# NEW $R$ VALUES IN 2-5 GEV FROM THE BESII AT BEPC

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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). On average, the uncertainties of the $R$ values we measured are $\sim 7\%$. The new $R$ values has a significant impact on the prodicted mass of the Higgs ($m_H$) from the global fit to the electroweak data, and will also contribute to the interpretation of the E821 $g-2$ experient.

## 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 dadat, is sensitive to the predicted mass of the Higgs. Theoretically, $a_\mu$ 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, $a_\mu^{SM}$, and that from the experimentally measured one, $a_\mu^{Exp}$, may hint new physics. However, the uncertainties in both $\alpha(M_Z^2)$ and $a_\mu^{SM}$ are dominanted by the hadronic vacuum polarization, which cannot be reliably calculated but are related to $R$ values through dispersion relations [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 $a_\mu^{SM}$ 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 measured about 20 years ago with a precision of about 15-20% in the energy region of 2-5 GeV [1,3].

## 2 $R$ scan with BESII at BEPC

Following the first $R$ scan with 6 energy points in 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 $J/\psi$ to determine the trigger efficiency.

The scan was done with BESII, a conventional collider detector which has been described in detail in ref. 5.

## 3 Data Analsis

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

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

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; $\delta$ is the radiative correction; $\epsilon_{had}$ 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. Clear Bhabha events are first rejected. Then the hadronic events are selected based on charged track information. Cuts on fiducial, vertex, track fit quality, maximum and minimum energy deposition, momentum and time-of-flight are applied 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 a 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 polynomial of degree two for the background. 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 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%.

A great effort has been made by the Lund group and 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 in string fragmenation 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 fragmentaion function. Above 3.77 GeV, the production of charmed mesons are included in the generator based on Eichten Model [7,8].

The parameters in LUARLW are tuned with $R$ scan data to reproduce distributions of kinematic variables such as multiplicity, sphericity, angular and momentum distributions, etc.

We find that the same 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 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 differnt sources are listed in table 1.

Table 1. Error Sources for $E_{cm}$=3.0 GeV. Adding the systematic and statistic errors in quadrature gives a total error of 5.8%.

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

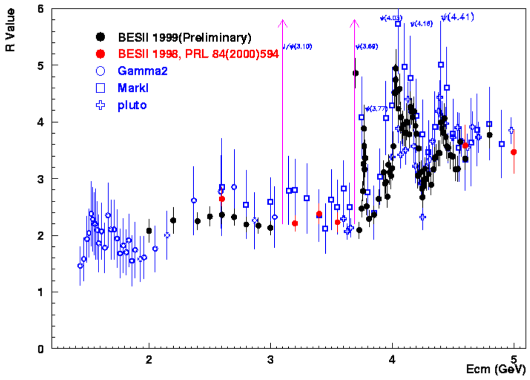


Figure 1. $R$ values below 5 GeV.

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 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 previously 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 $\chi^2$ 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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