

One of the most intriguing aspects of Quantum Chromodynamics (QCD) is the concept of asymptotic freedom (Nobel prize 2004) that allows for a rich phenomenology, much of which remains unexplored. The gluon content of bound states shows a rapid increase with decreasing parton fractional momentum leading to predictions of gluon saturation for which various hints, but no conclusive evidence, have been found. The discovery of gluon saturation is one of the goals of the electron-ion collider (EIC) recently approved by the DOE.

Saturation effects are thought to be enhanced in ions and will manifest themselves in a suppression of particle production due to shielding effects due to the gluons. This project requires the student to calculate cross-sections for the exclusive production of vector mesons in proton-lead collisions at the LHC. Many theoretical uncertainties can be cancelled by considering ratios of cross-sections in the forward and backward directions. To cross-check the results, the student can make use of publicly available computer code to generate particle collisions. Saturation effects can be added or removed to demonstrate the feasibility of proposed experimental observables.

#### References:

- P.D.B Collins "An Introduction to Regge Theory and High Energy Physics", Cambridge monographs on theoretical physics.
- V.P. Goncalves et al., "Color dipole predictions for the exclusive vector meson photoproduction in pp, pPb, and PbPb collisions at run 2 LHC energies", *Phys.Rev.D* 96 (2017) 9, 094027.
- L. Harland-Lang et al., "A new approach to modelling elastic and inelastic photon-initiated production at the LHC: SuperChic 4", *Eur.Phys.J.C* 80 (2020) 10, 925.
- S.R. Klein et al., "STARlight: A Monte Carlo simulation program for ultra-peripheral collisions of relativistic ions", *Comput.Phys.Commun.* 212 (2017) 258-268
- R. McNulty, "Results and Future Plans on Central Exclusive Production with the LHCb Detector", *Int.J.Mod.Phys.A* 29 (2014) 28