BES RECENT RESULTS AND FUTURE PLANS

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We report the preliminary R values for all the 85 energy points scanned in the energy region of 2-5 GeV with the upgraded Beijing Spectrometer (BESII) at Beijing Electron Positron Collider (BEPC). Preliminary results from the J/ψ data collected with both BESI and BESII are presented. Measurements of the branching fraction of the $\psi(2S)$ decays and the $\psi(2S)$ resonance parameters are reported. The future plans, i.e. significantly upgrade the machine and detector are also discussed.

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 center-of-mass energy in 2-5 GeV and directly produce charmonium and charmed mesons, has been running for more than 10 years. Both BEPC and BES were upgraded from 1995 to 1997. BEPC has single bunch and the peak luminosity reached so far is about $5 \times 10^{30}/cm^2s$ at the J/ψ resonance, giving a hadronic event rate about 6-8 Hz. The Beijing Spectrometer (BES) is a conventional cylindrical magnetic detector and is described in detail in Ref. 1 and 2. Table 1 listed some major parameters of the performance of BESII.

Table 1. The major parameters of the performance of BESII

System	Parameter	BESII
VC	$\sigma_{xy}(\mu)$	90
MDC	$\sigma_{xy}(\mu)$	190-210
	$\Delta p/p$	$1.78\%\sqrt{(1+p^2)}$
TOF	$\sigma_t(\text{ps})$	180
BSC	σ_E/E	$21\%/\sqrt{E}$

About 7.8×10^6, 3.96×10^6 J/ψ and $\psi(2S)$ events have been collected with BESI, and 22×10^6 J/ψ events with BESII, in addition to the R scan done with BESII in the energy region of 2-5 GeV. This presentation will firstly report the new measurement of the R values in the 2-5 GeV energy region, and then present recent results from the analysis of the BES J/ψ and $\psi(2S)$ data. All results reported in this article are preliminary. The future plans for the BES will be briefly discussed in the end.

2 New R values from the BES

The QED running coupling constant evaluated at the Z pole, $\alpha(M_Z^2)$, and the anomalous magnetic moment of the muon, $a_\mu = (g-2)/2$, are two fundamental quantities to test the Standard Model(SM) [3,4]. $\alpha(M_Z^2)$, as one of the three input parameters in the global fit to the electroweak data, is sensitive to the predicted mass of the Higgs. Theoretically, a_μ is sensitive to large energy scales and very high order radiative corrections [5]. Any deviation between the SM predicted value of anomalous magnetic moment of the muon, a_μ^{SM}, and that from the experimentally measured one, a_μ^{exp}, may hint new physics. However, the uncertainties in both $\alpha(M_Z^2)$ and a_μ^{SM} are dominated by the hadronic vacuum polarization, which cannot be reliably calculated but are related to R values through dispersion relations [4]. Here R is the lowest order cross section for $e^+e^- \to \gamma^* \to$ hadrons, which is defined as $R = \sigma(e^+e^- \to \text{hadrons})/\sigma(e^+e^- \to \mu^+\mu^-)$, where the denominator is the lowest-order QED cross section, $\sigma(e^+e^- \to \mu^+\mu^-) = \sigma^0_{\mu\mu} = 4\pi\alpha^2/3s$.

Since the uncertainties in $\alpha(M_Z^2)$ and a_μ^{SM} are limited by the second order loop effects from the hadronic vacuum polarization, which dominated by the errors of the values of R in the cm energy range below 5 GeV [4], it is crucial to significantly reduce the uncertainties in the R values measured about 20 years ago with a precision of about 15-20% in the energy region of 2-5 GeV [3,5].

Following the first R scan with 6 energy points in 2.6-5 GeV range done in 1998 [6], the BES collaboration did a finer R scan with 85 energy points in the energy region of 2-4.8 GeV. To understand the beam associated background, separated beam running was done at 24 energy points and single beam running for both e^- and e^+ was done at 7 energy points distributed over the whole scanned energy region. Special runs were taken at the J/ψ to determine the trigger efficiency. The J/ψ and $\psi(2S)$ resonances were scanned at the beginning and at the end of the R scan for the energy calibration.

The R values from the BESII scan data are measured by observing the final hadronic events inclusively, i.e. the value of R is determined from the number of observed hadronic events (N^{obs}_{had}) by the relation

$$R = \frac{N^{obs}_{had} - N_{bg} - \sum_l N_{ll} - N_{\gamma\gamma}}{\sigma^0_{\mu\mu} \cdot L \cdot \epsilon_{had} \cdot (1+\delta)}, \qquad (1)$$

where N_{bg} is the number of beam associated background events; $\sum_l N_{ll}$, $(l = e, \mu, \tau)$ and $N_{\gamma\gamma}$ are the numbers of misidentified lepton-pairs from one-photon and two-photon processes events respectively; L is the integrated luminosity; δ is the radiative correction; ϵ_{had} is the detection efficiency for hadronic events.

The typical errors from different sources at 3.0 GeV are listed in table 2. To further improve the measurement of R values at BEPC, one needs better performance from the detector and a better handle on the uncertainty arising from the hadronic event generator, as well as higher machine luminosity, particularly for the energies below 3.0 GeV.

Table 2. Error Sources for E_{cm}=3.0 GeV. Adding the systematic and statistic errors in quadrature gives a total error of 5.8%.

Source	N_{had}	L	ϵ_{had}	$1+\delta$	Stat.
Err.(%)	3.3	2.3	3.0	1.3	2.5

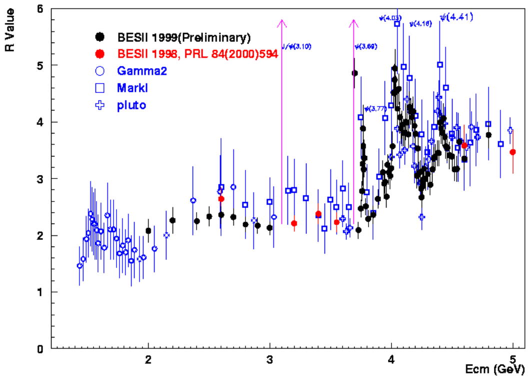

Figure 1. R values below 5 GeV.

The preliminary R values obtained at all 85 energy are graphically displayed in Fig. 1, together with the 6 energy points measured in the first scan and those measured by MarkI, $\gamma\gamma 2$ and Pluto about twenty years ago. The preliminary R values from BESII have an average uncertainty of about 7% and are slightly lower than that from the previous measurements. The two to three factor improvement in precision of the R values in 2-5 GeV has a significant impact on the global fit to the electroweak data for the determination of m_H. The preliminary fit results show that the predicted m_H is significant increased with the preferred value lying just above the LEP2 excluded region, and the new χ^2 profile of the fit accommodates the LEP2 bound on the mass more comfortably [10,11]. On the other hand, BESII R values can also greatly contribute to the interpretation of the E821 $g-2$ measurement [5].

3 Results on charmonium physics

The decays of J/ψ and $\psi(2S)$ is an unique laboratory to systematically study the charmonium family members, search for gluonic matters and test of QCD.

3.1 Study of the J/ψ decays

Glueball, the bound state of gluons, has been predicted for all low-energy approximations of QCD. Glueball spectrum is one of the least understood features of the Standard Model. The present consensus is that the ground state should be in the 1-2 GeV mass range, and there is little doubt that radiative J/ψ decays are the best place to search for glueballs.

3.1.1 Results from BESI J/ψ data

• Partial Wave Analysis on $J/\psi \to \gamma K^+K^-$

Based on BESI 7.8×10^6 J/ψ data, a partial wave analysis is performed to the $f_J(1710)$ mass region in $J/\psi \to \gamma K^+K^-$ channel. Fig. 2 shows the mass projection of the components in the fit to the real data. Apparently, 0^{++} is dominant in $f_J(1710)$ mass region.

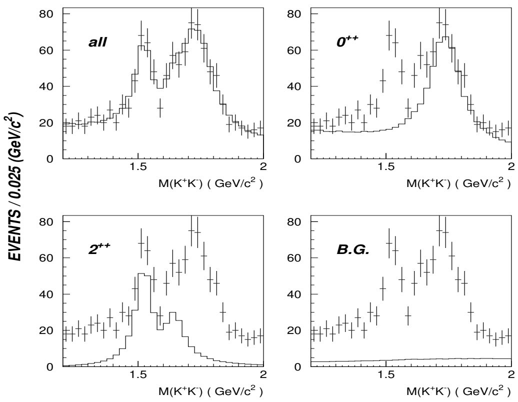

Figure 2. Projection of the different components on the K^+K^- mass

• 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 [13]. In order to understand the structure of $\eta(1430)$, other J/ψ decay channels should be analyzed.

• N^* results from J/ψ decay [12]

The behaviour 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 $p\bar{p}\pi^0$ decays. 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 $S_{11}(1650)$.

3.1.2 Preliminary results from BESII J/ψ data

The inclusive ϕ, Λ, K^* and K_s^0 signals and their fitted masses from the newly collected 22×10^6 J/ψ events sample with BESII are shown in Fig. 3.

Fig. 4 is the invariant mass spectra and Daliz plot for $J/\psi \to \omega\pi^+\pi^-$ decay. Clear π^0 and ω signals are seen in 2γ's and $\pi^+\pi^-\pi^0$ invariant mass spectra, respectively. In $\pi^+\pi^-$ mass distribution, which recoils against ω, an $f_2(1270)$ and a big bump around 500 MeV are observed. The invariant masses of $M_{\pi^+\pi^-}$ and $M_{K\pi}$ are plotted in Fig. 5 for $J/\psi \to K^{*\pm}K^{\mp}, K^{*\pm} \to K_s^0\pi^\pm$ and $K_s^0 \to \pi^+\pi^-$ decay. Both K_s^0 and K^* are nicely peaked.

• Partial Wave Analyses on $J/\psi \to \phi\pi^+\pi^-$ and ϕK^+K^-

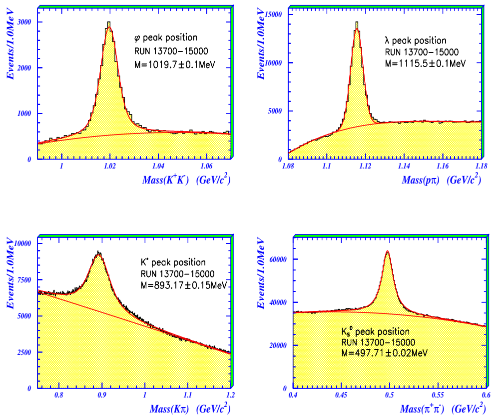

Figure 3. Inclusive ϕ, Λ, K^* and K_s^0 signals

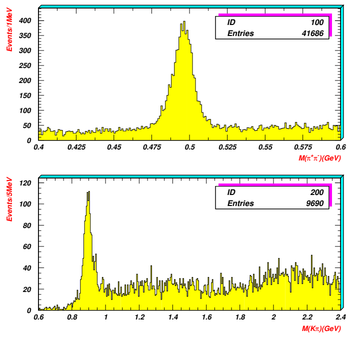

Figure 5. $J/\psi \to K^{*\pm}K^{\mp}$, $K^{*\pm} \to K_s^0\pi^{\pm}$, $K_s^0 \to \pi^+\pi^-$

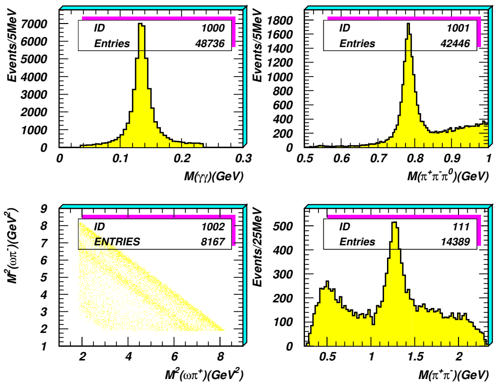

Figure 4. $J/\psi \to \omega\pi^+\pi^-$, $\omega \to \pi^+\pi^-\pi^0$

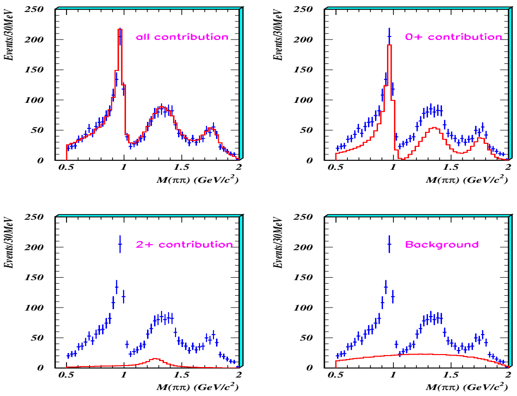

Figure 6. Projection of every component on $\pi^+\pi^-$ mass in $J/\psi \to \phi\pi^+\pi^-$ (Very preliminary).

Partial Wave Analyses of $J/\psi \to \phi\pi^+\pi^-$ and ϕK^+K^- are performed. Fig. 6 represents the contribution of every component from the fit in $J/\psi \to \phi\pi^+\pi^-$. Three 0^{++}, located at 980 MeV, 1370 MeV and 1770 MeV, and one 2^{++} at 1270 MeV are observed in $\pi^+\pi^-$ invariant mass recoiling against ϕ. In $J/\psi \to \phi K^+K^-$, $f_2'(1525)$ and $f_0(1710)$ components are found to be needed for a best fit. The projection of different components on K^+K^- mass is shown in Fig. 7.

- Inclusive γ spectrum

In addition to studying the radiative decays exclusively, the inclusive γ spectrum is another place to search for glueballs. Due to the relatively poor energy resolution for BSC, we use γ conversion to e^+e^- pair inside our detector and then measure the momenta of e^+ and e^- in MDC, which has a momentum resolution of $1.8\%\sqrt{1+p^2}$ (p in GeV). The inclusive γ spectrum is plotted in Fig. 8.

3.2 Results from $\psi(2S)$ data

One expects the following relation holds for any hadronic final state, according to perturbative QCD,

$$Q_h \equiv \frac{B(\psi(2S) \to h)}{B(J/\psi \to h)} \simeq \frac{B(\psi(2S) \to e^+e^-)}{B(J/\psi \to e^+e^-)} = (14.8 \pm 2.2)\%.$$

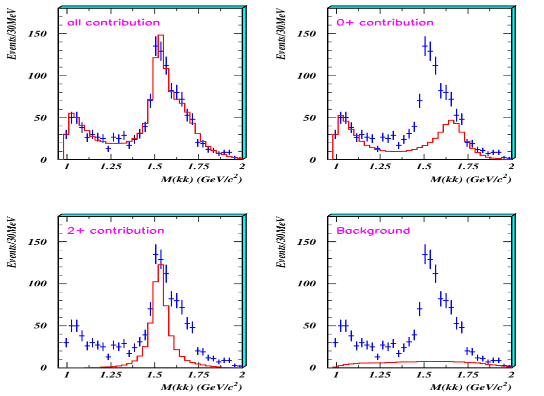

Figure 7. Projection of every component on K^+K^- mass in $J/\psi \to \phi K^+K^-$ (Very preliminary).

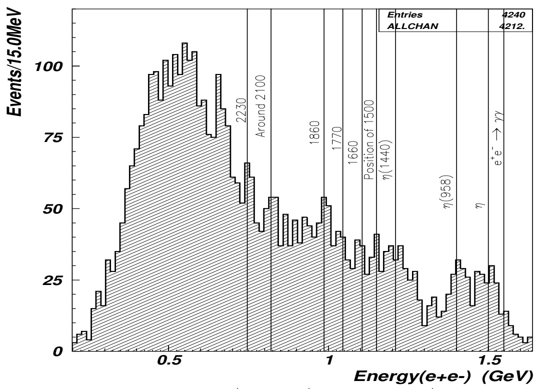

Figure 8. Inclusive γ ($E_{e^+e^-}$) spectrum (Very preliminary).

Table 3. BES preliminary $B(\psi(2S) \to h)$ and 15% rule test (limit at C.L.90%)

h	$B_h(10^{-5})$	$Q_h(\%)$
ωK^+K^-	12.5 ± 5.6	16.9 ± 9.4
$\omega p\overline{p}$	6.4 ± 2.6	5.0 ± 2.2
$\phi\pi^+\pi^-$	16.8 ± 3.2	21.0 ± 5.1
ϕK^+K^-	5.8 ± 2.2	7.0 ± 2.9
$\phi p\overline{p}$	0.82 ± 0.52	18.1 ± 12.8
ϕf_0	6.3 ± 1.8	19.6 ± 7.8
$K^*K^-\pi^+ + c.c.$	60.4 ± 9.0	?
$K^*\overline{K}^* + c.c.$	3.92 ± 1.03	13.6 ± 4.9
$K^*\overline{K_2}^* + c.c.$	7.98 ± 5.28	1.20 ± 0.93
$\pi^0\pi^+\pi^-p\overline{p}$	34.9 ± 6.4	15.2 ± 6.6
$\eta\pi^+\pi^-p\overline{p}$	24.7 ± 9.6	?
$\eta p\overline{p}$	$< 18.$	< 8.6

Table 4. Branching fractions of $\psi(2S) \to B\overline{B}$ (limit at C.L.90%)

Decay	B (10^{-4})	Q_h (%)	$\mid M_i \mid^2_{\psi(2S)}$ (10^{-4})
$p\overline{p}$	$2.16 \pm .39$	10.1 ± 1.9	$1.60 \pm .29$
$\Lambda\overline{\Lambda}$	$1.81 \pm .34$	13.4 ± 2.9	$1.45 \pm .27$
$\Sigma^0\overline{\Sigma}^0$	$1.2 \pm .6$	9.4 ± 4.6	$1.0 \pm .5$
$\Xi^-\overline{\Xi}^+$	$0.94 \pm .31$	10.4 ± 4.1	$0.86 \pm .28$
$\Delta^{++}\overline{\Delta}^{--}$	$1.28 \pm .35$	11.6 ± 4.5	$1.10 \pm .30$
$\Sigma^{*-}\overline{\Sigma}^{*+}$	$1.1 \pm .4$	11 ± 4	$1.1 \pm .4$
$\Xi^{*0}\overline{\Xi}^{*0}$	$< .81$		< 0.93
$\Omega^-\overline{\Omega}^+$	$< .73$		< 1.11

where the leptonic branching fractions are taken from PDG2000 [14]. This relation is referred to as PQCD 15% rule.

BES measured, for the first time, branching fractions of 12 $\psi(2S)$ hadronic decays as shown in table 3.

In the context of flavor SU(3) symmetry, a pure $c\overline{c}$ state is a flavor singlet. In the limit of SU(3) flavor symmetry, the phase-space-corrected reduced branching ratio $\mid M_i \mid^2$

$$\mid M_i \mid^2 = \frac{B(\psi(2S) \to B_i\overline{B_i})}{\pi p^*/\sqrt{s}}$$

should be the same for every baryon B_i in the same multiplet (p^* is the momentum of the baryon in the $\psi(2S)$ rest frame). This relation works reasonably well for $J/\psi \to B\overline{B}$, but has not been tested for the $\psi(2S)$.

BES measured, as listed in Table 4, branching fractions of eight $\psi(2S) \to B\overline{B}$ channels, five of which are for the first time.

The $\mid M_i \mid^2$ for $\psi(2S) \to B\overline{B}$ have been calculated based on BES data and also listed in Table 4. The results show a tendency of smaller values for the higher masses, only marginally consistent to flavor-SU(3) symmetry prediction, similar to J/ψ case.

By studying the radiative decays of $\psi(2S) \to \gamma(\pi\pi, K\overline{K}, \eta\eta)$, BES has measured 8 branching fractions for the first time, and their preliminary results are listed in Table 5. The branching fractions for $\psi(2S) \to$

Table 5. Preliminary branching fractions from $\psi(2S)$ radiative decay (limit at C.L.90%)

Process	$B(10^{-4})$
$\psi(2S) \rightarrow \gamma f_2(1270)$	2.27 ± 0.43
$\rightarrow \gamma f_J(1710) \rightarrow \gamma\pi\pi$	$.336 \pm .165$
$\rightarrow \gamma f_J(1710) \rightarrow \gamma K^+K^-$	0.55 ± 0.21
$\rightarrow \gamma f_J(1710) \rightarrow \gamma K_S^0 K_S^0$	0.21 ± 0.15
$\chi_{c0} \rightarrow \pi^0\pi^0$	26.8 ± 6.5
$\chi_{c2} \rightarrow \pi^0\pi^0$	8.8 ± 5.6
$\chi_{c0} \rightarrow \eta\eta$	19.4 ± 10.0
$\chi_{c2} \rightarrow \eta\eta$	< 12.2

$\gamma f_2(1270)$ and $\psi(2S) \rightarrow \gamma f_J(1710) \rightarrow \gamma K\overline{K}$ agree with PQCD 15% prediction. The ratio of $\chi_{c0} \rightarrow \eta\eta$ to $\chi_{c0} \rightarrow \pi^0\pi^0$ is equal to 0.73 ± 0.39, consistent with the theoretical prediction of 0.95 based on the flavor SU(3) symmetry.

4 BES future plans

The plan for our near future is to collect 50×10^6 J/ψ events with BESII before 2001.

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 exploring the rare decays in J/ψ decays.

The plan for the middle term future is to significantly upgrade BEPC and BESII. The upgraded machine and detector will be named BEPCII and BESIII. The upgrade goal for the machine is to increase the peak luminosity from about $5 \times 10^{30}/cm^2s$ to about $5 \times 10^{31}/cm^2s$ at the J/ψ resonance. Multi-bunch train with prizel orbit is considered to be applied. The bunch length will be shorten to about 1 cm, and the injection rate will be significantly increased. For the detector, we will build an new electromagnetic calorimeter using scintilating fiber with lead, which gives an energy resolution better than $10\%/\sqrt{E}$. The time-of-flight may also be rebuilt to have a resolution less than 150 ps. We are also considering building a drift chamber using Helium gas and Aluminum field wires.

The upgrade project has been endorsed by the Chinese central government with a budget about 40 M US dollars. R&D program has been started for both machine and detector.

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