# ABSTRACT FOR THE GENERAL PUBLIC (IN ENGLISH)

One of the central questions in physics is to elucidate the fundamental structure of matter. The combined effort of generations of physicists eventually led to the formulation of the Standard Model of particle physics, the quantum field theory for the basic ingredients of matter and their interactions (apart from gravity, whose quantum version is not known yet). In the Standard Model, the quarks and leptons play the role of fundamental building blocks of matter, and can interact which each other via three different types of forces: electromagnetic, weak and strong forces. Each of these forces is resulting from exchanges of carrier particles, like photons for electromagnetism, or gluons for the strong force. Finally, the Higgs particle is a byproduct of the mechanism giving mass to quarks, to leptons and to the carriers of the weak interaction in the Standard Model. All of these elementary particles contained in the Standard Model have been confirmed by experimental observations over several decades, culminating with the discovery of the Higgs particle at the Large Hadron Collider (LHC) at CERN in Switzerland, in 2012.

The strong force, carried by the gluons, is acting only on the quarks and on the gluons themselves. The part of the Standard Model describing the strong force and the dynamics of quarks and gluons is called Quantum Chromodynamics (QCD). Under the action of the strong force, quarks and gluons are bound together to form composite particles called hadrons, which include notably protons and neutrons. QCD is thus essential to understand the fundamental structure of ordinary matter, since the nucleus of atoms is formed from protons and neutrons. Moreover, the mass of quarks and electrons coming from the Higgs mechanism represents only a small fraction of the mass of ordinary matter, whereas the main contribution comes from the binding energy of quarks and gluons into hadrons, and is thus of purely QCD origin. Unfortunately, the precise theoretical description of low energy phenomena in QCD is extremely challenging, like the formation of hadrons and their low energy collisions. By contrast, large angle scattering of hadrons is very precisely under control both theoretically and experimentally, since it is directly driven by the underlying scattering of individual quarks or gluons inside the hadrons, thanks to the property of asymptotic freedom of QCD.

It has been understood from theoretical studies that a third regime of QCD opens up between these two, relevant in the case of high energy scattering at moderate angle, which effectively resolve the content of the incoming hadrons at shorter and shorter timescales. When increasing the energy of the collision, the density of quarks and especially gluons resolved in the hadrons increase exponentially. Eventually, when the density of gluons is large enough, non-linear QCD interactions set on, and stop the exponential growth. This is called gluon saturation. Hadronic collisions in this nonlinear high-energy regime are driven by multiple scattering between quarks and gluons, instead of single scattering in the large angle regime. Numerous hints of gluon saturation have been found over the years, by comparing the qualitative theoretical predictions to the experimental data about electron-proton, proton-proton or proton-nucleus collisions performed at various particle accelerators. However, no firm discovery of gluon saturation could be claimed, partly due to the limited amount of data in the expected validity range of gluon saturation, and mostly due to the very limited precision of available theoretical predictions in this regime.

With the continuation of data taking at the LHC, and the future construction of the Electron Ion Collider (EIC) at BNL in the USA which will perform both electron-proton and electron-nucleus collisions, a large amount of experimental data relevant to the study of gluon saturation is expected in the next decades. It is thus timely to reexamine the theory, and push the calculations to higher precision. The main goal of this project is indeed to study and include various types of subleading corrections in the theoretical description of the high-energy nonlinear regime of QCD, in order to produce precise predictions for collisions at the EIC and LHC. This will allow us to settle the question of gluon saturation and of its validity range, and thus to make an important further step towards the full understanding of QCD and of the structure of protons and neutrons.