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1 Abstract

The following project concerns investigation of strong forces governing interactions of fundamental constituents of matter: quarks and gluons and the underlying basic theory describing these interactions – Quantum Chromodynamics (QCD). We are especially interested in the so-called High Energy Physics (HEP), which involves experiments that collide hadrons accelerated to velocities close to the speed of light in large facilities, like the Large Hadron Collider (LHC) at CERN or Relativistic Heavy Ion Collider (RHIC) at Brookhaven Laboratory in USA.

Hadrons are extremely complex systems formed by elementary quarks and gluons (partons) located in a region of space-time. The way these partons are distributed inside the hadrons typically needs to be determined experimentally, as the standard QCD tool – the perturbation theory – is inapplicable whereas the effective QCD models are not precise enough and hard to apply for barionic systems. Collisions of hadrons injected in accelerators give information on the dynamics of the strong interactions. When the hadrons are smashed against each other at high energy the interactions can occur between individual partons. This allows to scrutinize the microscopic structure of hadrons. For very energetic collisions the theory of QCD can be applied to predict some interesting final state events.

When hadrons are accelerated close to the speed of light the number of gluons inside them increases considerably. Each of those gluons must carry only a small fraction of the total energy due to the total energy-momentum conservation. This regime is the so called small-x limit. On the other hand, larger hadronic structures such as heavy nucleus are composed by many hadrons. The dynamics of these larger objects are described in terms of a semi-classical theory for the distribution of gluons called the Color Glass Condensate.

In the present project we investigate particle production in proton-nucleus (pA) and proton-proton (pp) collisions in the small-x regime. Our objectives are separated in three parts. The first part consists in the investigation of angular correlations between two particles produced in pA collisions. Such correlations are of great interest because there angle between the 'tracks' of produced particles (or jets of particles) is potentially sensitive to the details of the initial state. In terms of fundamental constituents each of the produced particles could be originated either by quarks or gluons that constitue colliding hadrons. So far there is no persuasive explanation of the angular correlation in the framework of QCD. Our goal is to explain the related experimental data in terms of the basic theory and the CGC theory, as well as to understand the hierarchy of the correlation when we go from smaller systems pA to larger systems Helium-nucleus (HeA). The second objective aims to investigate the quantum interference contributions that exists in two particle production, which are neglected in general phenomenological analysis. We want to compute the scattering amplitudes using different existing formalisms and calculate the corresponding cross sections. Finally, the third objective attempts to connect the small-x physics and elastic scattering of hadrons. The idea is to study the proton-proton elastic scattering using microscopic models containing information of partonic distribution and quantum effects using the apparatus developed for small-x physics.