Measurement of R Between 2-5 GeV at BES

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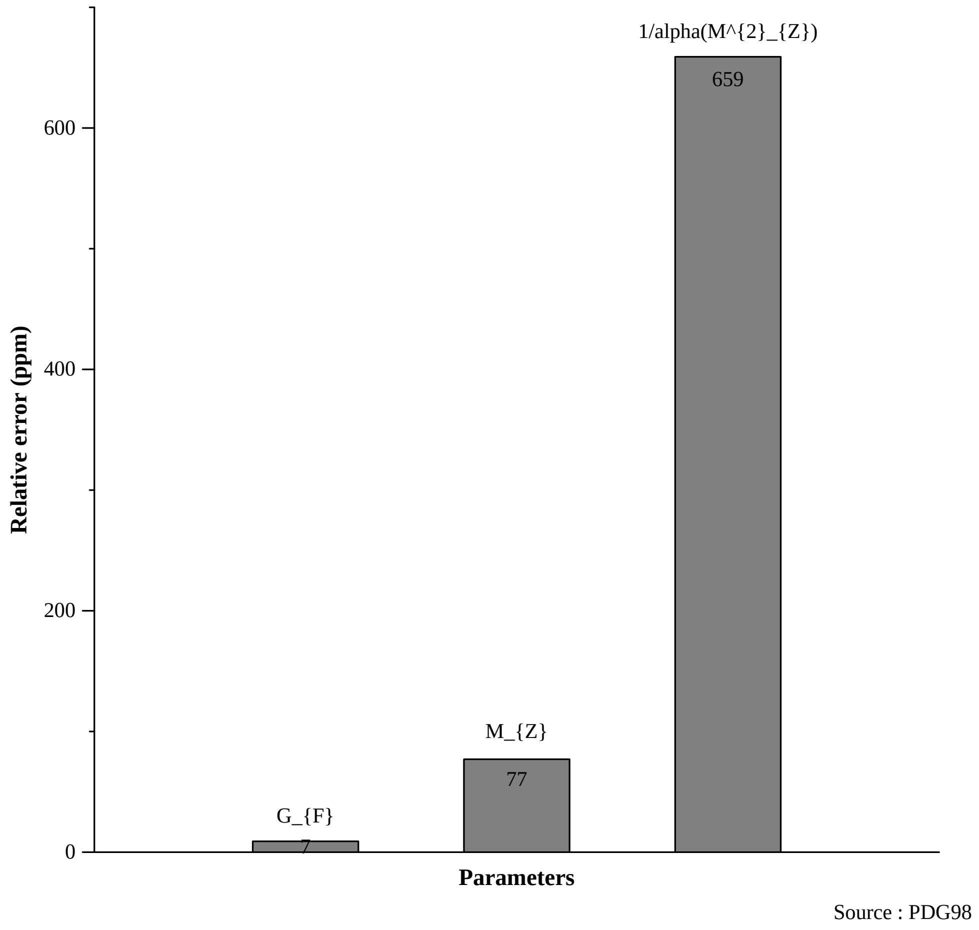
Introduction

"The uncertainty [in $\alpha(M_Z)^{-1}$], due to the low energy hadronic contribution to vacuum polarization, is the dominant theoretical uncertainty in the interpretation of precision data. . . . Further improvement will require better measurements of the cross section for $e^+e^- \to$ hadrons at low energy" — PDG98, page 90.

Motivation

$\alpha(M_Z^2)^{-1}$, along with G_F and M_Z can be used as one of three input parameters to the standard model. However, when comparing uncertainties of the three, the error in $\alpha(M_Z^2)^{-1}$ stands out:



Determination of $\alpha(M_Z^2)^{-1}$

The value of the QED fine structure constant, α, runs as a function of $\sqrt{s}$, and is given by

$$\alpha(s) = \frac{\alpha(0)}{1 + \Pi_{\gamma\gamma}(s)} \quad (1)$$

$$\Delta\alpha(s) = -\Pi_{\gamma\gamma}(s) \quad (2)$$

The evaluation of the $\Delta\alpha$ can be related to a cross section measurement using a dispersion integral along with the optical theorem to give

$$\text{Im } \Pi_{\gamma\gamma}(s) = \frac{\alpha}{3} R_{had}(s) \quad (3)$$

$$\text{Re } \Pi_{\gamma\gamma}(s) = \frac{\alpha s}{3\pi} P \int_{4m_\pi^2}^{\infty} ds' \frac{R_{had}(s')}{s'(s'-s)}, \quad (4)$$

enabling evaluation of $\Delta\alpha(M_Z^2)$ from the measured R (or σ).

BES contribution to (g-2)

g-2 experiment at BNL (E821) will reach precision of $\sigma^{a_\mu}_{expt} = \pm$ 4x10^{-10} (0.35 ppm).

BES will take data in energy range from $E_{cm} =$ 2.0 to 5.0 GeV; potential contribution to a_μ in 2.0 to 3.1 GeV energy range.

Spring 98 Results

Data taken during Spring 98:

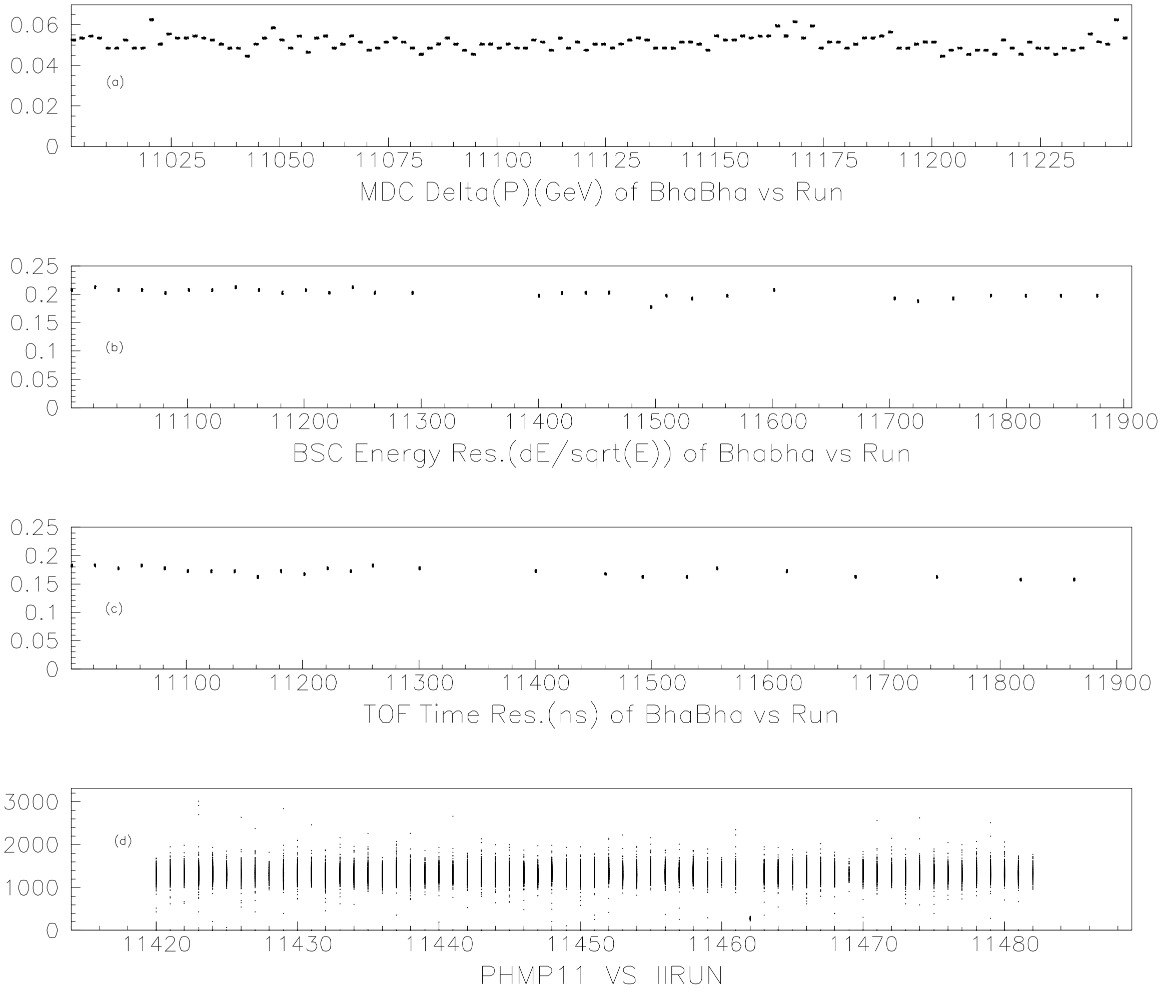
E_{cm}(GeV)	$\mathcal{L}$(nb^{-1})	N_{had}	ϵ_{had}(%)	T (hrs)
2.60	286.4	3836	41.7	162
3.20	106.7	1545	51.0	30
3.40	130.5	1538	55.5	41
3.55	199.7	1891	55.7	44
4.60	80.3	970	72.2	42
5.00	100.9	1148	73.9	53

Experimental Determination of R

$$R \equiv \frac{\sigma^0_{had}}{\sigma^0_{\mu^+\mu^-}} = \frac{N^{obs}_{had} - N^{tot}_{bg}}{\sigma^0_{\mu^+\mu^-} \cdot \epsilon_{had} \cdot \epsilon_{trig} \cdot (1+\delta) \cdot \mathcal{L}} \tag{5}$$

We address each of these factors below, as well as overall BES/BEPC performance and run stability.

Run Stability



Hadronic Event Selection

Basic scheme is to identify and remove clear Bhabha/dimuon/cosmic events, then examine the events to pick out true hadronic events.

General cuts:

- Angular and vertex cuts
- Require reasonable track fit
- Maximum and minimum energy deposition
- TOF and momentum cuts

Background Subtraction

Four sources of background considered:

- Cosmic rays. Removed via TOF, vertex cut, muon ID.
- Beam associated background. Separated/ single beam data taken at 2.6, 3.4, 3.55, 4.6, 5.0 GeV to provide info. Total deposited energy cut removes most.
- Misidentified lepton pairs. Back-to-back cut and rejection of radiative events to remove. MC simulation.
- Misidentified two-photon events. 2γ MC generator.

Hadronic Detection Efficiency

ϵ_{had} is determined using the Lund model: LUND - JETSET74 generator.

Parameters specially tuned for low energy region (with help from T. Sjostrand and B. Andersson) using data at 2.6, 3.55, and 4.6 GeV.

Trigger Efficiency

Efficiencies measured run by run and cross-checked in special runs taken at J/ψ and ψ' to provide independent measurements.

Event type	ϵ_{trig}
Bhabha	99.5%
dimuon	98.2%
hadronic	99.2%

Error in trigger is $\pm$0.5%.

ISR calculations

Initial state radiation calculations performed by H.M. Hu at IHEP.

Four different schemes examined:

- Berends and Kleiss (1981)
- Bonneau and Martin (1971)
- Edwards, et al (Crystal Ball) (1990)
- Kureav and Fadin (1985)/Alexander (1989)

The radiative correction $(1 + \delta)$ calculated by these methods are all consistent to within 1% for off-resonance points, but larger discrepances near peaks. Error conservatively estimated to be 3.5%, but further work hopes to reduce this.

Bonneau and Martin scheme selected.

Summary of R values

Table lists value $\pm$ systematic error for R.

These are **preliminary** numbers.

E_{cm} (GeV)	R
2.6	2.32 ± 0.21
3.2	2.33 ± 0.21
3.4	2.35 ± 0.21
3.55	2.08 ± 0.19
4.6	3.37 ± 0.30
5.0	3.68 ± 0.33

Summary

- R values have been obtained at 6 points (E = 2.6, 3.2, 3.4, 3.55, 4.6, 5.0 GeV).
- Stability/quality of data is acceptable.
- Further refinement of values/errors to bring total error down to 6-7%.
- Additional data will be taken this spring in systematic manner to cover energy range from 2.0 to 5.0 GeV.
- Reduction of error in $\alpha(M_Z^2)^{-1}$ should be signifigant.
- Possible contribution to reduction in error of a_μ^{had}.