QCD ANALYSIS OF STRUCTURE FUNCTIONS OF REAL
AND VIRTUAL PHOTONS

I. Schienbein

Institut für Physik, Universität Dortmund
D-44221 Dortmund, Germany
E-mail: schien@hal1.physik.uni-dortmund.de

Parameter–free and perturbatively stable leading order (LO) and next–to–leading
order (NLO) parton densities for real and virtual photons are presented.

1 Introduction

The hadronic structure of real and virtual photons can be measured in electron
positron scattering processes in which one lepton serves as a source of target
photons with virtuality $P^2 << Q^2$ where $Q^2$ is the virtuality of the probing
photon. The measured $e^+ e^−$ cross section can then be obtained by a convo-
lution of a flux of target photons with the deep inelastic electron (positron)
photon scattering cross section which is (completely analogous to the case of
deep inelastic electron proton scattering) described by two structure functions
$F_{2,L}$. In the QCD improved parton model the photon structure funct ions
$F_{\gamma L}(P^2)(x,Q^2)$ are given by a convolution of non-perturbative parton densities
of the (real or virtual) photon with appropriate perturbatively calculable short
distance coefficient functions. The photonic parton distributions are governed
by inhomogenous evolution equations which have to be supplemented with
appropriate boundary conditions.

Here we briefly describe recently proposed parameter–free leading order
(LO) and next–to–leading order (NLO) boundary conditions for real and virtual photons.

2 Boundary Conditions

The boundary conditions are given in the DIS$_\gamma$ scheme at a low resolution scale
$Q^2_0 \approx 0.3$ GeV$^2$. The exact LO and NLO values of the universal (i. e. hadron–
independent) input scale $Q_0$ are fixed by the experimentally well constrained
radiative parton densities of the proton.$^3$

$^3$Talk given at the DIS-2000 conference, Liverpool, 25-30 April 2000
2.1 Real Photon

The boundary conditions for the real photon \( \gamma \) are given by a vector meson dominance (VMD) ansatz where (at the low scale \( Q_0 \)) the physical photon is assumed to be a coherent superposition of vector mesons which have the same quantum numbers as the photon

\[
\gamma(x, Q_0^2) = \gamma_{\text{had}}(x, Q_0^2) = \alpha G^2 f_{\gamma}^0(x, Q_0^2)
\]

with \( G_{u,d}^2 = (g_\rho \pm g_\omega)^2 \) and \( G_g^2 = G_\rho^2 + G_\omega^2 \) \((g_\rho = 0.50, g_\omega = 0.043)\). This optimal coherence maximally enhances the up quark which is favoured by the experimental data.

Since parton distributions of vector mesons \((\rho, \omega, \ldots)\) are experimentally undetermined, we furthermore assume that these are similar to pionic parton distributions. Thus, for given pionic parton distributions our model has no free parameter.

2.2 Pion

Since only the pionic valence density is experimentally rather well known, we utilize a constituent quark model to relate the pionic light sea and gluon to the much better known parton distributions of the proton. In Mellin-\( n \)-space one easily finds the following boundary conditions for the pion distribution functions

\[
g^\pi(n, Q_0^2) = \frac{v^\pi}{v^p} g^p, \quad q^\pi(n, Q_0^2) = \frac{v^\pi}{v^p} q^p,
\]

which only depend on the rather well determined valence distribution of the pion and the parton distributions of the proton.

2.3 Virtual Photon

In the virtual photon case we propose the following boundary conditions which of course smoothly extrapolate to the real photon case \((P^2 \to 0)\):

\[
f_{\gamma}(P^2) = f_{\gamma}(\tilde{P}^2) = \eta(P^2) f_{\gamma}(x, \tilde{P}^2).
\]

The employed dipole suppression factor (rho-meson propagator) \( \eta(P^2) = (1 + P^2 / m_\rho^2)^{-2} \) is somewhat speculative and can be regarded as the simplest choice of modelling the \( P^2 \)-suppression.
3 Numerical results

The presented model successfully describes LEP data on the photon structure function $F_2^\gamma$ and H1 dijet data. For details see Ref. 1 and references therein. As an example, in Fig. 1 the evolution of $F_2$ with $Q^2$ is shown for two different $x$-bins. Also shown are the GRV$_\gamma$ predictions 6. For $0.1 < x < 0.6$ all curves are close together because this $x$-range is already dominated by the point-like solution, whereas for $0.01 < x < 0.1$ our results are larger at small values of $Q^2$ and evolve weaker with $Q^2$ due to the different boundary conditions.

Acknowledgments

Supported in part by the Graduiertenkolleg 'Erzeugung und Zerfälle von Elementarteilchen' of the Deutsche Forschungsgemeinschaft at the Universität Dortmund and by the Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie, Bonn.

References

1. M. Glück, E. Reya, and I. Schienbein, Phys. Rev. D 60, 054019 (1999).
2. M. Glück, E. Reya, and A. Vogt, Eur. Phys. J. C 5, 461 (1998).
3. G. Altarelli, N. Cabibbo, L. Maiani, and R. Petronzio, Nucl. Phys. B 69, 531 (1974).
4. M. Glück, E. Reya, M. Stratmann, Eur. Phys. J. C 2, 159 (1998).
5. M. Glück, E. Reya, I. Schienbein, Eur. Phys. J. C 10, 313 (1999).
6. M. Glück, E. Reya, and A. Vogt, Phys. Rev. D 45, 3986 (1992); ibid. D 46, 1973 (1992).