2023 Helmholtz – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project:

Parton shower based on the Gribov-Levin-Ryskin equation

Helmholtz Centre, division:

DESY-FH

Project leader:

Katarzyna Wichmann

Contact Information of Project Supervisor: (Email, telephone)

Katarzyna Wichmann, katarzyna.wichmann@desy.de , +49 40 8998 2595

Web-address:

https://cms.desy.de/activities/physics/standard_model_physics_in_cms/

DESY Group:

CMS

DESY-OCPC Programme Coordinator (Email, telephone and telefax)

Frank Lehner; frank.lehner@desy.de; +49 40 8998 3612

Description of the project:

Since the early HERA times, saturation effects were investigated in different approaches. The Gribov-Levin-Ryskin equation provides a description of saturation effects by explicitly involving parton densities. This approach is in particular well suited for an implementation in Monte Carlo event generators. However, until recently, it was unclear, whether the GLR can be formulated in a form, applying Sudakov form factors, that can be implemented as a parton shower. In a recent publication [1] it has been shown, that the GLR equation can be reformulated such that it can be solved numerically applying Sudakov form factors. The project will consist of an implementation of the GLR equation into the QCD evolution program updfevolv2 [2]. The updfevolv2 package is the core evolution package of the PB method [3,4], which has been applied to determine collinear parton densities and transverse momentum dependent (TMD) parton densities from inclusive HERA cross section measurements [5]. With the implementation of the GLR equation into updfevolv2, new collinear and TMD parton densities can be determined from fits to HERA measurement, a consistent implementation of GLR is achieved for the first time where the parton densities will be valid from very small to large momentum fraction x as well as from very small to very large momentum transfer Q^2. After this initial step, the simulation of parton showers will be implemented in the frame of the TMD based Monte Carlo event generator CASCADE3 [6]. This will for the first time allow to simulate in a consistent way saturation effects including parton emissions. Results from such Monte Carlo event simulation can be directly compared to measurements from HERA (as benchmarks) but then also to recent measurements from the LHC. It will be the first time ever, that saturation effects are simulated in detail, based on theoretical evolution equations. Once the first steps of a complete simulation of saturation effects in a parton shower approach have been successfully performed, investigations will start on extending the description of saturation as a recombination of gluons in the initial state towards a full simulation of multi-parton interactions, which according the AGK rules of perturbative QCD [7,8] are just another side of the medal. This last step is the most challenging: it is at the moment unclear, whether it can be achieved at all, but if it can, it would solve one of the pending and unsolved problems in QCD at high energies: a uniform description including saturation, multi-parton interaction and eventually diffraction. The implementation of the GLR equation and the simulation of parton showers according to GLR can only be performed within the frame of unintegrated, transverse momentum dependent parton densities. The CASCADE3 Monte Carlo event generator is the only generator at present which is based entirely on TMD parton densities, and is therefore the only place, where this implementation can be consistently performed. The successful completion of this program will have a direct impact on the understanding of high-energy processes at the LHC, and will be of utmost importance for any physics simulation at the possible LHeC as well as the EIC collider.

[1] Y. Shi, S. Y. Wei and J. Zhou, Phys. Rev. D **107** (2023) no.1, 016017, [arXiv:2211.07174 [hep-ph]].
[2] F. Hautmann, H. Jung and S. T. Monfared, Eur. Phys. J. C **74** (2014), 3082, [arXiv:1407.5935 [hep-ph]].
[3] F. Hautmann, H. Jung, A. Lelek, V. Radescu and R. Zlebcik, JHEP **01** (2018), 070, [arXiv:1708.03279 [hep-ph]].
[4] F. Hautmann, H. Jung, A. Lelek, V. Radescu and R. Zlebcik, Phys. Lett. B **772** (2017), 446-451, [arXiv:1704.01757 [hep-ph]].
[5] A. Bermudez Martinez, P. Connor, H. Jung, A. Lelek, R. Zlebcik, F. Hautmann and V. Radescu, Phys. Rev. D **99** (2019) no.7, 074008, [arXiv:1804.11152 [hep-ph]].

[6] S. Baranov, A. Bermudez Martinez, L. I. Estevez Banos, F. Guzman, F. Hautmann, H. Jung, A. Lelek, J. Lidrych, A. Lipatov and M. Malyshev, *et al.* Eur. Phys. J. C **81** (2021) no.5, 425, [arXiv:2101.10221 [hep-ph]].
[7] V. A. Abramovsky and A. V. Popov, [arXiv:1112.1297 [hep-ph]].
[8] M. Salvadore, J. Bartels and G. P. Vacca, [arXiv:0709.3062 [hep-ph]].

Description of existing or sought Chinese collaboration partner institute (max. half page)**:**

Key Laboratory of Particle Physics and Particle Irradiation (MOE),
Institute of Frontier and Interdisciplinary Science, Shandong University, Qingdao, Shandong 266237, China

A study on “Parton shower generator based on the Gribov-Levin-Ryskin equation” has been recently published in PhysRevD.107.016017 by the group in Shandong. We are already in contact about the basic ideas, and how to implement the approach into a full Monte Carlo event generator.

From the group in Shandong interest in a closer cooperation with the phenomenology group at DESY has been expressed.

Required qualification of the postdoc:

- PhD in particle physics, experimental or theoretical
- Experience with in computing, especially in simulation of parton showers
- Additional skills in Monte Carlo simulation and parton evolution is of advantage
- Language requirement: very good knowledge of English (spoken, written)