Letter of intent for HORIZON-INFRA-2025-01-SERV-03

Small-x gluons in colliders

Project Leaders

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Research Objectives

Research area: Quantum Chromodynamics (QCD) is the widely accepted fundamental theory describing strong interactions and has successfully accounted for a broad spectrum of phenomena. A particularly intriguing domain arises in high-energy collisions involving at least one hadron or nucleus, when transverse momenta of a few GeV are probed. In this semi-hard regime, although perturbative methods remain applicable since the QCD coupling is weak, the parton densities grow significantly at small-x, giving rise to non-linear effects associated with strong gauge fields, ultimately leading to gluon saturation. The Color Glass Condensate (CGC) effective theory has proven to be a powerful framework for both qualitative and quantitative analysis of such semi-hard processes, as observed in past and current experiments at colliders such as DESY, RHIC, and the LHC. Moreover, these small-x gluons dominate the bulk of particle production in relativistic heavy-ion collisions. Thus they set the initial conditions for quark-gluon plasma formation at the LHC and they can provide the link from microscopic QCD dynamics to macroscopic collective behavior. Looking ahead, Deep Inelastic Scattering (DIS) of electrons off nuclei at the upcoming Electron-Ion Collider (EIC) and also off nuclei and protons at CERN via a possible upgrade to LheC will enter completely unexplored kinematic settings, and will provide more refined and ideal conditions for studying parton dynamics under gluon saturation.

Current state: Over the last few years, there have been significant advancements in developing the theoretical machinery for exploring the domain of small-x gluons, which include derivations of NLO evolution equations, calculations of NLO impact factors for various processes, calculations of correlations in cross sections with two or more particles in the final state, proofs of TMD factorization in processes with disparate transverse scales and associated resummations of Sudakov effects, computations of next to eikonal corrections, determination of nuclear PDFs etc. Many of these tools have been used to explain experimental data with significant success.

Objectives:

- Continuation of the work towards the construction of a more complete set of theory tools. These include, extending CGC calculations to more observables, studying diffractive processes which by definition exhibit a rapidity gap whose presence in high energy collisions can be directly related to gluon saturation, deriving precise impact factors for more processes, understanding the size and the implications of Sudakov corrections, developing a more accurate JIMWLK equation which is necessary for addressing certain multi-gluon amplitudes etc
- Proper implementation of the aforementioned theoretical tools, which are either already available or will be available in due time, in flexible numerical algorithms which shall be publicly available in a designated depository.

The joint effort will foster transnational collaboration in putting together building blocks of the complex physical problem under study, it will reduce potential errors due to open access and cross-checking and it will lead to more precise confrontation with experimental data. The aforementioned tools have revealed hints of gluon saturation in experimental data. However, in order to discover saturation effects and map in detail the properties of dense gluonic matter, collaborative effort in both theoretical and phenomenological fronts is required.

Connection to Transnational Access infrastructures (TAs) and Virtual Access projects (VAs)

- The research objectives of the project are directly related to the physics program at CERN and BNL.
- Collaboration meetings to take place at ECT* (see estimated budget request).
- Researchers from the participating Institutions are expected to provide, apart from the theoretical and phenomenological input, codes which shall be publicly available.

Estimated budget request

The can be broken down in two main categories:

- Personnel: 2 postdocs for a total of 4 postdoctoral years, with experience in the field of the project to actively participate in the software development. Approximate cost 50k€ x 4 years = 200k€.
- Travelling for: (i) collaboration meetings and/or focused small size workshops, mainly at the ECT* which qualifies as an infrastructure and offers the necessary administrative support and (ii) for disseminating the activities and the progress of the group in international conferences and workshops. Approximate cost: 2.5k€ x 4 year per institution = 140k€.
- Total estimated budget: 340k€

Participating and partner institutions/representing researchers

- Autonomous University of Madrid, Spain (A. Sabio Vera)
- École Polytechnique, Université Paris-Saclay, France (C. Marquet)
- ECT*, Trento, Italy (D. Triantafyllopoulos)
- IPhT, CEA, Université Paris-Saclay, France (E. Iancu)
- Jagiellonian University, Poland (P. Korcyl)
- IFJPAN Krakow, Poland (A. van Hameren)
- AGH Universiy, Krakow, Poland (P. Kotko)
- Université Paris-Saclay, CNRS, IJCLab, 91405 Orsay, France (Samuel Wallon)
- National Centre for Nuclear Research, Warsaw, Poland (T. Altinoluk)
- Subatech, Nantes, France (P. Caucal)
- University of Bielefeld, Germany (S. Schlichting)
- University of Calabria, Italy (A. Papa)
- University of Florence, Italy (D. Colferai)
- University of Jyväskylä, Finland (H. Mäntysaari)
- University of Santiago de Compostela, Spain (N. Armesto)