

## RESEARCH ACTIVITY

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During the third year of my Ph.D., I focused my research on resummation in the high-energy region of the phase-space. Resummation is a way to handle divergent terms arising in the perturbative expansion in some regions of the phase-space. It allows restoring the predictivity of the perturbative expansion in QCD, allowing us to make ever more precise predictions on observables measured in experiments.

My work is focused on finding a method to increase by one order the current accuracy of the techniques of resummation of large logarithmic contribution in the high-energy region of the phase space, the small-x limit. I work on this project together with my supervisors, Simone Marzani and Giovanni Ridolfi, and with Marco Bonvini and Federico Silveti from *Università la Sapienza* in Rome.

The current method used to resum small-x logarithm ([1],[2],[3]) is based on the  $k_t$ -factorization. This means that the process can be factorized in two parts: the hard part that has to be computed in perturbation theory and the ladder part, given by an evolution operator. Together, these two ingredients allow to resum small-x logarithms up to Leading-Logarithmic (LL) accuracy.

The first step of our work has been to pick a specific process, as simple as possible, to understand how this procedure can be extended up to the Next-to-Leading Logarithmic (NLL) accuracy. We chose to focus on the Deep-Inelastic Scattering (DIS) induced by a Higgs boson.

We found two main issues that particularly complicate the calculation of this process. The first is the requirement to work in a physical gauge (like axial gauge) while the second is to define the sum over polarization of an off-shell gluon. During this year, we solved the main problems due to the use of axial gauge, while some work is still required on the sum over polarization-side.

The difficulties in choosing to work in axial gauge are essentially two: the rising of spurious singularities in loop-integrals and the correct definition of ultraviolet counterterms.

The problem of the presence of spurious singularities, that must be correctly regulated and that must not be present in the final result, was solved during last year and you can find more details in my previous report. This year, we addressed the renormalization problem and so we had to deal with the correct definition of counterterms in axial gauge. This has been particularly complicated because we chose to work in a effective theory and so we had to define the one-loop effective-vertex counterterm.

The other important issue we found is linked to the requirement to have the incoming gluon off-shell. This would require knowing the sum over polarization of an off-shell gluon, which is not well defined. The prescription ([1],[2]) in tree-level computations is to use

$$d_{\text{off}}^{\mu\nu} = (d-2) \frac{k_t^\mu k_t^\nu}{\vec{k}_t^2},$$

where  $\vec{k}_t^2$  is the offshellness of the incoming gluon. This prescription works well at tree-level but we do not know if has to be modified at one-loop. We are currently studying the effects of using different polarization tensors.

In conclusion, this year we made important steps forward in the understanding of the mechanism of small-x resummation at NNL. Only one aspect remain unclear, the role of the polarization tensor of an off-shell gluon, and we are working to clarify it.

## ATTENDED COURSES

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During this year, I passed the following exams:

- **Black holes thermodynamics**

Stefano Giusto

In order to pass this exam, I did a seminar with the title: “*Explicit calculation of black hole entropy*”.

- **Conformal field theories**

Andrea Amoretti

In order to pass this exam, I did a seminar with the title: “*Minkowsky-space correlators in AdS/CFT correspondence*”.

## SCHOOLS AND CONFERENCES

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I attended the following schools and conferences:

- **Conference:** *Milan Christmas Meeting 2021*,

Milan, from 21<sup>th</sup> to 23<sup>th</sup> December 2021;

link to conference’s website: <https://indico.cern.ch/event/1095418/>.

During the *Milan Christmas Meeting 2021* conference I presented a talk with the title “*NLL small- $x$  resummation for Higgs induced DIS*”.

- **Conference:** *A life in phenomenology*,

from 15<sup>th</sup> to 16<sup>th</sup> September 2022;

link to conference’s website: <https://indico.cern.ch/event/1114706/>.

- **Conference:** *Diffraction and Low- $x$  2022*,

Corigliano Calabro, from 24<sup>th</sup> to 20<sup>th</sup> September 2022;

link to conference’s website: <https://indico.cern.ch/event/1148802/>.

During the *Diffraction and Low- $x$*  conference I presented a talk with the title “*Next-to-Leading Order virtual correction to Higgs-induced DIS*”.

## BIBLIORAPHY

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- [1] S. Catani, M. Ciafaloni, and F. Hautmann, “High-energy factorization and small  $x$  heavy flavor production”, *Nucl. Phys. B*, vol. 366, pp. 135–188, 1991.
- [2] S. Catani and F. Hautmann, “High-energy factorization and small  $x$  deep inelastic scattering beyond leading order”, *Nucl. Phys. B*, vol. 427, pp. 475–524, 1994. arXiv: hep-ph/9405388.
- [3] M. Bonvini, S. Marzani, and C. Muselli, “Towards parton distribution functions with small- $x$  resummation: HELL 2.0”, *JHEP*, vol. 12, p. 117, 2017. arXiv: 1708.07510 [hep-ph].