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Deeply virtual Compton scattering at small x_B and the access to the GPD H

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Abstract

We give a partonic interpretation for the deeply virtual Compton scattering (DVCS) measurements of the H1 and ZEUS Collaborations in the small-x_B region in terms of generalized parton distributions. Thereby we have a closer look at the skewness effect, parameterization of the t-dependence, revealing the chromomagnetic pomeron, and at a model-dependent access to the anomalous gravitomagnetic moment of nucleon. We also quantify the reparameterization of generalized parton distributions resulting from the inclusion of radiative corrections up to next-to-next-to-leading order. Beyond the leading order approximation, our findings are compatible with a 'holographic' principle that would arise from a (broken) SO(2, 1) symmetry. Utilizing our leading-order findings, we also perform a first model-dependent "dispersion relation" fit of HERMES and JLAB DVCS measurements. From that we extract the generalized parton distribution H on its cross-over line and predict the beam charge-spin asymmetry, measurable at COMPASS.

Keywords: Deeply virtual Compton scattering; Generalized parton distributions

1. Introduction

The electron/positron–proton collider experiments H1 and ZEUS at the HERA ring in DESY improved not only the quantitative understanding of inclusive processes, e.g., by pinning down the small-x behavior of parton distribution functions (PDFs) [1,2], but also led to new insights into the proton structure. Two decades ago, it was mostly unforeseen that at high energies the

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deep inelastic scattering (DIS) cross section steeply rises, that the proton remains intact in almost one third of all scattering events, and that even exclusive processes become measurable, contributing considerably to the total cross section. The reader may find comprehensive reviews in Refs. [3–5].

These exclusive processes, e.g., the electro- or photo-production of a vector meson or a photon, were extensively studied in the small-x_{B} kinematics by the H1 and ZEUS Collaborations [6–26]. The amplitude of the subprocesses,

$$\gamma^{(*)}(q_1)p(P_1) \to V(q_2)p(P_2), \quad V = \gamma, \rho, \omega, \phi, J/\Psi, \Upsilon, \tag{1}$$

is necessarily dominated by t-channel exchanges that carry the quantum numbers of the vacuum. The large amount of HERA data calls for a phenomenological description and it challenges the theoretical understanding of the nucleon in terms of its partonic substructure. Needless to say, a quantitative understanding of the parton dynamics will be crucial at the frontier of exploration of the structure of matter at LHC [27,28]. In this context, it is worth noting that exclusive Higgs production via gluon fusion is a rather clean channel [29,30]; however, for cross section estimates the gluonic content of the proton must be quantified.

One might have hoped to master the phenomenology of such exclusive processes in the framework of Regge theory. Unfortunately, for an 'incoming' virtual photon S-matrix theory is not applicable. Thus, Regge theory loses the theoretical foundation and might possibly be replaced by a pragmatic Regge phenomenology [31]. Consequently, firm conclusions valid for *on-shell* scattering, like the one that unitarity requires that the rightmost singularity in the complex angular momentum plane belongs to a $J = 1$ exchange, might not be appropriate for *off-shell* processes. In fact, one of the lessons of H1/ZEUS experiments is that cross sections, *effectively* parameterized as

$$\frac{d\sigma^{\gamma^* p \to V p}}{dt} \propto \left(\frac{W^2}{W_0^2}\right)^{2(\alpha(t)-1)}, \quad W^2 = (P_1 + q_1)^2, \tag{2}$$

rise steeply, contrarily to what is implied by the pomeron ($J = 1$) trajectory

$$\alpha_{\mathbb{P}}(t) = 1 + 0.25t/\mathrm{GeV}^2. \tag{3}$$

In addition, the *effective trajectory* $\alpha(t)$ varies with the photon virtuality $Q^2 = -q_1^2$. The corresponding *effective Regge pole* in the complex angular momentum plane might also be understood as a convenient implementation of cuts.

Inspired by QCD, a phenomenological description of cross sections at small x_{B} has been achieved in terms of the color dipole model [32,33], making direct contact to the high energy approximation (BFKL) of scattering amplitudes [34,35]. The physical picture might be set up in the rest frame of the proton in which the highly energetic virtual photon fluctuates into a quark–antiquark pair. The quark–antiquark pair forms a small color dipole, spatially distributed in transverse direction, that interacts with the proton by a gluonic exchange. Finally, the quark–antiquark pair forms a meson or annihilates into a photon. The physical amplitude is given as convolution (with respect to longitudinal momentum fraction and transverse separation) of the color dipole spectral function (cross section) with the corresponding wave functions, describing the transition of the initial photon into a quark–antiquark pair or the quark–antiquark pair into the final state.

A perturbative QCD framework, applicable for longitudinally polarized photons, is founded on factorization theorems [36]. Here, in setting up the partonic space–time picture, one may