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Recent Charmonium Results from BES

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Abstract: The $\psi(2S) \to \tau^+\tau^-$ branching ratio, $B_{\tau\tau}$, has been measured for the first time using the BES detector at the Beijing Electron Positron Collider. The result is $B_{\tau\tau} = 2.71 \pm 0.43 \pm 0.55) \times 10^{-3}$. Using both the J/ψ and $\psi(2S)$ BESI data sets, we have determined the η_c mass and width to be $M_{\eta_C} = (2975 \pm 3.9 \pm 1.2)$ MeV and $\Gamma\eta_C = (11.0 \pm 8.1 \pm 4.1)$ MeV. Some preliminary results from the recently completed 50 million event BESII J/ψ sample, which is the world's largest sample, are shown.

1. Introduction

The Beijing Spectrometer (BES) is a general purpose solenoidal detector at the Beijing Electron Positron Collider (BEPC). BEPC operates in the center of mass energy range from 2 to 5 GeV with a luminosity at the J/ψ energy of approximately 5×10^{30} cm^{-2}s^{-1}. BES (BESI) is a conventional cylindrical detector and has been described in detail in Ref. [1], and the upgraded BES detector (BESII) is described in Ref. [2]. This paper presents some recent and some preliminary results. Details can be found in the references.

2. $\psi(2S) \to \tau\tau$ Decays

BES has the world's largest sample of e^+e^- produced $\psi(2S)$ events: 3.96×10^6 events. Here we present the first measurement of the branching ratio for $\psi(2S) \to \tau\tau$, $B_{\tau\tau}$, and compare it to the branching ratios, B_{ee} and $B_{\mu\mu}$, measured by previous experiments [3]. For this decay, we select events where $\psi(2S) \to \tau\tau \to e\nu\bar{\nu}\mu\nu\bar{\nu}$. We require only one μ and one e with no neutrals. To select events in the sensitive region of the detector and reject backgrounds, cuts are made on the polar angles of the tracks and on the acolinearity and acoplanarity angles. The leptons must satisfy particle identification requirements, and the momenta of the leptons must be less than the maximum kinematically allowed value for a τ decay at the c.m. energy of the $\psi(2S)$. A comparison of data with Monte Carlo data is shown in Fig. 1.

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Sample	$n_{e\mu}$	n_{bg}	ϵ_d	$B_{\tau\tau}$ (10^{-3})
I	77	0.27	0.1449	$2.76 \pm 0.73 \pm 0.56$
II	140	0.49	0.1439	$2.68 \pm 0.53 \pm 0.56$
Total	217	0.76	0.1442	$2.71 \pm 0.43 \pm 0.55$

Table 1: Numbers used to calculate $B_{\tau\tau}$.

To determine the background remaining in the sample, we analyze the 7.8 million BESI J/ψ sample with the same cuts. We determine $B_{\tau\tau}$ using

$$B_{\tau\tau} = \frac{(n_{e\mu} - n_{bg})/B\epsilon_{trig}\epsilon_d - \sigma_{Q+I}\mathcal{L}}{N_{\psi(2S)}},$$

where $n_{e\mu}$ is the number of events passing cuts, n_{bg} is the number of background events, B is the fraction of $\tau^+\tau^-$ events yielding the $e\mu$ topology, ϵ_{trig} is the trigger efficiency (approximately 100 %), ϵ_d is the detection efficiency determined from Monte Carlo simulation, σ_{Q+I} is the QED τ-pair production cross section including interference, $\mathcal{L}$ is the accumulated luminosity, and $N_{\psi(2S)}$ is the number of $\psi(2S)$. $\sigma_{Q+I} = 2.230$ nb^{-1} and $\mathcal{L} = 6.1$ pb^{-1}. The values obtained for the two running periods and the total results are shown in Table 1.

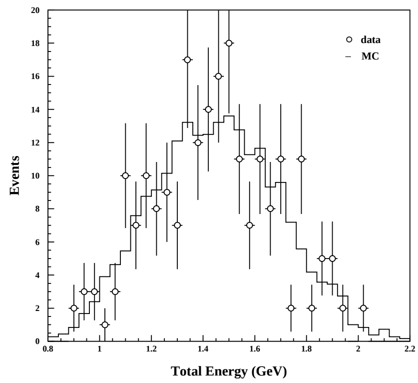

Figure 1: Comparison of event energies for data and Monte Carlo data

If Universality holds, the branching ratios are related by

$$\frac{B_{ee}}{\nu_e(\frac{3}{2} - \frac{1}{2}\nu_e^2)} = \frac{B_{\mu\mu}}{\nu_\mu(\frac{3}{2} - \frac{1}{2}\nu_\mu^2)} = \frac{B_{\tau\tau}}{\nu_\tau(\frac{3}{2} - \frac{1}{2}\nu_\tau^2)},$$

where $\nu_l = \left(1 - \frac{4m_l^2}{M^2_{\psi(2S)}}\right)^{\frac{1}{2}}$. Putting in known masses, we obtain $B_{ee} \simeq B_{\mu\mu} \simeq \frac{B_{\tau\tau}}{0.3885} \equiv B_{ll}$. The $\psi(2S)$ lepton branching ratios are shown in Table 2

Averaging, we obtain $B_{ll} = (8.4 \pm 1.0) \times 10^{-3}$. We can use this result and $\Gamma_{ee} = (2.12 \pm 0.18)$ keV [4] to obtain $\Gamma_{tot} = \frac{\Gamma_{ee}}{B_{ll}} = (252 \pm 37)$ keV, which is in good agreement with the PDG value of (277 ± 31) keV [4].

B_{ee} (10^{-3})	$B_{\mu\mu}$ (10^{-3})	$\frac{B_{\tau\tau}}{0.3855}$ (10^{-3})
8.8 ± 1.3	10.3 ± 3.5	$7.0 \pm 1.1 \pm 1.4$

Table 2: $\psi(2S)$ leptonic branching fraction comparison. B_{ee} and $B_{\mu\mu}$ are from Ref. [4].

3. η_c Parameters

The mass and width of the η_c are rather poorly known; the confidence level for the PDG weighted average mass is only 0.001 [4]. We measured the η_c mass using our $\psi(2S)$ sample and obtained $M_{\eta_c} = (2975.8 \pm 3.9 \pm 1.2)$ MeV [5]. We have also used the 7.8 M BESI J/ψ data set to determine the η_c mass and obtained $(2976.6 \pm 2.9 \pm 1.3)$ MeV and a combined result of $(2976.3 \pm 2.3 \pm 1.2)$ MeV [6]. The results are shown along with other measured values in Fig. 2. Using the combined J/ψ and $\psi(2S)$ samples, we obtain an η_c width of $(11.0 \pm 8.1 \pm 4.1)$ MeV. A comparison of η_c width measurements is shown in Table 3.

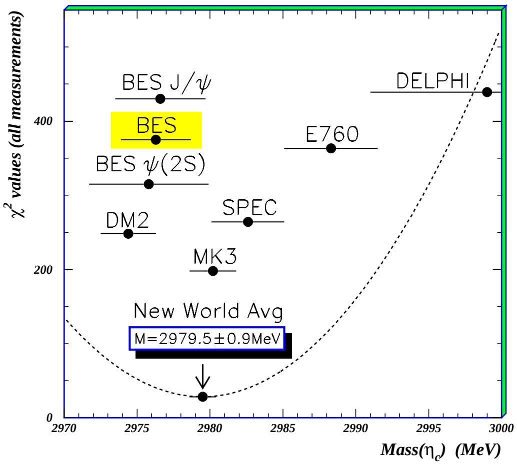

Figure 2: ηc mass results. The χ^2 versus weighted average η_c mass is shown.

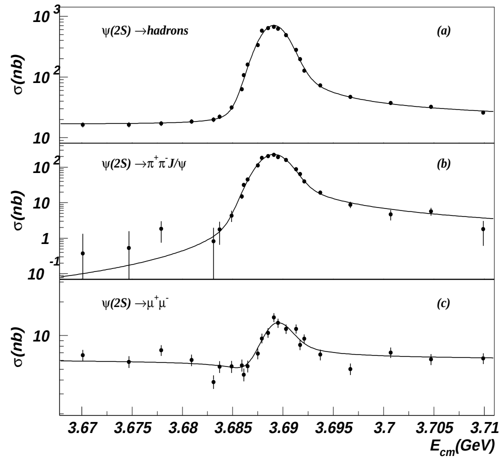

Figure 3: Cross section versus scan point and preliminary fits for $\psi(2S)$ $\rightarrow$hadrons, $\pi^+\pi^- J/\psi$, and $\mu^+\mu^-$ from the $\psi(2S)$ scan data.

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	$23.9^{+12.6}_{-7.1}$
PDG2000 [4]		2000	$13.2^{+3.8}_{-3.2}$
BES [6]	$J/\psi, \psi(2S) \to \gamma X$	2000	$11.0 \pm 8.1 \pm 4.1$
CLEO [7]	$e^+e^- \to \gamma\gamma$	2000	$27.0 \pm 5.8 \pm 1.4$

Table 3: η_c widths.

4. BES $\psi(2S)$ Scan

In 1999, after the R-scan run [8], BES did a careful $\psi(2S)$ scan. The purpose was to improve the accuracies of the $\psi(2S)$ parameters: Γ, Γ_h, Γ_μ, $\Gamma_{\pi^+\pi^- J/\psi}$, $B(h)$, $B(\mu)$, and $B(\pi^+\pi^- J/\psi)$. $B(\pi^+\pi^- J/\psi)$ and $B(\mu)$ are important because these decays are used to identify $\psi(2S)$ in B decays ($B \to \psi(2S) K^0_S$).

A total of 24 energy points between 3.67 and 3.71 GeV were scanned. The integrated luminosity was 760 nb^{-1}. The cross sections versus scan point energy and preliminary fit curves are shown in Fig. 3. The full preliminary scan results are available in Ref. [9].

5. BES J/ψ Data

At the end of April, BES completed the second part of its BESII J/ψ run and accumulated a grand total of 50 M events. The accumulated number versus time is shown in Fig. 4.

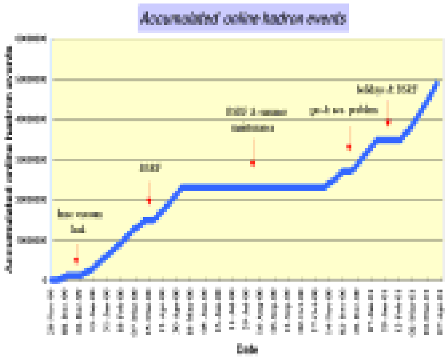

Figure 4: Plot showing J/psi data accumulation versus time.

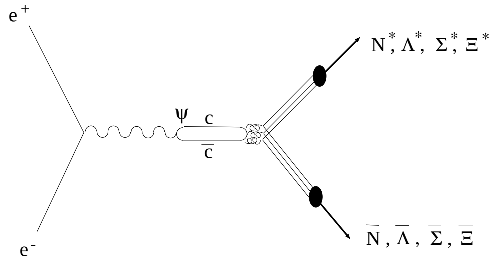

Figure 5: Schematic for N^* production in J/ψ decays.

This is the world's largest sample, and it will provide a wealth of opportunites for searching for hybrids, studying light meson spectroscopy, observing excited baryon states, measuring SU(3) mixing angles, and probing lepton flavor violation and CP violation.

5.1 Study of Excited Baryon States

Our present knowledge of excited nucleon states is very rudimentary. It mostly comes from old generation πN scattering experiments performed more than 20 years ago. New experiments are required to probe the internal structure of light quark baryons and to better understand the strong force in the non-perturbative regime. It is also important to search for missing baryons predicted by the Quark Model [10], and to better determine masses and widths of many poorly known states. For example, the mass of the first radial excitation of the nucleon, the $N^*(1440)$, is only known to be in the range from 1430 to 1470 MeV, and the width is only known to be in the range from 250 to 450 MeV.

J/ψ decays are an excellent place to study excited baryon states. Branching ratios are relatively large in $J/\psi \to b\bar{b}m$ decays. For example, $B(J/\psi \to p\bar{p}\pi^o) = (2.0 \pm 0.1) \times 10^{-3}$ [4]. The production process is shown in Fig. 5. Since the J/ψ is an isosinglet state, the N^* recoiling against a nucleon is produced in a pure isospin 1/2 state, and the πN and $\pi\pi N$ states produced in the N^* decay will be pure isospin 1/2 states. We can use J/ψ decays to study not only N^*, but also Λ^*, Σ^*, and Ξ^*. J/ψ decays will play a unique role in Baryon Spectroscopy

$N^*(1535)$	BES	PDG00
Mass (MeV)	1530 ± 10	1520 - 1555
Γ (MeV)	95 ± 25	100 - 250
$N^*(1650)$	BES	PDG00
Mass (MeV)	1647 ± 20	1640 - 1680
Γ (MeV)	145^{+80}_{-45}	145 - 190

Table 4: Partial wave analysis results from $J/\psi \to p\bar{p}\eta(\pi^0)$ [11].

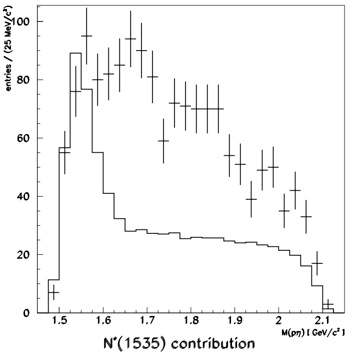

Figure 6: $M_{p\eta}$ distribution (crosses) from $J/\psi \to p\bar{p}\eta(\pi^0)$ with $N^*(1535)$ PWA contribution (histogram).

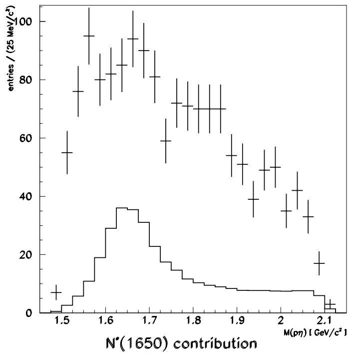

Figure 7: $M_{p\eta}$ distribution (crosses) from $J/\psi \to p\bar{p}\eta(\pi^0)$ with $N^*(1650)$ PWA contribution (histogram).

The process $J/\psi \to p\bar{p}\eta(\pi^0)$ has been studied using the BESI (7.8 M) J/ψ sample [11]. Fig. 6 shows the $p\eta$ mass distribution (points with error bars). There are enhancements at around 1530 and 1650 MeV. Partial wave analysis fit results for the ($J^P = \frac{1}{2}^-$) $N^*(1535)$ and $N^*(1650)$ states are shown in Figs. 6 and 7, respectively. The masses and widths obtained and the PDG values are shown in Table 4.

The 50 M BESII J/ψ sample will allow many more excited baryon studies. Using 24 M J/ψ events, we have investigated $J/\psi \to p\bar{n}\pi^-$. A very preliminary mass distribution for this process is shown in Fig. 8. Clear peaks are seen at around 1500 and 1650 MeV. The first peak is consistent with coming from $N^*(1535)(\frac{1}{2}^-)$ and $N^*(1520)(\frac{3}{2}^-)$, and the second from $N^*(1675)(\frac{5}{2}^-)$ and $N^*(1680)(\frac{5}{2}^+)$.

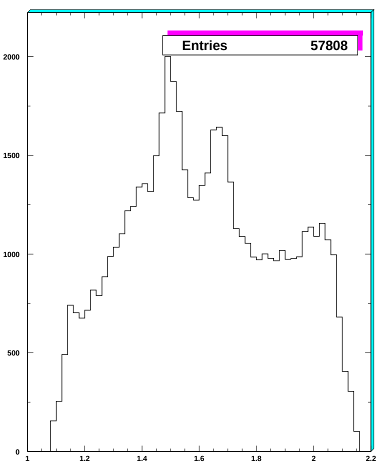

Figure 8: $M_{p\pi^-}$ distribution in $J/\psi \to p\bar{n}\pi^-$. Very preliminary.

5.2 J/ψ Radiative Decays

The Quark model works well in describing most observed states. However, QCD predicts the existence of other types of hadrons with explicit gluonic degrees of freedom – glueballs and hybrids. Radiative J/ψ decays are an excellent place to search for glueballs. BES is currently analyzing $J/\psi \to \gamma\pi^+\pi^-$ and $J/\psi \to \gamma K^+K^-$. A very preliminary $m_{\pi\pi}$ mass distribution for $J/\psi \to \gamma\pi^+\pi^-$ is shown in Fig. 9. A clear $f_2(1270)$ peak is seen, as well as a possible enhancement around 1700 MeV.

A very preliminary m_{KK} mass distribution for $J/\psi \to \gamma K^+K^-$ is shown in Fig. 10. Clear peaks are seen corresponding to the $f_2'(1525)$ and the $f_0(1710)$. The peak region around 1700 MeV is primarily $J^{PC} = 0^{++}$ [12]. Partial wave analyses of these and other mass distributions are underway.

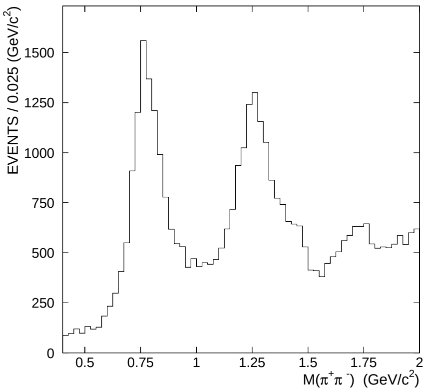

Figure 9: $M_{\pi^+\pi^-}$ distribution for $J/\psi \to \gamma\pi^+\pi^-$. Very preliminary.

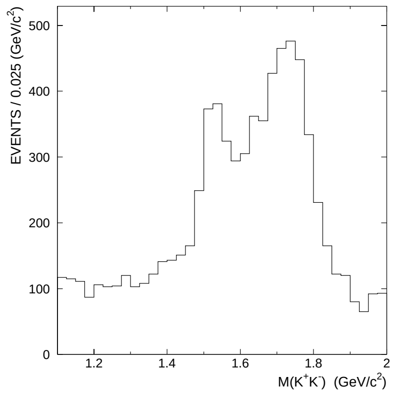

Figure 10: $M_{K^+K^-}$ distribution for $J/\psi \to \gamma K^+K^-$. Very preliminary.

6. Summary

We report the first measurement of $\psi(2S) \to \tau^+\tau^-$ and obtain $B(\psi(2S) \to \tau^+\tau^-) = 2.71 \pm 0.43 \pm 0.55$. Using our combined $\psi(2S)$ and BESI J/ψ samples, we determine the mass and width of the η_c: $M_{\eta_C} = (2975 \pm 3.9 \pm 1.2)$ MeV and $\Gamma\eta_C = (11.0 \pm 8.1 \pm 4.1)$ MeV. We have completed our 50 M J/ψ run and expect to have many new results in the future.

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