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Measurements of the photon structure function at LEP

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Abstract. In this contribution we discuss recent measurements by the LEP experiments on photon structure functions.

PACS. 13.60.Hb Total and inclusive cross sections (including deep-inelastic processes) – 14.70.Bh Photons – 13.66.Bc Hadron production in e^+e^- interactions

1 Introduction

Photon structure functions are traditionally measured in $e\gamma$ scattering at electron-positron colliders. One of the electrons emits a photon which is almost on mass shell, and which is probed by a photon with virtuality Q^2 emitted by the second electron. The latter electron will be scattered within the acceptance of the detectors, typically for polar angles larger than 25 mrad, while the first electron will go undetected in the beam-pipe, leading to so called single-tag events. For a recent review see [1].

Recent new data include measurements of $F_2^\gamma(x, Q^2)$, where x is the Bjorken-x value of the parton in the photon, from ALEPH and DELPHI; the charm structure function of the photon from OPAL; a first measurement of the electron structure function by DELPHI. New parton density parametrizations have been extracted using the (almost) complete data sets on $F_2^\gamma(x, Q^2)$, and an interesting extraction of α_s has been reported.

2 New ALEPH data on $F_2^\gamma(x, Q^2)$

ALEPH [2] reports a measurement of $F_2^\gamma(x, Q^2)$ based on 584.4 pb^{-1}, in the medium Q^2 range: at 17.3 GeV^2 and 67.3 GeV^2. The Tikhonov unfolding procedure was used to extract the data, and the results are shown in Fig. 1. The data are compatible with earlier measurements, but are more precise. In contrast to the proton, the structure function of the photon is predicted to rise linearly with the logarithm of the momentum transfer Q^2, and to increase with increasing Bjorken-x [3]. The ALEPH data allows to demonstrate the rise of $F_2^\gamma(x, Q^2)$ with increasing Q^2: $F_2^\gamma(0.1 < x < 0.5, < Q^2 >= 17.3\,\mathrm{GeV}^2) = 0.41 \pm 0.01(stat.) \pm 0.08(sys.)$ and $F_2^\gamma(0.1 < x < 0.7, < Q^2 >= 67.2\,\mathrm{GeV}^2) = 0.52 \pm 0.01(stat.) \pm 0.06(sys.)$.

3 New DELPHI data on $F_2^\gamma(x, Q^2)$

DELPHI [4] presents new LEP1 and LEP2 data analyses based on 78 pb^{-1} and 548 pb^{-1} respectively. No unfolding procedure is used but the different cross section components are fitted to the data based on hadronic models. The LEP2 data are shown in Fig. 2. DELPHI chooses to present different $F_2^\gamma(x, Q^2)$ values calculated/corrected with different hadronic models, but do not give a single measurement with a total error including the hadronic uncertainty. Hence it is somewhat difficult to compare these measurements with results from other experiments.

4 OPAL data on $F_{2,charm}^\gamma$

OPAL reported end of last year on a new measurement of the charm content of $F_2^\gamma(x, Q^2)$, namely $F_{2,charm}^\gamma$ [5], which depends directly on the gluon content of the photon. The complete luminosity collected by OPAL during the years 1997-2000 was used, namely 654.1 pb^{-1}. The measurement is made in the Q^2 region of $5 < Q^2 < 100$ GeV^2. The decays $D^{*+} \to D^0\pi^+ \to K^-\pi^+\pi^+$ and charge conjugates, have been used. After selection cuts, exploiting the small mass difference between the D^* and the D decay, 55.3±11.0 signal events are selected. Divided in two bins in x gives 23.6 ± 7.4 events for $x < 0.1$ and 31.4 ± 8.1 events for $x > 0.1$.

Converting the number of events to a structure function measurement and comparing this with QCD calculations, one finds that the high-x region is well described but the low-x data is above the prediction. In the high-x region the charm structure function is dominated by the pointlike part of the cross section. If one subtracts the NLO pointlike part from the low-x data then the resulting measurement of the hadronic part of the cross section for

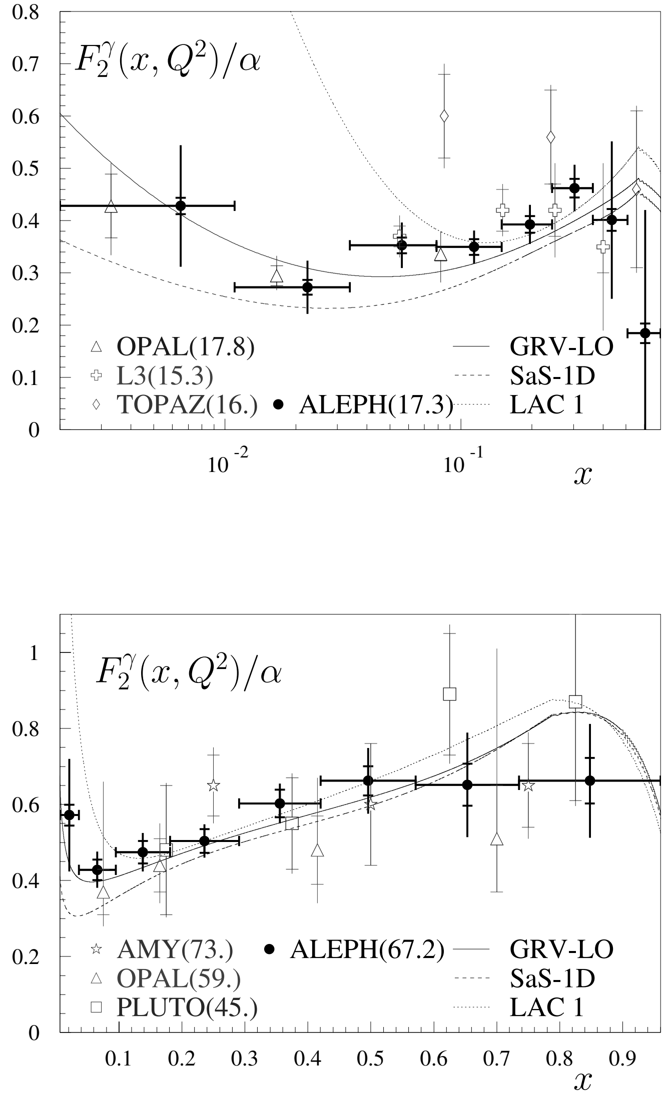

Fig. 1. Values of $F_2^\gamma(x, Q^2)/\alpha$ from ALEPH, compared to previous measurements and predictions of photon PDFs

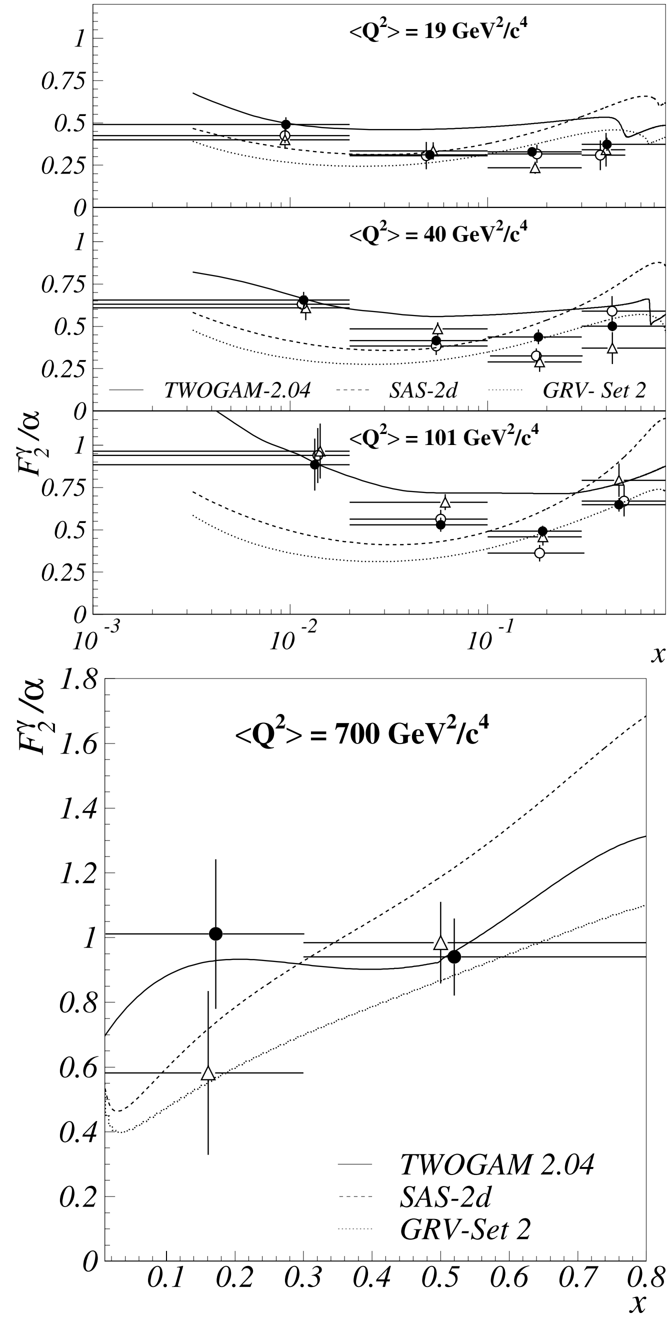

Fig. 2. $F_2^\gamma(x, Q^2)/\alpha$ measurements at different Q^2 values, using LEP2 data. The results are extracted from data using TWOGAM (*black points*), PYTHIA (*open triangles*) and PHOJET(*open circles*) and are compared to model predictions

$0.0014 < x < 0.1$ gives $34.5 \pm 14.3 \pm 69$ pb with a theory prediction of $7.7^{+2.2}_{-1.6}$ pb, i.e. the low-x excess is about 2σ.

A further improvement of this measurement can only be achieved if also the other LEP experiments will have a go at it.

5 Electron structure function

A few years ago it was argued [6] that one could circumvent some of the dominant systematics of present photon structure function measurements, namely the necessity to measure and use the hadronic final state to reconstruct the kinematic variable x, by making a measurement of the electron structure instead. Here the emitted real photon is considered as part of the structure of the electron. The kinematics of the process can be reconstructed from the scattered electron, and no unfolding procedure is necessary. Furthermore no correction due to the small but finite virtuality of the target photon is needed. On the downside the rapid falling photon flux with increasing photon energy is now absorbed in the measurement (instead of being factorized out as for the photon structure function case) and obscures the sensitivity to the QCD dynamics of the photon structure. Furthermore the radiative corrections can become quite large.

DELPHI has presented a first preliminary measurement [7], shown in Fig. 3. The electron structure function

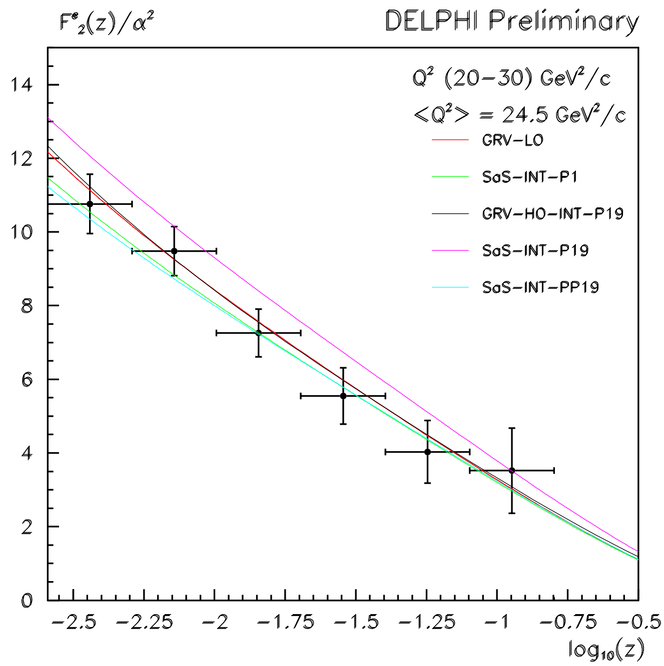

Fig. 3. The electron structure function averaged in the region of Q^2 = 20-30 GeV^2

falls rapidly with increasing z (= the Bjorken-x w.r.t. the electron) as expected. The measurements are consistent with the $F_2^\gamma(x, Q^2)$ results, but within the large error bars no significant increased sensitivity to the underlying dynamics is seen: the predictions of the different models are much closer to each other than in the case of the photon structure function. It constitutes however an important cross check of the photon structure function measurement, and it is noted [7] that the statistical uncertainties on this measurement may be better understood.

6 Summary of the world data

A summary of the world data is shown in Figs. 4 and 5. The first figure shows the data in different Q^2 bins as function of x. It contains in total over 50 measurements in the kinematical range $0.001 < x < 0.9$ and $1.9 < Q^2 < 780$ GeV^2.

In Fig. 5 the data is shown in different x bins as function of Q^2. A fit of the form $F_2^\gamma(x, Q^2) = a + b \ln(Q^2/\Lambda^2)$ gives b values of $0.061 \pm 0.003, 0.095 \pm 0.008$ and 0.135 ± 0.013, for x ranges of $0.01 - 0.1, 0.2 - 0.3$ and $0.4 - 0.6$ respectively, and $\Lambda = 0.2$ GeV. Hence there is a significant increase of the slope with increasing x.

7 Parton distributions and α_s

Using all $F_2^\gamma(x, Q^2)$ data measured at LEP, apart from the new data reported in this paper, recently new parton distributions and an extraction of the strong coupling constant α_s have been reported.

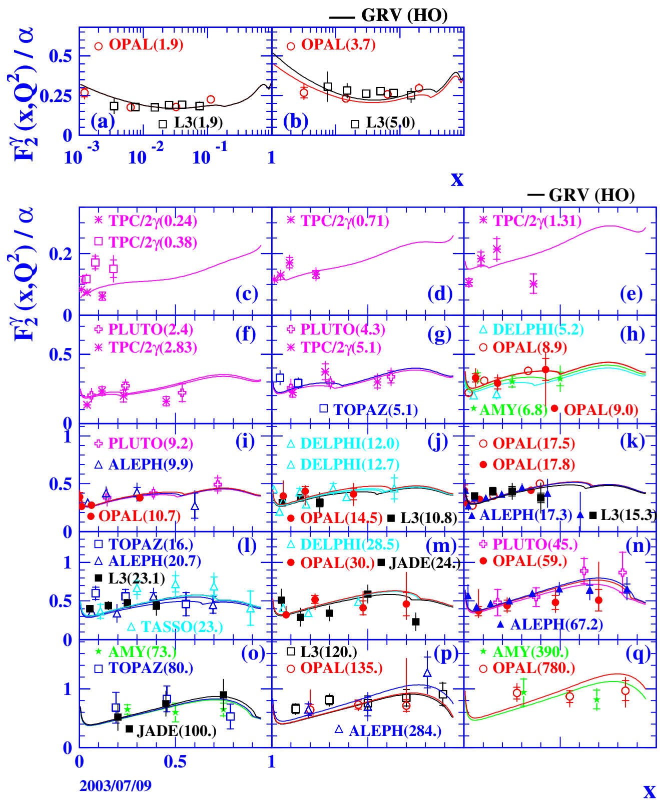

Fig. 4. Summary of measurements of the hadronic structure function $F_2^\gamma(x, Q^2)$, compared with the GRV-HO prediction [1]

LO parton distributions were reported in [8]. These PDFs were radiatively generated, and use the ACOT (and FFNS) heavy flavour scheme. NLO densities are in progress.

Fits to the $F_2^\gamma(x, Q^2)$ data to extract α_s were reported in [9]. Two different extractions have been made. The first uses data with $x > 0.45, Q^2 > 59$ GeV^2, and α_s is fitted directly from its logarithmic asymptotic behaviour. The result (NLO/$\overline{MS}$) is $\alpha_s = 0.1183 \pm 0.0050(exp)^{+0.0029}_{-0.0028}(theo)$. The second fit uses all data but makes a 5 parameter fit, one of which is α_s. The result of this fit is $\alpha_s = 0.1198 \pm 0.0028(exp)^{+0.0034}_{-0.0046}(theo)$. The results are consistent with each other and the precision is interesting in view of the total precision of the world data $\alpha_s = 0.1172 \pm 0.0020$ [10].

8 Outlook and conclusion

In the near future what can we still expect from LEP? OPAL works on a low-x analysis for $F_2^\gamma(x, Q^2)$ and $F_2^e(z, Q^2)$ using the complete statistics; L3 plans an analysis in the full kinematical plane using the complete LEP statistics, and ALEPH may possibly perform an analysis with the full data sample at high Q^2.

On the longer term, an extension of the present kinematic region and improved quality of the data can be expected only at a future linear collider [1] or photon collider [11]. At a photon collider the coverage and precision

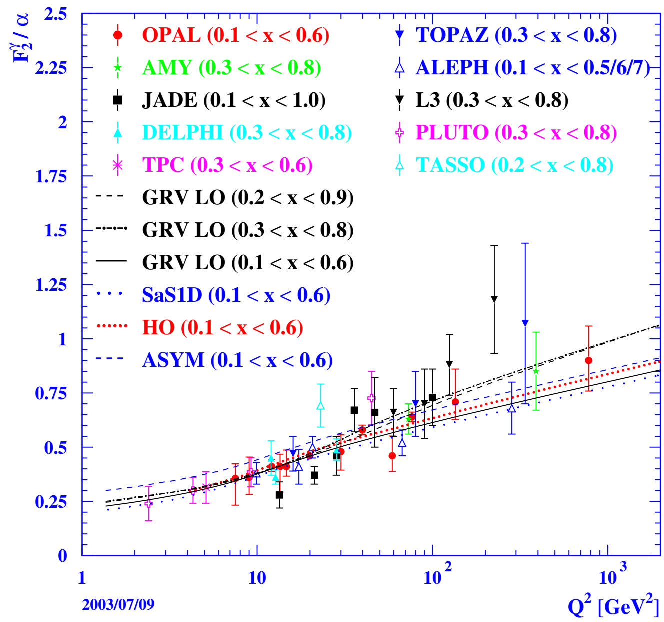

Fig. 5. Measurements of the Q^2 evolution of $F_2^\gamma(x, Q^2)$ compared to a linear fit of the type $a + b\ln(Q^2/\Lambda^2)$ with $\Lambda = 0.2$ GeV (*dashed line*) and the 1σ errors of the fit (*dotted line*). In addition photon PDFs are shown [1]

can be of similar quality as the one of today's proton measurements.

In summary the structure of the photon is now measured in the kinematical range of $0.001 < x < 0.9$ and $1.9 < Q^2 < 780$ GeV^2. The precision has been improving over the years. The charm structure function measurement can become significant if the data of all experiments will be analysed and combined. A first extraction of the electron structure function has been presented.

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References

1. R. Nisius: Phys. Rep. **332**, 165 (2000); updated figures available at: http://www.mppmu.mpg.de/~nisius/welcomeaux/struc.html
2. ALEPH Collab.: Contributed paper to this conf., ID-169
3. T.F. Walsh and P.M. Zerwas: Phys. Lett. B **44**, 196 (1973)
4. DELPHI Collab.: Contributed paper to this conf., ID-645
5. OPAL Collab., G. Abbiendi et al.: Phys. Lett. B **539**, 13 (2002), hep-ex/0206021
6. W. Slominski and J. Szwed: Acta Phys. Polon. **27**, 1887, (1996) hep-ph/9606395
7. T. Szumlak: Proc. of Photon03, Frascati 2003
8. F. Cornet et al.: Phys. Rev. D **68**, 014010 (2003), hep-ph/0212160
9. S. Albino, M. Klasen, and S. Soldner-Rembold: Phys. Rev. Lett. **89**, 122004 (2002), hep-ph/0205069
10. K. Hagiwara et al.: Phys. Rev. D **66**, 010001 (2003)
11. A. De Roeck and A. Vogt: LC-note LC-TH-2001-032