R measurement at BES

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By using the upgraded Beijing Spectrometer (BESII), the total cross section for e^+e^- annihilation into hadronic final states at center-of-mass energies between 2 to 5 GeV are measured. Values of R at 2.6, 3.2, 3.4, 3.55, 4.6 and 5.0 GeV are determined, preliminary results for part of the successive points are also presented.

1. INTRODUCTION

The cross section for $e^+e^- \to \gamma^* \to$ hadrons is comparable to that of $e^+e^- \to \mu^+\mu^-$, the lowest order hadronic cross section is then usually parameterized in terms of the ratio R, which is defined as $R = \sigma(e^+e^- \to \text{hadrons})/\sigma(e^+e^- \to \mu^+\mu^-)$. This ratio has been measured by many experiments over the center-of-mass (cm) energy range from the hadron production threshold to the Z pole [1]. The measured R values are, in general, consistent with quark parton model predictions in both the three color degrees of freedom and generations of quarks.

R value measurement is important. The uncertainties of R, especially in the low energy region, limit the precision of the QED running coupling constant evaluated at the mass of the Z boson, $\alpha(M_Z^2)$, which in turn limits the precision of the determination of the Higgs mass from radiative corrections in the Standard Model [2]. Measurements of R, particularly for cm energies below the J/ψ mass, are also required for the interpretation of the muon $(g-2)$ measurement at Brookhaven like the searching of new physics [3]. About 50% and 20% of the error in $\alpha(M_Z^2)$ and $a_\mu = (g-2)/2$, respectively, are due to the uncertainty of the values of R in the 2-5 GeV cm energy region [4].

However, the existing R measurements for cm energies below 5 GeV were performed 17 to 25 years ago [5–10] and have average experimental uncertainties of about 15% [11]. Hence it's necessary to measure the R values in energy reion of 2-5 GeV.

2. DETECTOR

BEPC covers an energy range of 2-5 GeV. The measurements were carried out with the BESII, which is a conventional solenoidal detector that is described in detail in Ref. [12]. Upgrades include the replacement of the central drift chamber with a retired vertex chamber (VC) from MARKIII, which provides a spatial resolution of about 90 μm. The barrel time-of-flight counter (BTOF) was replaced with a new array of 48 plastic scintillators that are read out by fine mesh photomultiplier tubes situated in the 4K Gauss magnetic field volume, providing 180 ps resolution. A new main drift chamber (MDC), similar to the old one, has a momentum resolution of $\sigma_p/p = 1.8\%\sqrt{(1+p^2)}$ for charged tracks with momentum p in GeV. The sampling-type barrel electromagnetic calorimeter (BSC) has an energy resolution of $\sigma_E/E = 21\%/\sqrt{E}$ (E in GeV). The outermost μ chamber has a position resolution of 5.5 cm along z.

3. DATA ANALYSIS

The value of R is determined from the number of observed hadronic events (N_{had}^{obs}) by the relation

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

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; L is the integrated luminosity; δ is the radiative correction; and ε_{had} and ϵ_{trg} represent the detection and trigger efficiency for hadronic events.

3.1. Trigger

Triggers are formed from signals derived from the BTOF, VC, MDC, and BSC, and referenced in time to signals from a beam pickup electrode located upstream of the detector [12]. Event categories are classified according to numbers of charged and neutral tracks seen at the trigger level. Trigger efficiencies for sub-detectors are determined by irrelevant subdetectors with special trigger study runs at J/ψ. Actually, BES has an overall trigger efficiency of more than 99% with the systematic error around 0.5%.

3.2. Luminosity

The integrated luminosity is determined by using large-angle Bhabha events with BSC information only. And the BSC selection efficiency is corrected by a BSC-independent subdetector (*e.g.* MDC) data sample. It reduces the systematic error of the luminosity to 3%.

3.3. Hadronic event selection

To identify the single-photon hadron production, apparent Bhabha events are removed first. A minima energy of $0.28E_{beam}$ is required to reject part of beam gas events. Then, good tracks are selected according to their time-of-flight, vertex position, energy, and momentum to eliminate cosmic rays, beam-gas, and beam-wall events. Two good tracks at least are required. However, two-prong events must be distinguished from cosmic ray and lepton pair events, requiring in addition not be back-to-back and at least two isolated neutral tracks that have more than 100 MeV of energy and are at least $15°$ from the closest charged track in azimuthal angle.

3.4. Background subtraction

Most of the background events are removed during the event selection, such as the cosmic rays, Bhabha, dimuon events and some two-photon process events. τ-pair production events, survived in the hadron sample due to the τ decay to hadrons, are subtracted out statistically by Monte-Carlo simulation. Some beam-gas and beam-wall interactions are, however, residual after the selection. They are subtracted by a scale to the remaining hadronic events in the separated beam data at some energy points.

3.5. Hadronic detection efficiency

The detection efficiency for hadronic events is determined via a Monte Carlo simulation using the JETSET7.4 event generator[13]. Parameters in the generator are tuned [14] using two large hadronic event samples collected at 2.6 and 3.55 GeV respectively. Distributions of multiplicity, sphericity, transverse momentum, etc. for both the real and simulated event samples are compared to get the optimized parameters.

3.6. Initial state radiation

Radiative corrections determined using four different schemes [15–18] agreed with each other to within 1% below charm threshold. Above charm threshold, where resonances are important, the agreement is within $1 \sim 3\%$. The major uncertainties to all models are due to errors in previously measured R-values and in the choice of values for the resonance parameters. For the measurements reported here, we use the formalism of Ref. [17] and include the differences with the other schemes in the systematic error of 2.2-4.1%.

4. RESULTS

The R values obtained at the six energy points taking in 1998 are shown in Table 1 and graphically displayed in Fig. 1. The largest systematic error is due to the hadronic event selection and is determined to be $3.8 - 6.0\%$ by varying the selection criteria. R values from events with greater than two charged tracks agree well with the results shown here. The R values for E_{cm} below 4 GeV are in good agreement with results from $\gamma\gamma 2$ [8] and Pluto [10] but are below those from Mark I [9]. Above 4 GeV, our values are consistent with previous measurements. In Fig. 1 is also shown the preliminary R results for the data points in the continuum region which were taken in 1999, they are consistent with our previous results. The overall results for data in the whole 2-5 GeV energy region will come out in around one year.

Table 1
Summary of R data and values.

E_{cm} (GeV)	N_{had}^{obs}	N_{bg}	L (nb^{-1})	ϵ_{had} (%)	$(1+\delta)$	R	Stat. error	Sys. error
2.60	5617	127	292.9	54.11	1.009	2.64	0.05	0.19
3.20	2051	100	109.3	65.71	1.447	2.21	0.07	0.13
3.40	2149	178	135.3	69.33	1.173	2.38	0.07	0.16
3.55	2672	216	200.2	70.66	1.125	2.23	0.06	0.16
4.60	1497	282	87.7	81.75	1.079	3.58	0.20	0.29
5.00	1648	463	102.3	83.94	1.068	3.47	0.32	0.29

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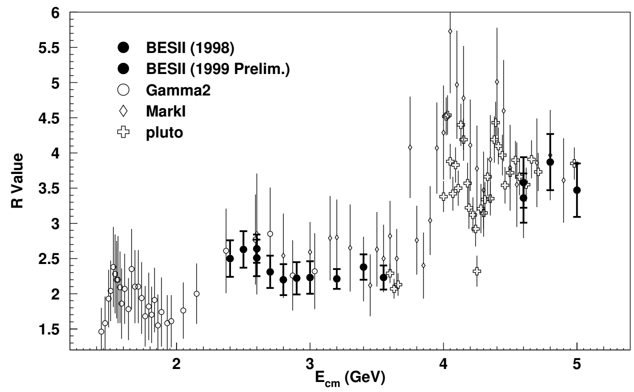

Figure 1. Plot of R values vs E_{cm}.

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