NLO PHOTON PARTON PARAMETRIZATION USING *ee* and *ep* DATA

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Abstract. An NLO photon parton parametrization is presented based on the existing F_2^γ measurements from e^+e^- data and the low-x proton structure function from ep interactions. Also included in the extraction of the NLO parton distribution functions are the dijets data coming from $\gamma p \to j_1 + j_2 + X$. The new parametrization is compared to other available NLO parametrizations.

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INTRODUCTION

A new parametrization of the parton distributions in the photon is extracted in next-to-leading order (NLO) of perturbative QCD. It differs from other NLO parametrizations [1, 2, 3, 4, 5] in that the data used in the fitting procedure include the expected behaviour of F_2^γ at low-x, as derived from F_2^p measurements [6] under Gribov factorization assumption [7], as suggested in [8] and, in addition, the measurements of the dijet photoproduction cross sections [9].

GRIBOV FACTORIZATION

It was suggested [8] that for low Bjorken x ($x < 0.01$) one can use the relation based on Gribov factorization [7], to find a simple relation between F_2^γ and F_2^p. Gribov factorization relates the total $\gamma\gamma$ cross section to those of γp and pp. For low x one can thus obtain

$$F_2^\gamma(x,Q^2) = F_2^p(x,Q^2)\frac{\sigma_{\gamma p}(W)}{\sigma_{pp}(W)}. \tag{1}$$

Here Q^2 is the virtuality of the probing photon and W is the center of mass energy. Using the parameterization of Donnachie and Landshoff [10], which gives a good representation of the data, one obtains at large W

$$F_2^\gamma/\alpha = 0.43 F_2^p, \tag{2}$$

[1] also at Max Planck Institute, Munich, Germany, Alexander von Humboldt Research Award.

where α is the electromagnetic coupling constant. In extracting parton distributions in the photon, this last relation allows the use of the precise F_2^p data to constrain the low-x region, where F_2^γ data are very scarce.

THE PARAMETRIZATION

Our parametrization of the initial parton distributions, defined at $Q_0^2 = 2\,\mathrm{GeV}^2$, aims at describing the experimental data below the charm threshold. Thus we explicitly parametrize only the u,d,s quarks and the gluon. The c,b and t quarks are generated radiatively once their respective thresholds are crossed.

All quark distributions in the photon are parametrized as a sum of point-like and hadron-like contributions,

$$f_q(x) = f_{\bar{q}}(x) = e_q^2 A^{\mathrm{PL}} \frac{x^2 + (1-x)^2}{1 - B^{\mathrm{PL}} \ln(1-x)} + f_q^{\mathrm{HAD}}(x)\,. \tag{3}$$

Apart from the e_q^2 factor, the point-like contribution is the same for all quarks. The hadron-like contribution is assumed to depend on the quark mass only. For u and d quarks we parametrize it as

$$f_u^{\mathrm{HAD}}(x) = f_d^{\mathrm{HAD}}(x) = A^{\mathrm{HAD}} x^{B^{\mathrm{HAD}}} (1-x)^{C^{\mathrm{HAD}}}\,, \tag{4}$$

and for the s quark we fix it to be

$$f_s^{\mathrm{HAD}}(x) = 0.3\, f_d^{\mathrm{HAD}}(x)\,. \tag{5}$$

The gluons in the photon are assumed to have hadron-like behaviour

$$f_G(x) = A_G^{\mathrm{HAD}} x^{B_G^{\mathrm{HAD}}} (1-x)^{C_G^{\mathrm{HAD}}}\,. \tag{6}$$

As there are no data at x close to 1 we fix $C^{\mathrm{HAD}} = 1$ and $C_G^{\mathrm{HAD}} = 3$ as suggested by counting rules [11, 12] based on dimensional arguments. Thus we are left with 6 free parameters.

THE FIT PROCEDURE AND THE DATA

We use the DIS$_\gamma$ scheme to relate F_2^γ to the parton densities. We use the zero mass variable-flavor-number-scheme (VFNS) for the DGLAP evolution of heavy flavor parton distribution functions (pdfs). For the heavy quark contribution to F_2^γ we adopt a phenomenological parametrization as a weighted sum of the Bethe-Heitler and pdf contributions [13]. The weights are defined so as to avoid double counting. The following masses of heavy quarks were used: m_c = 1.5 GeV, m_b = 4.5 GeV and m_t = 174 GeV.

For fitting the parameters we used all published data on the photon structure function F_2^γ, from LEP, PETRA and TRISTAN [14]. We also used the Gribov factorization relation in order to produce F_2^γ 'data' at low x from the proton structure function data measured by ZEUS [6]. In addition the dijet photoproduction measurements were taken from the ZEUS experiment [9]. All in all we used 164 points of F_2^γ measurements coming from e^+e^- reactions, 122 proton structure function data points from ep interactions and 24 points of dijet photoproduction reactions.

RESULTS

The fit to the 286 structure function data points gave a value of 1.06 for the χ^2 per degree of freedom. This increased to 1.63 when the additional 24 dijets points were added. Nevertheless, it had only a minor effect on the overall fit results and their errors. The best fit expectations (denoted as the SAL parametrization), using all the 310 data points, are shown in figure 1, where F_2^γ is plotted as a function of x in bins of Q^2. The

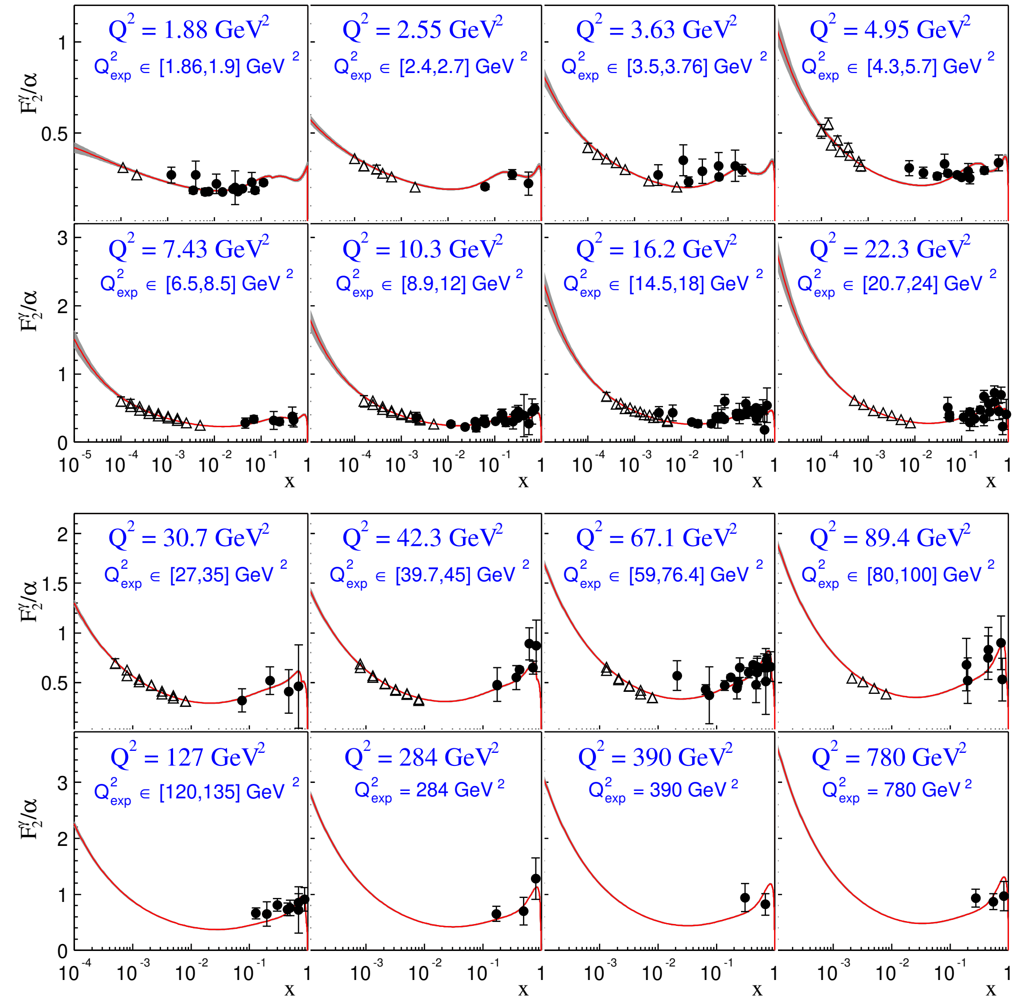

FIGURE 1. The SAL expectations for $F_2^\gamma(x,Q^2)$ as a function of x at selected Q^2 values, as denoted in th figure. The plotted data (dots for F_2^γ measured directly and triangles for F_2^γ deduced from F_2^p) are from the range Q^2_{exp} presented in the figure

real F_2^γ data and the ones deduced from F_2^p are shown with different symbols. Note that wherever available, the two data sets overlap within errors. To limit the number of plots without loss of information, the data are shown within a range of Q^2, while the corresponding curve is calculated for the average Q^2 of that bin. The shaded error band is calculated according to the final error matrix of the fitted parameters as returned by MINUIT. The uncertainty becomes smaller with increasing Q^2, due to the expected loss of sensitivity to the initial pdf parametrization.

The dijet data gave a poor fit and did not help to constrain the photon pdfs. The main reason is that the data are in a kinematical region where the gluons in the proton dominate and thus may need to be adjusted in order to get a better fit.

PARTON DISTRIBUTIONS

The SAL parton distributions in the photon are shown in figure 2. The features to be

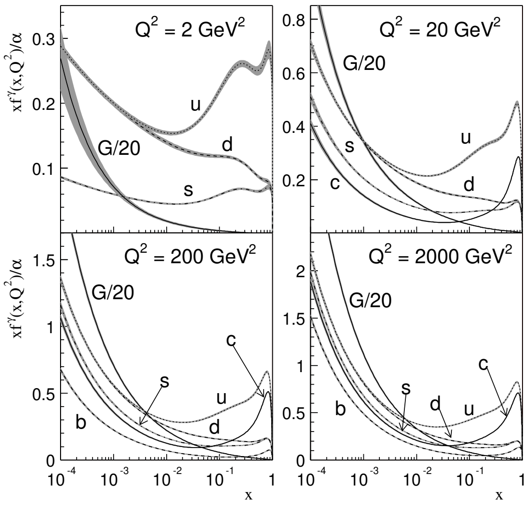

FIGURE 2. Parton distributions in the photon for different values of Q^2, as denoted in the figure.

noted are the behaviour of quarks at large x, typical of the point-like contribution of the photon, and the dominance of the gluon distribution at low x.

The comparison of the SAL pdfs and the other available NLO DIS$_\gamma$ photon parametrizations, GRV [1], GRS[2] [4], and CJK [5], is shown in figure 3 for Q^2 = 2.5 GeV^2. There are big differences between the various pdfs[3]. They are especially pronounced for $x < 10^{-3}$, where no F_2^γ data are available and the result is subject to additional theoretical assumptions. The SAL parametrization has the lowest gluon distribution down to $x \sim 10^{-4}$, below which value we observe a steep rise, steeper than other pdfs. At higher Q^2, where the sensitivity to initial conditions is diminished, there are still noticeable differences [13].

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[2] This parametrization uses Fixed Flavor Number Scheme (FFNS), where only u,d and s pdfs exist.
[3] A non-vanishing b-quark density at Q^2 = 2.5 GeV^2 is a feature of the CJK parametrization.

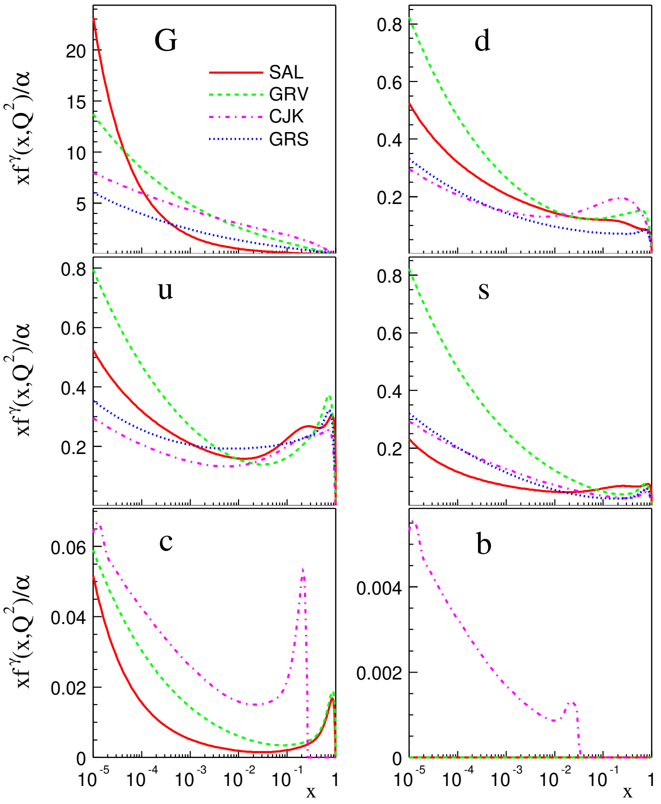

FIGURE 3. Comparison of SAL to other NLO parametrization at Q^2 = 2.5 GeV^2.

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REFERENCES

1. M. Gluck, E. Reya, A. Vogt, *Phys. Rev.* **D45** (1992) 3986, *Phys. Rev.* **D46** (1992) 1973.
2. P. Aurenche, J.-Ph. Guillet, M. Fontannaz, *Zeit. Phys.* **C64** (1994) 621.
3. L.E. Gordon and J.K. Storrow, *Nucl. Phys.* **B489** (1997) 405.
4. M. Gluck, E. Reya and I. Schienbein, *Phys. Rev.* **D60** (1999) 054019; Erratum *Phys. Rev.* **D62** (2000) 019902.
5. F. Cornet, P. Jankowski and M. Krawczyk, *Phys. Rev.* **D70** (2004) 093004.
6. ZEUS Collaboration, *Eur. Phys. J.* **C7** (1999) 609; *Eur. Phys. J.* **C21** (2001) 443.
7. V. N. Gribov, L. Ya. Pomeranchuk, *Phys. Rev. Lett.* **8** (1962) 343.
8. A. Levy, *Phys. Lett.* **B404** (1997) 369.
9. ZEUS Collaboration, *Eur. Phys. J.* **C23** (2002) 615.
10. A. Donnachie and P. Landshoff, *Phys. Lett.* **B296** (1992) 227.
11. R. Blankenbecler and S. J. Brodsky, *Phys. Rev.* **D10** (1974) 2973.
12. G. R. Farrar and D. R. Jackson, *Phys. Rev. Lett.* **35** (1975) 1416.
13. W. Slominski, H. Abramowicz and A. Levy, *NLO photon parton parametrization using ee and ep data*, arXiv:hep-ph/0504003.
14. See e.g. M. Krawczyk, A. Zembrzuski and M. Staszel, *Phys. Rep.* **345** (2001) 265;