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Low energy hadronic contribution to the QED vacuum polarization

H. Burkhardt [a], B. Pietrzyk [b]

[a] *CERN, AB Departement, CH-1211 Geneva 23, Switzerland*

[b] *Laboratoire de Physique des Particules LAPP, IN2P3-CNRS, F-74941 Annecy-le-Vieux Cedex, France*

Abstract

Recent improvements in the low energy e^+e^- annihilation data and their influence on the determination of the hadronic contribution to the running of the QED fine structure constant at m_Z are discussed. Using CMD-2 and KLOE measurements in the ρ region we obtain $\Delta\alpha^{(5)}_{\rm had}(s)$ = 0.02758 $\pm$ 0.00035 at s = m_Z^2.

Email addresses: Helmut.Burkhardt@cern.ch (H. Burkhardt), pietrzyk@lapp.in2p3.fr (B. Pietrzyk).

In the year 2001, we published an updated evaluation of the hadronic contribution to the running of the QED fine structure constant [1], based on a dispersion integral using a parametrization of the measured cross section of $e^+e^- \to$ hadrons. We obtained a hadronic contribution of $\Delta\alpha^{(5)}_{\rm had}(s)$ = 0.02761 $\pm$ 0.00036 at s = m_Z^2.

Our parametrization in the c.m.s. energy region of the ρ, the contribution of the $\pi^+\pi^-$ final state from threshold to 1.8 GeV, was based on a pion form factor parametrization obtained by the CMD-2 Collaboration which used results of their measurements in the c.m.s. energy region between 0.61 and 0.96 GeV at the VEPP-2M collider [2]. The overall uncertainty of the ρ region integral, including the statistical uncertainty, was 2.3% (that of Γ_{ee} in [2]) in our analysis.

Since then, the CMD-2 collaboration improved the treatment of radiative corrections twice. An intermediate improvement has appeared in the published document [3] and an additional improvement has become available in 2004 [4]. We have concluded that the most recent CMD-2 results imply only a small change in the estimate of the hadronic contribution [5].

Recently, the KLOE collaboration [6] has measured the cross section of $e^+e^- \to \pi^+\pi^-$ with high statistical accuracy in small energy bins using the "radiative return" from the ϕ resonance to the ρ in the $\pi^+\pi^-$ mass range between 0.59 and 0.97 GeV.

In our 2001 analysis, we used the parametrization of the pion form factor obtained by the CMD-2 collaboration. The contribution of the new results on $\Delta\alpha^{(5)}_{\rm had}(m_Z^2)$ is now obtained by direct integration between measured data points. For CMD-2 we use the "bare" cross section and for KLOE the pion form factor data. These are quantities, in which the vacuum polarization corrections have been removed. The small ρ contribution from lower and higher energies, not covered by new data, was evaluated as previously using the CMD-2 parametrization of the pion form factor. We treat the systematic uncertainties as fully correlated between different c.m.s. energies within the CMD-2 experiment. For the integration of the KLOE data, we constructed a covariance matrix based on the statistical covariance matrix with the addition of fully correlated systematic uncertainties as provided by the KLOE collaboration.

The results obtained from the integration of the KLOE and CMD-2 data are in good agreement with each other. They are treated as independent measurements and the results after integration are combined in the evaluation of the ρ contribution to $\Delta\alpha^{(5)}_{\rm had}(m_Z^2)$. We obtain a value of the hadronic contribution to the running of the QED fine structure constant of $\Delta\alpha^{(5)}_{\rm had}(s)$ = 0.02758 $\pm$ 0.00035 at s = m_Z^2 corresponding to $1/\alpha^{(5)}(m_Z^2) = 128.940 \pm 0.048$. The value of the ρ contribution has changed from 0.00350 in [1] to 0.00347 and the relative uncertainty has decreased from 2.3% to 0.9%.

For this letter, we adapted our analysis in the ρ region to make the best possible

use of the recent data. This was done by going to a direct integration using as input the many CMD-2 and KLOE data points. This is consistent with what we did previously in other energy regions, when significantly improved data became available. For our previous analysis [1] we moved to a direct integration of the data from BES [7], and already earlier, for our analysis published in [8], we included directly the average R-result with its uncertainty [9] provided by the Crystal Ball Collaboration in the c.m.s. energy region between 5.0 and 7.4 GeV.

The uncertainty quoted by us for the running of the fine structure constant is directly obtained from the experimental uncertainties. We would like to strongly encourage efforts to further clarify and improve the knowledge of the low energy hadronic cross section. In particular, it should be possible to significantly reduce the 15% uncertainty (see Fig. 1) in the 1-2 GeV energy region. Improvements could come from efforts by the experiments to combine all exclusive hadronic channels, further direct measurements or analysis of data with hard initial state radiation from BABAR and BELLE.

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References

[1] H. Burkhardt and B. Pietrzyk, Phys. Lett. **B513** (2001)46.

[2] R.R. Akhmetshin et al., CMD-2 Collaboration, hep-ex/9904027.

[3] R.R. Akhmetshin et al., CMD-2 Collaboration, Phys. Lett. **B527** (2002)161.

[4] R.R. Akhmetshin et al., CMD-2 Collaboration, Phys. Lett. **B578** (2004)285.

[5] B. Pietrzyk and H. Burkhardt, LAPP preprint LAPP-EXP 2003-07.

[6] A. Aloisio et al., Phys. Lett. **B606** (2005)12.

[7] J.Z. Bai et al., BES Collaboration, Phys. Rev. Lett. **88**:101802, 2002.

[8] H. Burkhardt and B. Pietrzyk, Phys. Lett. **B356** (1995) 398.

[9] C. Edwards et al., Crystal Ball Collaboration, SLAC–PUB–5160, Jan.1990.

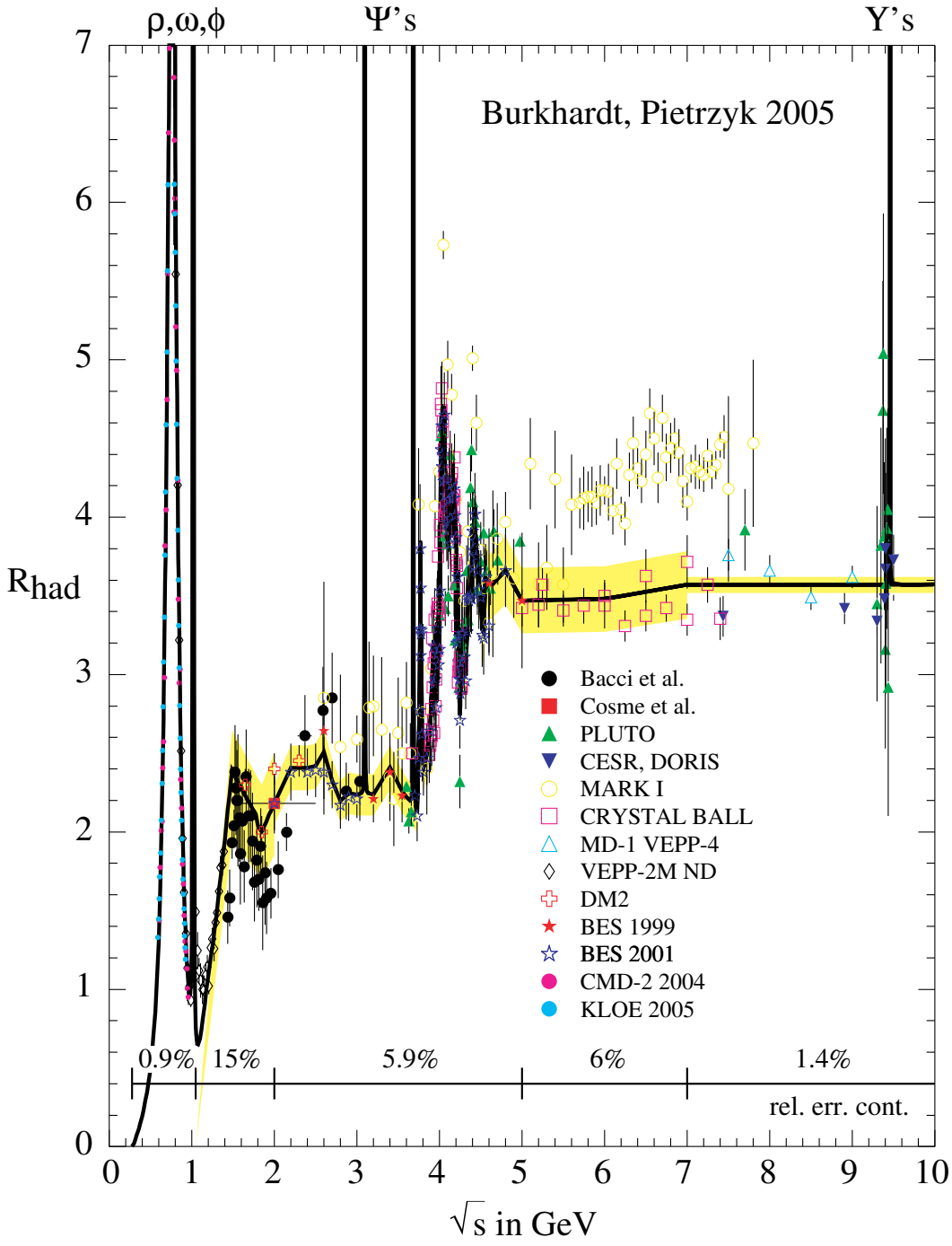

Fig. 1. R_{had} including resonances. Measurements are shown with statistical errors. The relative uncertainty assigned to our parametrization is shown as band and given with numbers at the bottom.