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Valence Quarks Distributions at Small-x and Saturation

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This presentation is based on work done in collaboration with K. Itakura, L. McLerran and D. Teaney [1].

The purpose of this work is to study the effect of gluon saturation on the valence quark distributions in hadrons and nuclei. Similar issues have been extensively studied in the recent years for the case of gluon distribution functions.

We begin by constructing the lowest order soft valence quark light cone wave function in a single proton or nucleus (see p. 3 of the presentation). This wave function is different from the corresponding soft gluon wave function by an overall factor of $z/2$ with z the momentum fraction of the proton carried by the particle in question (valence quark or gluon). We proceed by including into the wave function the effects of multiple rescatterings of the valence quark on other nucleons in the nucleus, calculated in the framework of McLerran-Venugopalan model (pp. 4,5). The resulting expression shown on p. 5 is different from the corresponding expression for soft gluons only by the same factor of $z/2$ and by the color factor C_F/N_c in the definition of the quark saturation scale $Q_s^{quark\,2}$. The valence quark distribution is infrared safe as shown on p. 6.

To include the effects of small-x quantum evolution in the soft valence quark distribution function we need to go to the specific scattering process of deep inelastic scattering (DIS). In the rest frame of the target all the QCD dynamics is included in the forward amplitude of a $q\bar{q}$ dipole scattering on the nucleus. Inclusion of multiple rescattering in this quantity is discussed on p. 7. The linear evolution for the flavor non-singlet distribution function as originally constructed by Kirschner and Lipatov is shown on p. 8. The peculiar property of the quark ladder is that the leading order Reggeon intercept is given by the double logarithmic approximation (DLA) and is proportional to $\sqrt{\alpha_s}$. On p. 9 we show which diagrams in conventional language we want to resum: we want to "dress" the quark ladder by gluon fan diagrams connecting to it. The evolution equation summing these ladders for the Reggeon amplitude R is constructed in the framework of Mueller's dipole model and is shown on p. 10. The external input for this evolution equation is the (flavor singlet) forward dipole scattering amplitude which has to be found first from the non-linear BK evolution equation (p. 11). On p. 12 we solve the equation for R showing that its linear part is identical to the DLA approximation of Kirschner and Lipatov. We also demonstrate that the effect of saturation on Reggeon amplitude R is to introduce a reduction of the intercept.

Valence quark distribution at small-x is likely to be relevant to the phenomenon of baryon stopping in heavy ion collisions, as we discuss on pp. 13, 14. In RHIC experiment one looks at the total baryon number left behind at mid-rapidity by the colliding nuclei. Much of the baryon number is transported by the valence quarks. On p. 14 we show that the small-x valence quark distribution is consistent with RHIC data on baryon stopping. A good fit can be achieved by taking $\alpha_s = 0.33$ with the DLA intercept.

[1] K. Itakura, Y. V. Kovchegov, L. McLerran and D. Teaney, arXiv:hep-ph/0305332.

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