NLO PARAMETRIZATION OF PHOTON PARTON DISTRIBUTIONS USING *ee* AND *ep* DATA *

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(Received December 9, 2005)

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.

PACS numbers: 14.70.Bh, 13.60.Hb, 13.66.Bc, 12.38.Bx

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 [1–5] mainly 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]. In addition, the measurements of the dijet photoproduction cross sections [9] are taken into account.

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.

* Presented by W. Slominski at the PHOTON2005 Conference, 31 August–4 September 2005, Warsaw, Poland.

† also at Max Planck Institute, Munich, Germany, Alexander von Humboldt Research Award.

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

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

The hadron-like contribution is assumed to depend on the quark mass only. For u and d quarks we parametrize it as

$$f_u^{\mathrm{HAD}}(x) = f_d^{\mathrm{HAD}}(x) = A^{\mathrm{HAD}} x^{B^{\mathrm{HAD}}} (1-x)^{C^{\mathrm{HAD}}}\,, \tag{2}$$

and for the s quark we fix it to be $f_s^{\mathrm{HAD}}(x) = 0.3\, f_d^{\mathrm{HAD}}(x)$.

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

$$f_G(x) = A_G^{\mathrm{HAD}} x^{B_G^{\mathrm{HAD}}} (1-x)^{C_G^{\mathrm{HAD}}}\,. \tag{3}$$

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 [10,11]. Thus we are left with 6 free parameters.

In order to take into account the heavy quark mass effects we propose a phenomenological approach which smoothly interpolates between the Fixed Flavour Number scheme (FFNS) and the Zero Mass Variable Flavour Number Scheme (ZM-VFNS) results.

In general one can write

$$\frac{1}{x} F_2^\gamma(Q^2) = \sum_{q=d,u,s} e_q^2 \mathcal{F}_q(Q^2) + \sum_h e_h^2\, \mathcal{H}_h(Q^2)\,, \tag{4}$$

where

$$\mathcal{F}_q(Q^2) = 2\left[1 + \frac{\alpha_{\mathrm{s}}(Q^2)}{2\pi}\, C_{F,2}^{(1)}\right] \otimes f_q^\gamma(Q^2) + \frac{\alpha_{\mathrm{s}}(Q^2)}{2\pi}\, C_{G,2}^{(1)} \otimes f_G^\gamma(Q^2)\,. \tag{5}$$

At low Q^2 ($Q^2 \lesssim m_h^2$) there are no heavy quarks in the probed target and a pair of heavy quarks can only be produced in the final state. Here the FFNS applies and $\mathcal{H}_h$ is given by a Bethe–Heitler type cross section [1,2,12], $\mathcal{H}_h^{\mathrm{BH}}$.

At $Q^2 \gg m_h^2$, the correct result is given by ZM-VFNS where the heavy quark masses, m_h, serve only as transition scales. When Q^2 crosses the value of m_h^2, the number of flavours entering the evolution equations, N_{f}, changes by one. This affects the Q^2 dependence of $\alpha_{\mathrm{s}}(Q^2)$ but apart from that, $\mathcal{H}_h$ is given by the same formula as for the light quarks, *i.e.* $\mathcal{H}_h \approx \mathcal{H}_h^{\mathrm{as}} \equiv \mathcal{F}_h$.

At the intermediate values of Q^2 we construct the heavy quark contribution to F_2^γ as a weighted sum of FFNS and ZM-VFNS expressions with a Q^2-dependent weight, $\mathcal{S}_{\mathrm{ev}}$,

$$\mathcal{H}_h(Q^2) = \left[1 - \mathcal{S}_{\mathrm{ev}}(m_h^2, Q^2)\right] \mathcal{H}_h^{\mathrm{BH}}(Q^2) + \mathcal{S}_{\mathrm{ev}}(m_h^2, Q^2) \mathcal{H}_h^{\mathrm{as}}(Q^2)\,. \tag{6}$$

Intuitively, $\mathcal{S}_{\rm ev}$ quantifies the amount of evolution and is taken to be proportional to the QCD evolution scale [13].

Let us now discuss briefly the experimental data used for fitting the parameters. First, we used all published data on the photon structure function F_2^γ, from LEP, PETRA and TRISTAN [15]. As the F_2^γ data at low x are very scarce, we deduce them from a relation between F_2^γ and F_2^p obtained in [8]. The claim, based on the Gribov factorization [7], is that at low x

$$F_2^\gamma(x,Q^2) = F_2^p(x,Q^2)\frac{\sigma_{\gamma p}(W)}{\sigma_{pp}(W)}. \tag{7}$$

Using the parametrization of Donnachie and Landshoff [14], which gives a good representation of the data, one obtains at large W

$$F_2^\gamma/\alpha_{\rm em} = 0.43 F_2^p\,. \tag{8}$$

This relation allows us to constrain F_2^γ at low-x by using the precise F_2^p data measured by ZEUS [6].

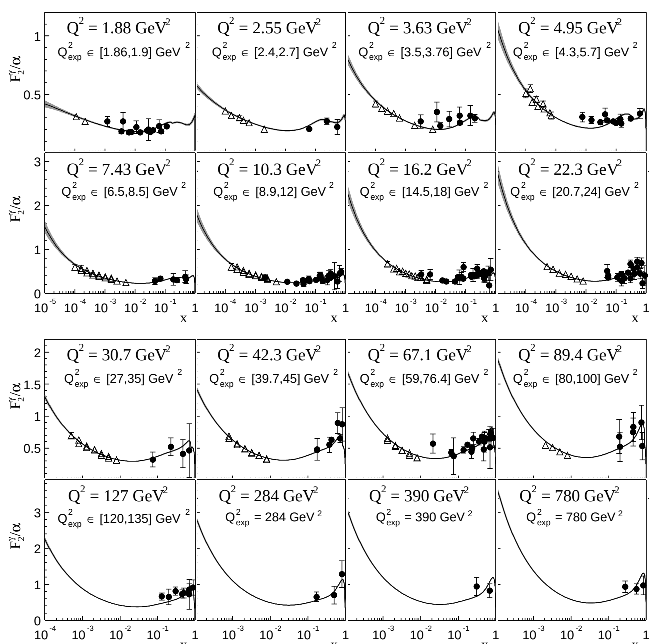

Fig. 1. The SAL expectations for $F_2^\gamma(x,Q^2)$ as a function of x at selected Q^2 values, as denoted in the figure. The plotted data (dots for F_2^γ measured directly and triangles for F_2^γ deduced from F_2^p) are within the $Q^2_{\rm exp}$ range shown in the figure

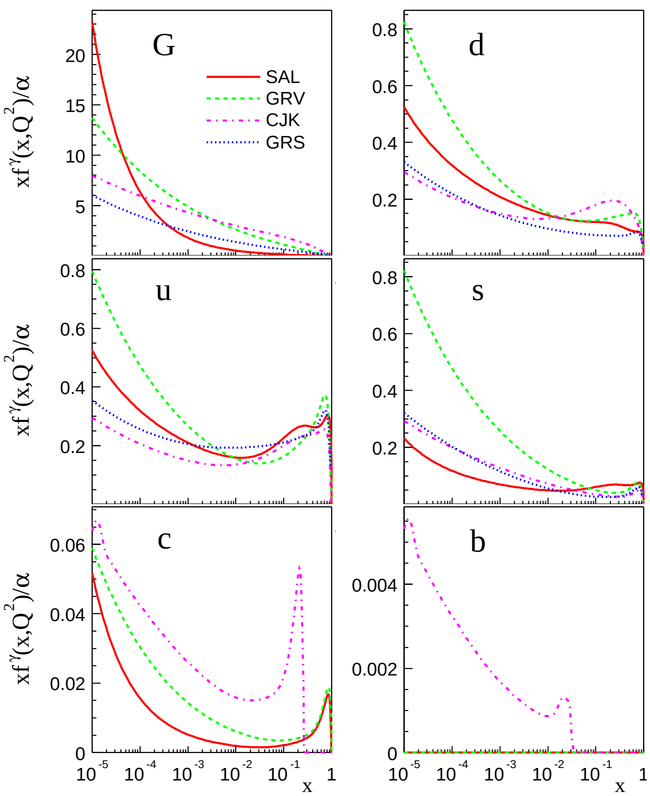

Fig. 2. Comparison of SAL to other NLO parametrization at $Q^2 = 2.5$ GeV^2.

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 data points from ep interactions and 24 points of dijet photoproduction reactions.

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 Fig. 1, where F_2^γ is plotted as a function of x in bins of Q^2. The 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 parametrization.

The dijet data gave a poor fit and did not help to constrain the gluon content of the photon. The main reason is that the data are in a kinematical region where the sensitivity to gluons in the proton is much higher than to the gluons in the photon.

The comparison of the SAL parton distributions with the other available NLO DIS$_\gamma$ photon parametrizations, GRV [1], GRS[1] [4], and CJK [5], is shown in Fig. 2 for $Q^2 = 2.5$ GeV^2. There are big differences between the various parametrizations. 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 in the other parametrizations.

In Fig. 3 we compare the SAL parametrization to the recent L3 data [16], which were not used in our fit. We get a very good agreement, especially at lower x values.

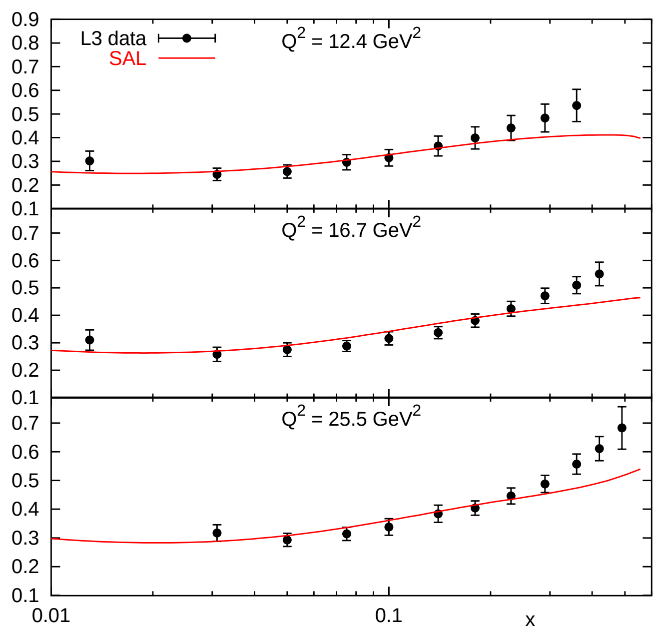

Fig. 3. Comparison of SAL to the recent measurement [16] of $F_2^\gamma/\alpha_{\rm em}$.

This work was supported in part by the Israel Science Foundation (ISF).

[1] This parametrization uses FFNS, where only u, d and s partons exist.

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