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Initial state in relativistic nuclear collisions and Color Glass Condensate

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Abstract

In this talk, I discuss recent works related to the pre-hydrodynamical stages of ultra-relativistic heavy ion collisions.
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1. Introduction

Hydrodynamical models are very successful at reproducing bulk observables in high energy heavy ion collisions. However, it is a long standing puzzle to understand from the underlying Quantum Chromodynamics (QCD) why this description is so effective. Indeed, the description of the early stages of heavy ion collisions which is most closely related to QCD – the Color Glass Condensate (CGC) framework – predicts at the very beginning of the fireball evolution a situation which is very different from a quasi perfect fluid.

The purpose of this talk is to discuss recent works aiming at a first principles CGC description of the early stages of heavy ion collisions, where by "early stages" we mean the pre-hydrodynamical evolution (left part of Fig. 1). Ultimately, the goal is to have a description of these early stages that explains how the hydrodynamical behavior develops and that matches smoothly into hydrodynamics (right part of Fig. 1), in such a way that the time τ_0 at which the switching happens becomes unessential (in the same spirit as a factorization scale for parton distributions). Note that the CGC, despite being is a weakly coupled framework, can be the siege

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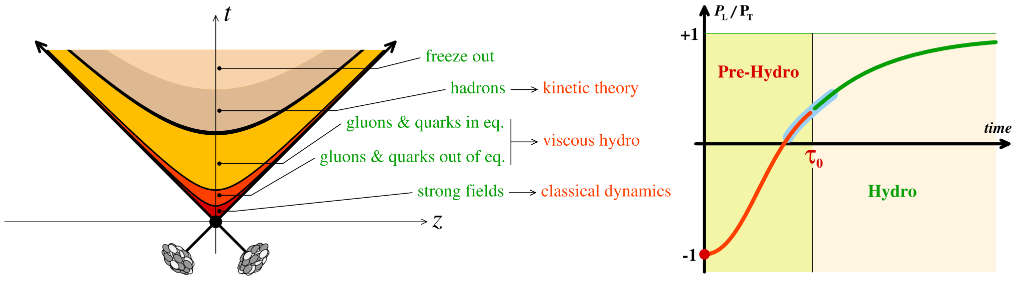

Fig. 1. Left: stages of a heavy ion collision. Right: matching to hydrodynamics.

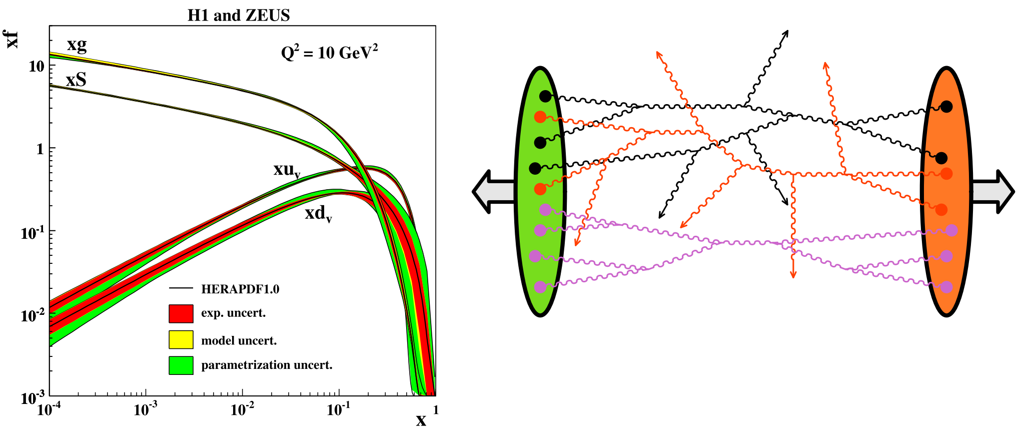

Fig. 2. Left: parton distributions in a proton. Right: multiparton scattering at high gluon density.

of strong interactions because the color fields are large, of order g^{-1} (or equivalently the gluon occupation number is of order g^{-2}).

2. Color Glass Condensate

In high energy heavy ion collisions, most particles are produced with a comparatively small transverse momentum of a few GeV at most. Given the longitudinal momentum of the incoming nucleons at the LHC energy, their constituents are probed with a longitudinal momentum fraction $x \lesssim 10^{-3}$, where the gluon distribution is very large (left plot in Fig. 2). In this regime of large gluon density, multigluon processes become important, as illustrated in the right panel of Fig. 2. These non-linear effects are one of the manifestations of *gluon saturation* [1,2], which plays a role for transverse momenta $k_\perp^2 \lesssim Q_s^2$, where Q_s is an x-dependent momentum scale known as the saturation momentum (roughly speaking, $\alpha_s^{-2} Q_s^2$ is the gluon density per unit of transverse area, and $\alpha_s^{-2} Q_s^2/k_\perp^2$ can be viewed as the gluon occupation number). The dependence of Q_s on x and the mass number A is shown in the left plot of Fig. 3. In the Color Glass Condensate framework [4–6], the partons that have a longitudinal momentum above a cutoff Λ are treated as a color current $J^\mu = \delta^{\mu +} \rho(\boldsymbol{x}_\perp)$ along the light-cone, while those that have a longitudinal momentum below the cutoff (mostly gluons) are described as usual gauge fields. The transverse color distribution of the fast partons, $\rho(\boldsymbol{x}_\perp)$, fluctuates event-by-event, and the CGC only provides its probability distribution $W[\rho]$. The cutoff Λ separating the two types of degrees of freedom is not

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