Nuclear modification factor in $p+Pb$ collisions at LHC and saturation

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We provide predictions for the nuclear modification factor R_{pA} for pions and direct photon production in $p+A$ collisions at LHC energy at midrapidity within different saturation models fitted to HERA data. In our approach we have no free parameters to adjust and all model parameters are fitted to other reactions. Our approach gives a rather good description of PHENIX data for R_{pA} for pions. We show that, in various saturation models, the pion Cronin enhancement is replaced by a moderate suppression at LHC energy at midrapidity due to gluon shadowing effects. However, Cronin enhancement of direct photons can survive at LHC energy in models with a larger saturation scale. We show that both shadowing and saturation effects are important at LHC in $p+A$ collisions and give rise to a rather sizable effect in the nuclear modification factor R_{pA}. Therefore, a precise measurement of $p+A$ collisions at LHC is crucial in order to understand the underlying dynamics of heavy ion collisions.
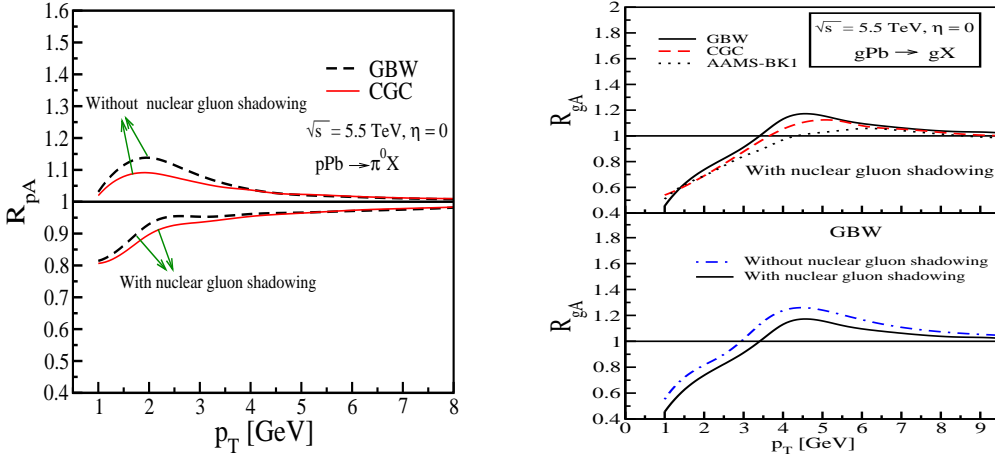
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Figure 1: Left:Nuclear modification factor R_{pA} for pion production at LHC at midrapidity in minimum bias proton-lead collisions within the CGC and GBW color dipole models. Right: R_{gA} for gluon production. In all curves in the upper panel gluon shadowing is incorporated. In the lower panel: gluon shadowing effects at LHC for the GBW model.

It is believed that data for $p + p$ and $p + A$ collisions can be indirectly translated into initial state effects in nuclear collisions. Therefore, in order to interpret jet-quenching, it seems mandatory to have a precise and firm understanding of the Cronin, shadowing and saturation effects in $p + A$ collisions [1]. The nuclear modification (Cronin) factor R_{pA} is defined as ratio of $p + A$ to $p + p$ cross-sections normalized to the average number of binary nucleon collisions. In our approach, the Cronin effect originates from initial-state broadening of the transverse momentum of a projectile parton interacting coherently with a nuclear medium [2]. The invariant cross-section of hadron and direct photon production in $p + A$ (and $p + p$) collisions can be calculated via the light-cone color-dipole factorization scheme [2], see also Refs. [3]. One should note that the multiple parton interactions that lead to gluon shadowing are also the source of gluon saturation. The saturation effects have been already included in the color-dipole cross-section fitted to DIS data. In order to avoid double counting, we incorporate the nuclear shadowing effect within the same color-dipole formulation. Details of calculations can be found in Ref. [2].

In Fig. 1, we show our prediction for the nuclear modification factor R_{pA} for π^0 production at LHC at midrapidity in minimum bias $p + A$ collisions within two very different saturation models, namely GBW [4] and CGC model [5]. The CGC model is based on the non-linear small-x Balitsky-Kovchegov equation [6]. The saturation scale in the phenomenological GBW model is bigger than in the CGC model (see Fig. 2 in Ref. [2]). However, both models are able to describe deep inelastic lepton-hadron scattering data. In Fig. 1 we also show the effect of nuclear gluon shadowing. It is seen that the Cronin enhancement will be replaced with moderate suppression due to nuclear gluon shadowing. It is obvious that a bigger saturation scale leads to a larger Cronin enhancement and works against the nuclear shadowing suppression. Note that a larger saturation scale leads to a stronger broadening of transverse momentum of the projectile partons and consequently it works against nuclear shadowing. This is more obvious in Fig. 1 (right, upper panel) where we plotted the Cronin ratio for gluon production at the LHC energy within various saturation color dipole models. In Fig. 1 (right, lower panel) we show the effect of nuclear shadowing within the GBW color dipole
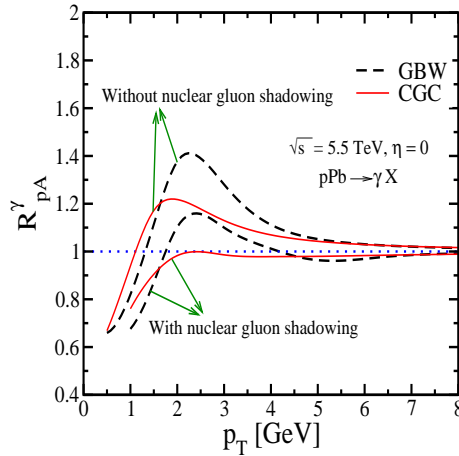
Figure 2: Same as Fig. 1(left) for direct photon production. For comparison, we also show the results with and without inclusion of gluon shadowing effects.

model. It is seen that both nuclear shadowing and saturation effects are important at LHC in $p + A$ collisions and give rise to a rather sizable effect in the nuclear modification factor R_{pA}. Kharzeev *et al.* [7] have shown a marked suppression for pions at mid-rapidity at LHC in $p + A$ collisions based on the CGC scenario. This suppression is stronger than our prediction. Other predictions based on different approaches can be found in Ref. [1]. In Fig. 2, We show our prediction for the nuclear modification factor R^{γ}_{pA} for direct photon production at LHC at midrapidity in minimum bias $p + A$ collisions for two models with different saturation scale. In comparison to pion production, the Cronin enhancement for direct photon production seems stronger and survives within the GBW color-dipole model which has a bigger saturation scale, even after the inclusion of nuclear shadowing suppression effects. Similar to pion production, the Cronin enhancement for direct photon production is bigger in a model with a larger saturation scale. Within the CGC model both pion and direct photon enhancement at RHIC will be replaced by suppression at LHC.

Acknowledgments

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