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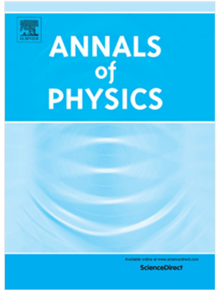

One-loop corrections to light cone wave functions: The dipole picture DIS cross section

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One-loop corrections to light cone wave functions: the dipole picture DIS cross section

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We develop methods needed to perform loop calculations in light cone perturbation theory using a helicity basis, refining the method introduced in our earlier work. In particular this includes implementing a consistent way to contract the four-dimensional tensor structures from the helicity vectors with d-dimensional tensors arising from loop integrals, in a way that can be fully automatized. We demonstrate this explicitly by calculating the one-loop correction to the virtual photon to quark-antiquark dipole light cone wave function. This allows us to calculate the deep inelastic scattering cross section in the dipole formalism to next-to-leading order accuracy. Our results, obtained using the four dimensional helicity scheme, agree with the recent calculation by Beuf using conventional dimensional regularization, confirming the regularization scheme independence of this cross section.

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I. INTRODUCTION

Light cone perturbation theory (LCPT), the Hamiltonian formulation of field theory on the light front [1–4] is a widely used calculational tool in particle and hadronic physics. Its added calculational complexity compared to covariant perturbation theory is balanced by several advantages in the description of bound states or other multiparton systems. The light cone wave functions (LCWF's) and operators have a simpler behavior under transverse Lorentz boosts than covariant ones. The perturbative expansion is organized in terms of a Fock state expansions involving only physical degrees of freedom with definite helicities. This gives a natural physical interpretation for the factorization of scattering processes into the properties of the incoming and outgoing hadronic states on one hand, and the short distance partonic scatterings between elementary constituents on the other.

Modern hadronic and nuclear scattering experiments probe QCD with increasing accuracy in the high energy or small-x regime. Here the large available phase space for gluon radiation enables the generation of a dense system of gluons with nonperturbatively large gluon fields. One the other hand, balancing the complication arising from the nonlinear dynamics of the gluons, the high collision energy simplifies the treatment of the scattering by allowing an eikonal approximation for the interactions of individual partons with the color field. Typically this situation is described using the effective theory of QCD known as the Color Glass Condensate (CGC) [5]. In this picture, the scattering of a dilute probe off the dense color field is factorized into the partonic structure of the "simple" probe (virtual photon, or an individual quark or gluon in the case of forward rapidities in proton-nucleus collisions), and the eikonal scattering of the partons of the probe with the target color field. This allows for a treatment that includes nonlinear interactions in the dense target color field to all orders, while the simple probe can be treated exactly. This picture is advantageous in particular for understanding exclusive processes. Light cone perturbation theory is the method of choice for understanding the structure of the probe.

In order to develop a more quantitative description of several scattering processes in the high energy limit, CGC calculations have recently been advancing to next-to-leading order (NLO) accuracy for several different processes. The NLO corrections to the small-x evolution equations (in particular the Balitsky-Kovchegov (BK) equation [6–8]) have been derived and the required resummations of collinear logarithms studied in several papers [9–19]. There have been several caluclations of single [20–25] and double [26] inclusive parton production at forward rapidity in high energy proton-nucleus collisions. In the context of deep inelastic scattering, both inclusive [27–31] and exclusive [32–34] processes have been studied at the NLO order.

Our present paper is a follow-up of our recent work [35], where we introduced the idea of performing loop calculations in LCPT using a helicity basis for the elementary vertices. In this paper we will present a better formulation of the calculational scheme introduced in [35], correcting a partially incorrect formulation used in that paper. As a demonstration, we will calculate the one-loop correction to the virtual photon to quark-antiquark dipole light cone wave function. We will then use this to derive the NLO cross section for inclusive DIS in the dipole factorization picture. We perform the calculation using the four-dimensional helicity (FDH) scheme, where polarization sums are calculated in four dimensions, and ultraviolet divergences are regularized by performing momentum integrals in d dimensions. Our results recover the ones obtained in [29, 30] after a lengthy manual calculation, in what we would argue to be a more systematical and economical way. Also, although intermediate results are different in the FDH scheme used here and the conventional dimensional regularization (CDR) used in [29, 30], we see that these scheme