Shadowing of gluons in perturbative QCD: A comparison of different models *

Jamal Jalilian-Marian and Xin-Nian Wang

In this paper, we continue our numerical study of the shadowing of gluons using two different QCD based formalisms; one is based on an all twist, Wilson renormalization group and effective action approach to high gluon density region of QCD. This approach takes high gluon densities into effect by including and re-summing all $n \to 1$ "hard pomeron" fusion terms in the evolution of both nuclear and nucleon gluon distribution functions. The other formalism is based on a generalization of the Mueller-Glauber multiple scattering formalism valid in the rest frame of the nucleus. The two approaches lead to similar but different expressions for the gluon distribution function. The difference between the two approaches becomes important only at very high energies (small x). Here we investigate the predictions of the two approaches for gluon shadowing numerically and show that the difference between the two is negligible in the RHIC kinematic region and becomes more appreciable as one goes to higher energies.

In this paper, we study the different perturbative QCD-based models for nuclear gluon distribution function and numerically investigated their predictions for x and Q dependence of shadowing in the kinematic region appropriate to RHIC and LHC. We show that predictions of different models for shadowing of gluons at RHIC are comparable while the difference at LHC can be of order $\sim 10\%$ for Gold or Lead. We also investigated the dependence of gluon shadowing on the parameterization of nucleon gluon distributions and showed that they lead to uncertainties in the nuclear gluon shadowing which are bigger than the uncertainty due to different pQCD based theoretical models. We finally considered the effects of initial non-perturbative shadowing on the shadowing generated by perturbative nonlinear evolution equations for gluons and showed that the magnitudes of perturbative and non-perturbative shadowing are comparable at RHIC but perturbative shadowing dominates over non-perturbative shadowing at smaller x's reached at LHC.

Since gluons do not directly couple to photons in DIS, one can not directly measure shadowing of gluons. One can, however, use other processes such as heavy quark and mini-jet production to measure the nuclear gluon distribution function since these processes are dominated by gluons at small x. For example, charm production at small x depends on the square of the nuclear gluon distribution function and will be very sensitive to gluon shadowing. This method relies on collinear factorization theorems and has already been used to extract the gluon distribution in a proton in good agreement with indirect measurements in DIS. A potential pitfall is the breakdown of collinear factorization theorems at small values of x due to higher twist effects which would invalidate this method and one would have to invent new methods to measure the gluon distribution directly.

The experimentally more relevant quantity to investigate is the shadowing of the nuclear structure function F_2^A since shadowing of gluons is not directly observable. The all twist F_2^N and F_2^A as well as the longitudinal structure function F_L can be computed at the classical level. Including the quantum loop effects due to gluons is straight forward and is currently under investigation . One can then predict the experimentally measured shadowing ratio F_2^A/F_2^N for different nuclei at different x, Q^2 as well as the longitudinal structure functions. This will be extremely important since then one can directly compare the predictions of pQCD for shadowing with experimental data. This work is in progress and will be reported later.

Footnotes and References

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