Strong Coupling Constant from the Photon Structure Function

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Abstract

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we compare our results to the fitted F_2^γ data in the region of low x and Q^2. This region is clearly dominated by the hadronic contribution and by the impact of the LEP data. A fit without the LEP data results in a rise of F_2^γ at low x, which is much too steep. The fits are perturbatively stable and the data are described almost equally well in the $\overline{\mathrm{MS}}$ and DIS_γ scheme.

Since the total error on $\alpha_s(m_Z)$ is smaller in the full fit than in the pointlike fit due to the larger number of data points, we adopt as our final result

TABLE I: χ^2/DF and $\alpha_s(m_Z)$ values obtained in LO and NLO in the $\overline{\mathrm{MS}}$ and DIS_γ factorization schemes with a single-parameter fit of the pointlike photon structure function F_2^γ. Also shown are the results obtained without LEP data and with very high Q^2 data.

Scheme	χ^2/DF	$\alpha_s(m_Z)$
LO	7.9/ 19	$0.1260 \pm 0.0055(\mathrm{ex})^{+0.0061}_{-0.0055}(\mathrm{th})$
$\overline{\mathrm{MS}}$	9.1/ 19	$0.1183 \pm 0.0050(\mathrm{ex})^{+0.0029}_{-0.0028}(\mathrm{th})$
DIS_γ	8.1/ 19	$0.1195 \pm 0.0051(\mathrm{ex})^{+0.0031}_{-0.0028}(\mathrm{th})$
w/o LEP	3.2/ 7	$0.1244 \pm 0.0126(\mathrm{ex})^{+0.0033}_{-0.0032}(\mathrm{th})$
high Q^2	11.9/ 8	$0.1159 \pm 0.0125(\mathrm{ex})^{+0.0018}_{-0.0018}(\mathrm{th})$

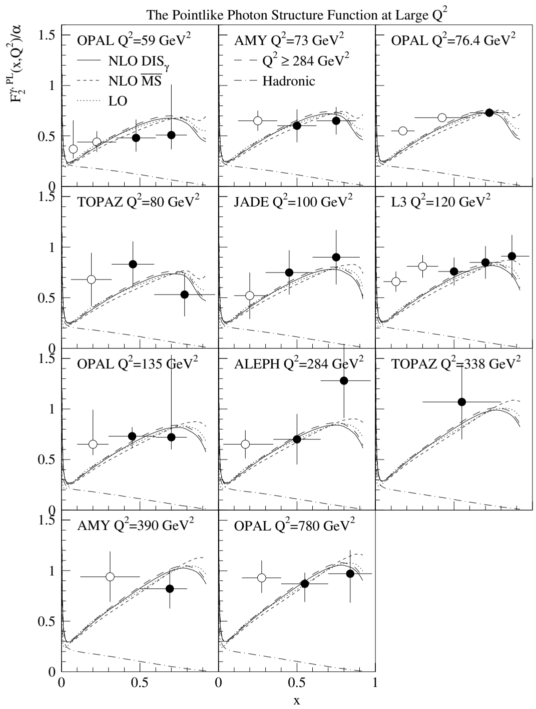

FIG. 1: Single-parameter fits of the pointlike photon structure function, compared to PETRA [26], TRISTAN [29, 31], and LEP [32, 34–36, 38] data at large Q^2. The data points marked by open circles have not been used in the fits. Also shown is the hadronic contribution from a five-parameter NLO fit of the full photon structure function in the DIS_γ scheme.

$$\alpha_s(m_Z) = 0.1198 \pm 0.0054 \tag{1}$$

in NLO and the $\overline{\mathrm{MS}}$ scheme, where the larger theoretical error has been added to the experimental error in quadrature. While our total error is slightly larger than those obtained in Z-boson- and τ-decays at LEP, it is comparable to the errors obtained in deep-inelastic scattering at HERA and heavy quarkonium decays. This encourages us to combine our result with the current world average of 0.1172 ± 0.0014 [1] to a new world average

$$\alpha_s(m_Z) = 0.1175 \pm 0.0014, \tag{2}$$

where the errors are assumed to be uncorrelated.

TABLE II: Q_0, χ^2/DF, and $\alpha_s(m_Z)$ values obtained in LO and NLO in the $\overline{\rm MS}$ and DIS$_\gamma$ factorization schemes with a five-parameter fit of the hadronic photon structure function F_2^γ. Also shown are the results obtained without LEP data.

Scheme	Q_0/GeV	χ^2/DF	$\alpha_s(m_Z)$
LO	0.79 ± 0.18	121/129	$0.1475 \pm 0.0074(\mathrm{ex})^{+0.0141}_{-0.0072}(\mathrm{th})$
$\overline{\rm MS}$	0.83 ± 0.09	118/129	$0.1198 \pm 0.0028(\mathrm{ex})^{+0.0034}_{-0.0046}(\mathrm{th})$
DIS$_\gamma$	0.85 ± 0.09	115/129	$0.1216 \pm 0.0028(\mathrm{ex})^{+0.0033}_{-0.0050}(\mathrm{th})$
w/o LEP	0.46 ± 0.10	37/ 38	$0.1147 \pm 0.0047(\mathrm{ex})^{+0.0282}_{-0.0033}(\mathrm{th})$

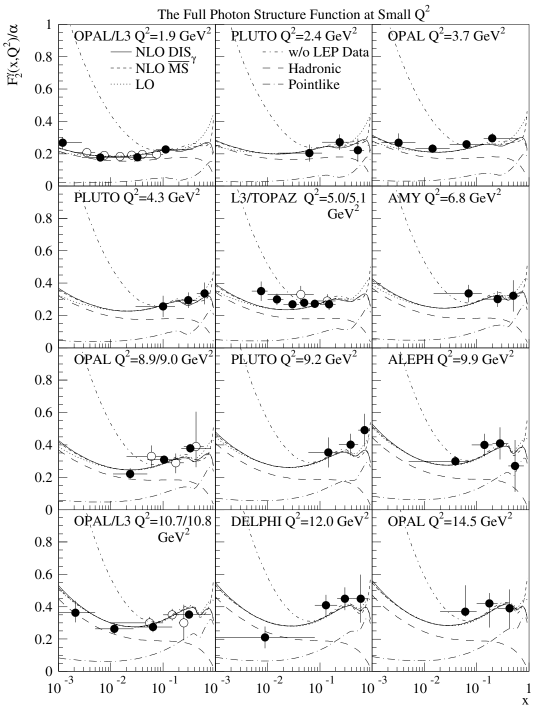

FIG. 2: Five-parameter fits of the full photon structure function, compared to data from PETRA [27], TRISTAN [30, 31], and LEP [32–35, 37] at small Q^2. The data points marked by open circles refer to the second experiment and/or Q^2 value. Also shown are the hadronic and pointlike contributions to the NLO fit in the DIS$_\gamma$ scheme.

In conclusion, we have for the first time fitted the now final PETRA, TRISTAN, and LEP data on the photon structure function F_2^γ in NLO of perturbative QCD. We have extracted the value of the strong coupling constant $\alpha_s(m_Z)$ with competitive experimental and theoretical errors from a single-parameter pointlike fit to data at large x and Q^2 and from a five-parameter full (pointlike and hadronic) fit at all x and Q^2. Our analysis proves that the available F_2^γ data contribute significantly to a precise determination of α_s and that future measurements of F_2^γ at linear colliders will have a large impact.

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