 GeV done with BESII are reported. Recent results based on the analysis of the data collected with BESI are summarized.

1. INTRODUCTION

The BEijing Spectrometer (BES) at Beijing Electron Positron Collider (BEPC), so far the only e^+e^- machine in the world which covers the cm energy in 2-5 GeV and directly produce charmonium and charmed mesons, has been running for 10 years. Both BEPC and BES were upgraded from 1995 to 1997. The upgrade of BEPC included moving the insertion quadrupoles closer to the interaction point and increasing the total RF voltage. The bunch length was shortened, and the vertical beta function at the interaction point was reduced. There is a factor of 1.5-2 improvement in the luminosity. The hadronic event rate recorded at J/ψ peak can now reach 6-8 Hz.

The BES is a conventional cylindrical magnetic detector and is described in detail in Ref. [1]. The upgrades of BES [2] included replacement of the central drift chamber with a vertex chamber composed of 12 tracking layers. The vertex chamber was rebuilt from the Mark III endplates and beryllium beam pipe and provides a spatial resolution of about 90 μm. A new barrel time-of-flight counter with shortened light pipes improves on the BES I design and provides 180 ps resolution. A new main drift chamber replaces the aging original, providing a similar momentum and dE/dx resolution to the old one. With the upgraded data acquisition system, the dead time has been reduced from 20 ms to 10 ms per event. Table 1 compares the performance of BESI with that of BESII.

2. R SCAN WITH BESII

QED running coupling constant $\alpha(s)$ and anomalous magnetic moment $a_\mu = (g-2)/2$ of the μ are fundamental physics observables to test the Standard Model [3]. Their theoretical precisions so far are limited by the second order loop effects from the hadronic vacuum polarization. About 50% and 20% of the errors in $\alpha(M_Z^2)$ and a_μ, respectively, are due to the uncertainty of the values of $R = \sigma(e^+e^- \to hadrons)/\sigma(e^+e^- \to \mu^+\mu^-)$ in the energy below 5 GeV, where the denominator is the lowest order QED cross section, $\sigma(e^+e^- \to \mu^+\mu^-) = \sigma^0_{\mu\mu} = 4\pi\alpha^2/3s$. To reduce the uncertainties in the values of R in 2-5 GeV region, we scanned 6 points covering cm energy from 2.6 to 5.0 GeV in 1998 (Run I) [4], and 85 points distributed in 2.0-4.8 GeV energy region with BESII in

Table 1
Comparison of the major parameters with BESI and BESII

System	Parameter	BESI	BESII
VC	$\sigma_{xy}(\mu)$	250 (CDC)	90
	planes	4	12
MDC	$\sigma_{xy}(\mu)$	200-250	190-210
	$\Delta p/p(\%)$(p in GeV)	$1.76\sqrt{(1+p^2)}$	$1.78\sqrt{(1+p^2)}$
TOF	σ_t(ps)	370	180
	$L_{attenuation}$(m)	1-1.2	3.5-5.5
BSC	$\Delta E/E(\%)$(E in GeV)	25	21
ESC	$\Delta E/E(\%)$(E in GeV)	23	22
DAQ	dead time/event(ms)	20	10

1999(Run II) [5]. The R values obtained at the six energy points are shown in Table 2. The preliminary R values at 9 points and the online R values for most of the points from Run II are illustrated in Fig. 1. The R scan done with BESII at BEPC can reduce the present uncertainties in R from ~15% to ~7% for $E_{cm} <$ 4.0 GeV and ~10% for 4.0 GeV $< \mathrm{E_{cm}} <$ 5.0 GeV. We expect to have the preliminary result for all the points scanned in the Summer of 2000.

Table 2
R values measured with BESII from Run I.

E_{cm}(GeV)	2.6	3.2	3.4	3.55	4.6	5.00
R	2.64	2.21	2.38	2.23	3.58	3.47
Stat. error	0.05	0.07	0.07	0.06	0.20	0.32
Sys. error	0.19	0.13	0.16	0.16	0.29	0.29

3. RESULTS ON CHARMONIUM

Based on the data collected with BESI shown in Table 3, BES has been studying the light hadron spectroscopy and searching for glueball, studying the properties of the charmonium and charmed mesons from the J/ψ, $\psi(2S)$ and the charmed meson decay.

3.1. Results from $\psi(2S)$ data

- $J/\psi \to l^+l^-$braching fraction [6]

The branching fraction for the leptonic decays $J/\psi \to e^+e^-$ (B_e) and $\mu^+\mu^-$ (B_μ), the basic parameters of the J/ψ resonance, can be used to determine the total number of J/ψ events in a wide variety of measurements that take advantage of the clean experimental $J/\psi \to l^+l^-(l = e$ or $\mu)$

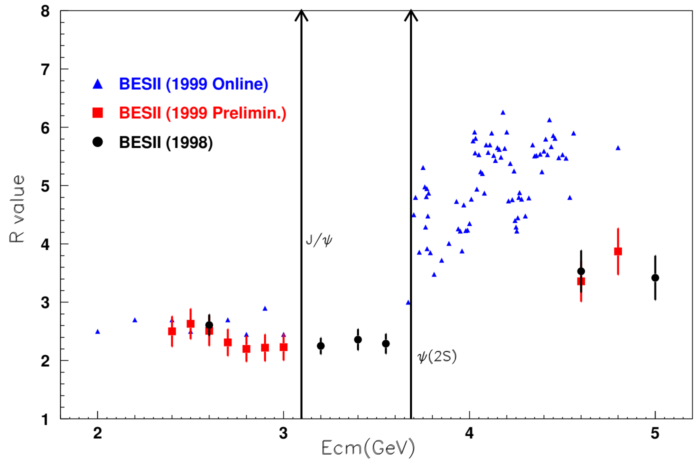

Figure 1. The online R values (triangle) in the energy region below 5 GeV. Notice that the background, the radiative correction and the detection efficiency have not been taken into account. The solid sqaures represent the preliminary R-values obtained from BESII data, of which the total errors are all conservatively assigned to be 10%. The final R-values of the 6 points listed in table 2 are also plotted with solid dots for comparison.

We determined J/ψ leptonic branching fraction from a comparison of the exclusive and inclusive processes: $\psi' \to \pi^+\pi^- J/\psi$ with $J/\psi \to l^+l^-$+anything.

The branching fractions are measured to be $B_e = (5.90 \pm 0.05 \pm 0.10)\%$ and $B_\mu = (5.84 \pm 0.06 \pm 0.10)\%$, which leads to $B_e/B_\mu = 1.011 \pm 0.013 \pm 0.016$.

Assuming $B_e = B_\mu$, we find a combined leptonic branching fraction of $B_l = B(J/\psi \to l^+l^-) = (5.87 \pm 0.04 \pm 0.09)\%$ and obtain a new world average $B_l = (5.894 \pm 0.086)\%$, of which the error is about half that in the 1998 PDG.

Table 3
Summary of the data taken with BESI.

E_{cm}(GeV)	Sample size
J/ψ resonance	7.8×10^6
$\psi(2S)$	3.7×10^6
4.03	$22.3pb^-1$

- Hadronic $\psi(2S)$ decay

BES has measured a large number of $\psi(2S)$ decay branching fractions. Many for the first time. Table 4 lists the recent preliminary results [7].

- χ_{cJ} hadronic decay

Besides about 30 channels of χ_{cJ} hadronic decay, of which many are for the first time and many improved PDG values, BES measured χ_{cJ} branching ratios of some new hadronic decay channels, as shown in Table 5.

Table 4
Hadronic $\psi(2S)$ decay branching fraction measured with BES

Channels	$Br_{PDG}(\times 10^{-4})$	$Br_{BES}(\times 10^{-4})$	$Q_h^{BES} = \frac{Br_{\psi'}}{Br_{J/\psi}}(\%)$
$\omega\eta$	–	< 0.33	< 2.1
$\pi^+\pi^-\pi^0$	0.9±0.5	$1.06 \pm 0.11 \pm 0.16$	7.1 ± 1.6
$K\overline{K}\pi$	–	$1.25 \pm 0.18 \pm 0.26$	2.1 ± 0.6
$\gamma f_2(1270)$	–	$2.36 \pm 0.24 \pm 0.32$	17.1 ± 2.9
$\gamma f_J(1710)$	–	$1.24 \pm 0.20 \pm 0.16$	12.8 ± 3.4
ϕK^+K^-	–	$0.61 \pm 0.18 \pm 0.15$	7.3 ± 3.0
$\phi\pi^+\pi^-$	–	$1.76 \pm 0.22 \pm 0.24$	22.0 ± 5.3
$\phi f_0(980)$	–	$0.66 \pm 0.17 \pm 0.07$	20.5 ± 8.1
$\omega\pi^+\pi^-$	–	$4.47 \pm 0.57 \pm 0.54$	6.3 ± 1.4
ωK^+K^-	–	$1.26 \pm 0.43 \pm 0.39$	17.0 ± 9.6
$\omega p\bar{p}$	–	$0.60 \pm 0.23 \pm 0.14$	4.6 ± 2.2
$\phi p\bar{p}$	–	$0.86 \pm 0.50 \pm 0.20$	18.9 ± 13.4
$\pi^+\pi^-\pi^0 p\bar{p}$	–	$3.85 \pm 0.37 \pm 0.56$	16.7±7.1
$\eta\pi^+\pi^- p\bar{p}$	–	$2.58 \pm 0.68 \pm 0.73$	
$\eta p\bar{p}$	–	$0.84 \pm 0.48 \pm 0.48$	4.00±4.00
$p\bar{p}$	1.9 ± 0.5	$2.62 \pm 0.17 \pm 0.55$	12.3 ± 2.8
$\Lambda\overline{\Lambda}$	< 4.0	$1.89 \pm 0.21 \pm 0.21$	14.0 ± 2.7
$\Sigma^0\overline{\Sigma}^0$	–	$1.20 \pm 0.40 \pm 0.30$	9.2 ± 4.1
$\Xi^-\overline{\Xi}^+$	< 2.0	$1.00 \pm 0.30 \pm 0.10$	11.1 ± 4.3
$\Delta^{++}\overline{\Delta}^{--}$	–	$1.34 \pm 0.11 \pm 0.33$	12.2 ± 4.5
$\Sigma^{*+}\overline{\Sigma}^{*-}$	–	$1.10 \pm 0.30 \pm 0.30$	10.7 ± 4.3

Table 5
Preliminary branching ratios of χ_{cJ} hadronic decay.

decay channels	BES $(\times 10^{-3})$	PDG$(\times 10^{-3})$
$Br(\chi_{c0} \to \pi^0\pi^0)$	$2.80 \pm 0.32 \pm 0.51$	3.1 ± 0.6
$Br(\chi_{c2} \to \pi^0\pi^0)$	$0.92 \pm 0.27 \pm 0.52$	1.1 ± 0.3
$Br(\chi_{c0} \to \eta\eta)$	$2.03 \pm 0.84 \pm 0.58$	2.5 ± 1.1
$Br(\chi_{c2} \to \eta\eta)$	< 2.5	0.8 ± 0.5

3.2. Study of J/ψ decay

• Partial Wave Analysis of $J/\psi \to \gamma K^+K^-\pi^+\pi^-$ [8]

For $J/\psi \to \gamma K^+K^-\pi^+\pi^-$, we found that the $K^*\bar{K}^*$ contribution peaks strongly near threshold, which can be fitted with a broad 0^{-+} resonance with mass $M = 1800 \pm 100$ MeV, width $\Gamma = 500 \pm 200$ MeV. A broad 2^{++} resonance peaking at 2020 MeV is also required with width ~ 500 MeV. There is further evidence for a 2^{-+} component peaking at 2.55 GeV. The non-$K^*\bar{K}^*$ contribution is close to phase space; it peaks at 2.6 GeV and is very different from $K^*\bar{K}^*$.

• Measurement of m_{η_c} and Γ_{η_c}

The decay modes of η_c: $K^+K^-\pi^+\pi^-$, $\pi^+\pi^-\pi^+\pi^-$, $K^\pm K^0_S\pi^\mp$(with $K^0_S \to \pi^+\pi^-$), $\phi\phi$(with $\phi\phi \to K^+K^-K^+K^-$) and $K^+K^-\pi^0$ from J/$\psi \to \gamma\eta_c$ have been analyzed and the mass of η_c is measured to be $2976.6 \pm 2.9 \pm 1.3$ MeV.

Combining the results from BES data analysis of $\psi(2S) \to \gamma\eta_c$, $m_{\eta_c} = 2976.3 \pm 2.3 \pm 1.2$ MeV and $\Gamma_{\eta_c} = 11.0 \pm 8.1 \pm 4.1$ MeV are obtained [9].

• The analysis of $J/\psi \to \gamma\gamma V(V = \rho, \phi)$

We studied the $J/\psi \to \gamma\gamma V(V = \rho, \phi)$ decay channels and found the evidence of the $\eta(1430)$ in both decay channels. The mass and width of the $\eta(1430)$ resonance are found to be 1431 ± 17 MeV and 88 ± 28 MeV from $\gamma\gamma\rho$ mode and 1427 ± 13 MeV and 77 ± 46 MeV from $\gamma\gamma\phi$ mode [10]. In order to understand the structure of $\eta(1430)$, other J/ψ decay channels should be analyzed.

• N^* results from J/ψ decay [11]

The behave of N^* baryon in J/ψ decay to baryon-antibaryon final states provides us a laboratory for the study of N^* baryon, especially in the mass range of ~1-2 GeV. Using PWA, we have studied the $J/\psi \to p\bar{p}\eta$ and $p\bar{p}\pi^0$ decay. Two resonances with $J^P = \frac{1}{2}^-$ are observed. Their masses and widths are: $M = 1540^{+15}_{-17}$ MeV with $\Gamma = 178^{+20}_{-22}$ MeV; and $M = 1648^{+18}_{-16}$ MeV with $\Gamma = 150$ MeV respectively. These two states are considered to be the nucleon resonances $S_{11}(1535)$ and $S_{11}(1650)$.

3.3. Charmed mesons

Though many precise measurements of exclusive decay branching fractions of charmed mesons has been made to understand the heavy flavor physics, our knowledge on the inclusive decay properties of the charmed mesons is still limited by the experimental data. Using 22.3 pb^{-1} data collected at 4.03 GeV, we directly measured the inclusive $\overline{K}^{*0}$ and K^{*0} decay branching fractions of the D_s^+ meson. From $183.6 \pm 24 \pm 6.5$ $D_s^+D_s^-$ pairs and 7.5 ± 4.4 $D_s^+ \to \overline{K}^{*0}$X observed events, we deduced the results of: $Br(D_s^+ \to \overline{K}^{*0}\mathrm{X}) = (20.3 \pm 11.9 \pm 1.8)\%$ and $Br(D_s^+ \to K^{*0}\mathrm{X}) < 7.5\%$ at 90% C.L. [12]. Our results may indicate that some decay of D_s^+ to $\overline{K}^{*0}$ are still missing.

4. PLANS FOR THE NEAR FUTURE OF BESII

The plans for our near future are:

• continue analyzing the R scan data and have the final R values for all the energy points in the summer of 2000;

• continue analyzing the data taken with BESI;

• collect $\sim 50 \times 10^6$ J/ψ events with BESII within 3 years.

With this amount of J/ψ event sample, ~6 times as more data as the largest sample existing in the world, BES collaboration can systematically study the light hadron spectroscopy and N^* baryons; search for glueball and hybrid states; as well as explore the rare decays in the tau charm sector.

The results presented here are preliminary and the results based on J/ψ data are from only the China side of the BES collaboration.

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