# $Q^2$ evolution studies of nuclear structure function $F_2$ at HERA

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**Abstract:** $Q^2$ dependence of nuclear structure functions is important for understanding perturbative QCD in nuclear environment. However, current experimental data are not sufficient for studying nuclear dependence in the $Q^2$ evolution because the data are limited in the small $Q^2$ region at small x. The future HERA program can study the evolution in the large $Q^2$ region, and it provides us crucial information on recombination effects and on higher-order $\alpha_s$ effects in the nuclear structure functions.

Nuclear modification of the structure function $F_2$ has been an interesting topic since the discovery of the EMC effect in 1983. Although most studies discuss $x$ dependence of the modification, $Q^2$ dependence becomes increasingly interesting. It is because the NMC measured $Q^2$ variations of the ratio $F_2^A/F_2^D$ [1]. Furthermore, it is found recently that there exist significant differences between tin and carbon $Q^2$ variations, $\partial[F_2^{Sn}/F_2^C]/\partial[\ln Q^2] \neq 0$ [1]. However, the NMC data are taken in the limited small $Q^2$ range at small $x$, so that they are not sufficient to test nuclear $Q^2$ evolution. The $Q^2$ dependence is important for understanding perturbative QCD in nuclear environment, and the future HERA nuclear program can make important contributions to this interesting topic.

The $Q^2$ dependence of structure functions can be calculated by using the DGLAP equations. They have been successful in describing many experimental data. However, as it becomes possible to reach the small $x$ region by high-energy accelerators, it is necessary to investigate the details of small $x$ physics. The longitudinal localization size of a parton exceeds the average nucleon separation in a nucleus in the small $x$ region ($x < 0.1$). It means that partons in different nucleons could interact in the nucleus, and the interaction is called parton recombination (PR). This mechanism is used for explaining nuclear shadowing. There are a number of studies on the recombinations. Among them, we employ the evolution equations proposed by Mueller and Qiu. They investigated gluon-gluon recombination effects on the evolution. The DGLAP and PR evolution equations are given by (see Ref. [2] for the details)

$$\frac{\partial}{\partial t}\, q_i(x,t) \;=\; \int_x^1 \frac{dy}{y} \left[ \sum_j P_{q_i q_j}\left(\frac{x}{y}\right)\; q_j(y,t) \;+\; P_{qg}\left(\frac{x}{y}\right)\; g(y,t) \right] + \left( recombination\ terms \;\propto\; \frac{\alpha_s A^{1/3}}{Q^2} \right) \;, \qquad (1a)$$