Small-x physics in the electron-ion collider era

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Understanding the high energy limit of hadronic and nuclear collisions is at the forefront of nuclear and particle physics. When boosted to ultrahigh energies, all hadrons and nuclei eventually transform into a universal form of matter called the Color Glass Condensate (CGC). The CGC is characterized by the high density (saturation) of small-x gluons which leads to distinct experimental signatures. Tantalizing hints of the CGC have been observed at HERA, RHIC and the LHC, but the prospects for the discovery of the CGC are more promising at future experiments such as the Electron-Ion Collider (EIC) at Brookhaven National Laboratory Indeed, according to the National Science Academy report published in 2019, one of the three major goals of the EIC is to address the nature of the gluon saturation. (The other two are the mass and spin structure of the nucleons.)

With this in mind, the small-x community is gearing up to meet the challenges of the EIC era. Over the past several years, there has been impressive progress in the next-to-leading order (NLO) calculations in the CGC framework of various observables such as single hadron production in proton-nucleus collisions, inclusive and exclusive dijet and trijet production in Deep Inelastic Scattering (DIS), jet-plus-photon production in DIS, *etc.* We expect that NLO calculations will be the standard tool to confront future experimental data at the EIC.

Another emerging trend of the community is the interplay between small-x physics and spin physics. The RHIC result for the gluon helicity ΔG has underscored the necessity to understand the longitudinal spin structure of the proton at small-x. There have been theoretical indications that a significant fraction of spin and orbital angular momentum is stored in the small-x region. As for the transversely polarized proton, a surprising new connection between the gluon Sivers function at small-x and the QCD Odderon has been pointed out and its implications at the EIC has been discussed.

On 15–17, December 2021, we have held a 3-day virtual workshop dedicated to small-x physics in order to summarize the present status of the field described above and to discuss future directions. A major focus of this workshop was to identify outstanding problems that could significantly benefit from collaborative efforts amongst scientists working on formal, phenomenological, and computational aspects of small-x physics. The topics covered include:

What are the best observables of gluon saturation at the EIC?

- NLO calculations in the CGC
- Interplay between spin and small-x
- TMD, GPD and Wigner distributions at small-x
- Initial conditions (momentum space, coordinate space, nonperturbative input, ...)
- Hadronization (MC implementation, coupling to existing event generators, ...)
- Outstanding open problems at small-x requiring a topical theory collaboration

We have had 102 registered participants and 31 invited talks including 6 experimental talks in a very interactive atmosphere. The most important outcome of the workshop is that, after this workshop, the participants have decided to apply for a topical collaboration of the U.S. Department of Energy (DOE). One of the organizers, B. Schenke (BNL) is taking a lead in this initiative and many other workshop participants who have faculty positions in the U.S. are serving as co-PIs. The workshop can be therefore regarded as a great success.

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