Forward jets and dense systems

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High energy collisions of protons and heavy nuclei at the Large Hadron Collider (LHC) provide a tool to probe dense systems of partons bounded in nucleons. Especially interesting are processes where jets of hadrons are produced in the forward direction with respect to the projectile nucleus. Kinematically, such jets have large rapidities. Thus, they trigger events in which the partons extracted from the nucleus carry small longitudinal momentum fraction x. Due to the well-known rise of gluon distributions at small x, this kinematic setup is perfectly suited to investigate the phenomenon of *gluon saturation*, which should occur at some value of x to prevent violation of the unitarity bound. For a review of theory and phenomenology see [1] and references therein.

In Color Glass Condensate (CGC) (effective theory of QCD at high energy, see eg. [2]), the calculation of forward jet production in proton-nucleus collisions relies on the so-called hybrid approach [3], where the large-x projectile is described simply by the conventional collinear PDFs, while the nucleus must be treated with nonlinear equations. However, the description of multi-jet production is rather complicated even in this simplified framework [4, 5]. A novel approach to such processes was proposed in Ref. [6] and it is known in the literature as the small-x Improved Transverse Momentum Dependent (ITMD) factorization. It provides a momentum-space factorization formula which has the form of a generalized factorization, *i.e.* it involves several transverse momentum dependent (TMD) gluon distributions characterizing partons in the dense target. In [7] a precise connection to the CGC theory was established – the ITMD formalism provides a resummation of all kinematic twists and neglects the genuine multi parton contributions.

In [8], the ATLAS collaboration studied azimuthal correlations of dijets in proton-lead (p-Pb) and proton-proton (p-p) collisions at the center-of-mass energy $\sqrt{s_{NN}} = 5.02\,\mathrm{TeV}$, covering, in particular, the forward rapidity region between $2.7 - 4.0$. The measurement indicates sizable nuclear effects at small values of x. In the paper [9] the ITMD factorization (including Sudakov resummation) was applied to describe the forward dijet measurement by the ATLAS collaboration [8]. The shapes of the $\Delta\phi$ distributions were described very well indicating strong support for the occurrence of saturation. In order to collect more evidence for such effects it is desirable to address different observables and different final states.

Recently the ITMD formalism has been extended to account for trijet final states [10] (see also [11] for the CGC calculations in the correlation limit). It has been named ITMD* since at present the formalism does not account for linearly polarised gluons inside the unpolarised target. The calculations of azimuthal angle related observables within ITMD* (which accounts for dominant effects) show that the trijet final state has great potential in the search for saturation effects as the difference between results based on k_T factorization and ITMD* calculations are more pronounced for trijets than for dijets.

In the contribution to Snowmass 2021 we would like to study in more detail the jet final state in forward rapidity region, in particular impact of the Sudakov resummation.

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