Particle production and correlations in dilute-dense collisions in the CGC framework: finite-width target effects

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Quantum Chromodynamics (QCD), the theory of strong interactions, has been very successful in describing strong scattering processes at high energies. At high energies, increasing energies of the scattering system correspond to decreasing longitudinal momentum fractions x carried by the partons participating in the collision. In the Regge-Gribov limit of small x, the number of gluons in colliding hadrons increases rapidly and leads to gluon occupation numbers and field strengths as high as possible - a phenomenon known as *gluon saturation*. The weak coupling (though non-perturbative) limit of this gluon saturation regime is referred to as Color Glass Condensate (CGC) which is an effective theory that describes the high energy scattering processes in QCD (for a review see [1]).

The CGC effective theory has been very often used to understand high energy collision data in proton-proton (pp) and proton-nucleus (pA) collisions, as well as the early stages of heavy ion collisions (HICs). One of the key approximations routinely employed in the CGC framework is the eikonal one, where target (assumed dense) is represented by a strong classical background field. In the high energy limit, this dense target is highly boosted and the classical background becomes squeezed into an infinitesimally thin shockwave due to Lorentz contraction. In reality, energies are finite and, especially at high transverse momenta, the eikonal approximation acquires corrections due to the finite longitudinal thickness of the target. This type of corrections are small at the LHC, but will be especially important at the planned Electron Ion Collider (EIC) and the Large Hadron-electron Collider (LHeC), since these machines will not probe so high energies. A systematic method to include the finite width corrections to the eikonal approximation has been developed in [2, 3]. Its application to single inclusive gluon production and various spin asymmetries has been performed. This study have been further developed and corrections to the Lipatov vertex due to finite target thickness have been calculated in [4].

Among the most intriguing observables described in the CGC framework is the azimuthal correlations between produced particles, extended in pseudorapidty, known as *the ridge*, see the review [5]. These correlations have been observed by all experimental groups at the LHC for high multiplicity pp and pPb data, thus in collision systems that are small compared to heavy ion collisions where such correlations are taken as characteristics of the quark-gluon plasma. Earlier observations of these correlations in HICs at RHIC and the LHC have an accepted explanation: its origin is the collective flow in the final state due to strong final state interactions, which is described very well in the framework of relativistic viscous hydrodynamics. However, such explanation in pp collisions looks tenuous since in a small size system like proton-proton one does not naturally expect sizeable final state interactions. Motivated by this fact, there has been a lot of activity to describe these correlations from the initial state point of view (for a review see [6]).

For a long time, one of the biggest challenges in the CGC for describing these correlations was its inability to produce odd flow harmonics. The origin of this problem is found in internal symmetry properties of the CGC. However, it was also shown that this symmetry can be broken and one can generate odd flow harmonics from the CGC [7–10]. In [9, 10], it was shown that finite-width target corrections break this symmetry and odd flow harmonics can be produced for pp collisions.

Motivated by the aforementioned studies, our goals are:

- To extend the study of the two particle correlations with finite-width target corrections from pp to pA collisions and study the effects of these corrections on even and odd azimuthal harmonics;

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- To study the finite-width effects for other observables relevant for the EIC and the LHeC.

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