Measurement of R in the energy region of 2-5 GeV with BES-II at BEPC

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The preliminary R values for 85+6 energy points scanned in the energy region of 2-5 GeV with the upgraded Beijing Spectrometer (BESII) at the Beijing Electron Positron Collider (BEPC) are presented. The typical uncertainty on the R values is $\sim 7\%$. The new R values have a significant impact on the predicted mass of the Higgs (m_H) coming from the global fit to the electroweak data, and will also contribute to the interpretation of the E821 $g-2$ experiment.

1 Introduction

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) [1,2]. $\alpha(M_Z^2)$, 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[3]. 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 can be related to R values through a dispersion relation [2]. 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 dominated by the errors of the values of R in the cm energy range below 5 GeV [2], it is crucial to significantly reduce the uncertainties in the R values in the energy region of 2-5 GeV [1,3], which were measured about 20 years ago with a precision of about 15-20%.

2 R scan with BESII at BEPC

Following the first R scan with 6 energy points in the 2.6-5 GeV range done in 1998 [4], 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 scan was done with BESII, a conventional collider detector which has been described in detail in ref. 5.

3 Data Analysis

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_{had}^{obs}) by the relation

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

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; and ϵ_{had} is the detection efficiency for hadronic events.

The hadronic event selection identifies one photon multi-hadron production from all other possible contamination mechanisms. Cosmic rays, lepton pair production, two-photon process and beam associated processes are the backgrounds involved in our measurement. First clear Bhabha events are rejected. Then the hadronic events are selected based on charged track information. Cuts are applied on the vertex, track fit quality, maximum and minimum energy deposition, momentum and time-of-flight in order to select hadronic events. Special attention is paid to two-prong events. Additional cuts are utilized to further reject cosmic ray, Bhabha and beam associated backgrounds [4].

The cosmic rays and part of the lepton pair production events are directly removed by the event selection. The remaining background from lepton pair production and two-photon processes is then subtracted out statistically according to a Monte Carlo simulation.

Most of the beam associated background events are rejected by the vertex cut. The same hadronic event selection criteria are applied to the separated-beam data, and the number of separated-beam events, N_{sep}, surviving these criteria are obtained. The number of the beam associated background events, N_{bg}, in the corresponding hadronic event sample is given by $N_{bg} = f \times N_{sep}$, where f is the ratio of the product of the pressure at the collision region times the integrated beam currents for colliding beam runs and that for the separated beam runs.

The beam associated background can also be subtracted by fitting the event vertex along the beam direction with a Gaussian for real hadronic events and a second degree polynomial for the background as shown in Fig. 1. The difference between R values obtained using these two methods to subtract the beam associated background is about $(0.3 \sim 2.3)\%$, depending on the energy. This difference was taken into account in the systematic uncertainty.

The integrated luminosity is determined by large-angle Bhabha events using only the energies deposited in the BSC. A cross check using only dE/dx information from the MDC to identify electrons was generally consistent with the BSC measurement; the difference was taken into account in the overall systematic error of 1.5-2.6%.

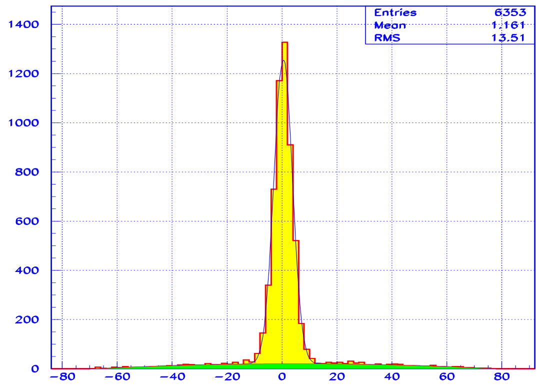

Figure 1: The vertex distribution along the beam axis (z component) of the selected hadronic event sample at the cm energy of 2.6 GeV.

Table 1: Error contributions for E_{cm}=3.0 GeV.

Source	N_{had}	L	ϵ_{had}	$1+\delta$	Stat.	Total
Error(%)	3.3	2.3	3.0	1.3	2.5	5.8

A great effort has been made by the Lund group and the BES collaboration to develop the formalism using the basic Lund Model Area Law directly for a Monte Carlo simulation, which removes the extreme high energy approximation and left-right symmetry in the string fragmentation in JETSET [6]. The final state simulation in LUARLW is exclusive as opposed to JETSET's inclusive method, and LUARLW has only one free parameter in the fragmentation function. Above 3.77 GeV, the production of charmed mesons are included in the generator based on the Eichten Model [7,8].

The parameters in LUARLW are tuned with R scan data to reproduce distributions of kinematic variables such as multiplicity, sphericity, transverse momentum, etc. We find that a single set of parameters can be applied to the energy region below open charm, and another set of parameters can be used for the energies above it. Parameters are also tuned point by point for the continuum region, and we find that the detection efficiencies determined are consistent within 2%, which is taken into account in the systematic errors.

Radiative corrections determined using four different schemes [4] agreed with each other to within 1% below charm threshold. Above charm threshold, where resonances are important, the agreement is within 1-3%. For the measurements reported here, we use the formalism of Ref. 9 and include the differences with the other schemes in the systematic error of less than 4%.

The errors from different sources are listed in Table 1. 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.

The preliminary R values obtained at all 85 energy are shown in Fig. 2, together with the 6 energy points measured in the first scan and those measured by Mark I, $\gamma\gamma2$ 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 previously measurements. The two to three factor improvement in precision of the R values from 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 significantly increased with the new preferred value lying just above the LEP2

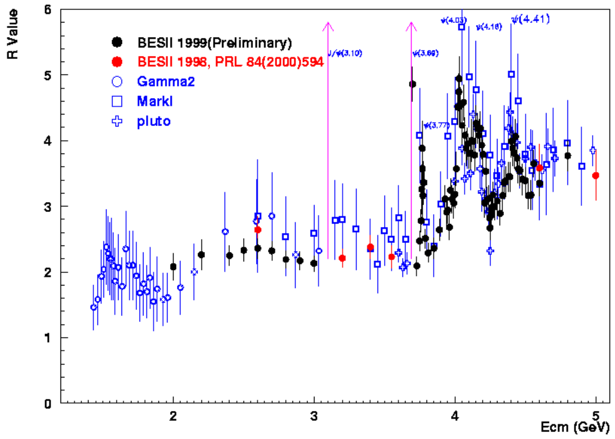

Figure 2: R values below 5 GeV.

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 [3].

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References

1. A. Blondel, Proc. of the 28th Int. Conf. on High Energy Physics, Warsaw, Poland, July 1996.
2. Z. G. Zhao, Proc. of LP99, SLAC, USA, July 1999.
3. Robert Carey, "New Results from g-2 Experiment", talk given at ICHEP2000, Osaka, Japan, July 2000.
4. J. Z. Bai, et. al. the BES collaboration, *Phys. Rev. Lett.* **84**, 594 (2000).
5. J.Z. Bai *et al.*, (BES Collab.), *Nucl. Instrum. Methods* A **344**, 319 (1994); J.Z. Bai *et al.*, (BES Collab.), "The Upgraded Beijing Spectrometer", accepted by NIM.
6. B. Andersson and Haiming Hu, "Few-body States in Lund String Fragmentation Model" hep-ph/9910285.
7. E. Eichten, et.,al., *Phys. Rev.* D **21**, 203 (1980).
8. J.C. Chen, et, al., *Phys. Rev.* D **62**, 034003 (2000).
9. G. Bonneau and F. Martin, *Nucl. Phys.* B **27**, 387 (1971).
10. B. Pietrzyk, "The Global Fit to the Electroweak Data", talk given at ICHEP2000, Osaka, Japan, July 2000.
11. A. Martin, et. al., hep-ph/0008078.