Anna Rinaudo

Supervisor: Giovanni Ridolfi
Co-supervisor: Simone Marzani

Research activity

During the second 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 resotring 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 Silvetti 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.
Since we want to implement the k_t-factorization in our computation, we found two main issues that particularly complicated the calculation of this process. The first is the requirement to work in a physical gauge while the second is to compute the hard part of the process with the incoming gluon of-shell.
The use of the axial gauge gives rise to spurious singularities in the loop-integrals that must be correctly regulated and that must not be present in the final result. These spurious singularities are of the form

$$I = \int \frac{d^d k}{(2\pi)^d} \frac{1}{k^2 (k-l)^2 (k-p)^2 (k \cdot n)},$$

and this makes the loop-integrals to be non-covariant. During this year, we developed a method to correctly address these non-covariant integrals and their singularities. We are now able to compute them.
Another 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

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

where $\overrightarrow{k}_t^2$ 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 few important steps forward in the understanding of the mechanism of small-x resummation at NNL. Still, some aspects remain unclear, like the role of the polarization tensor of an off-shell gluon, and we are working to clarify them.

Attended courses

During this year, I passed the following exams:

- **Fisica teorica (Theoretical physics)**

  Giovanni Ridolfi

  In order to pass this exam, I did a seminar with the title: *"Basis of small-x resummation"*.

- **Gravitational waves**

  Gianluca Gemme, Andrea Chincarini and Fiodor Sorrentino

  In order to pass this exam, I did a seminar with the title: *"Gravitational waves as messengers from early universe"*.

During this year, I attended the following courses:

- **Black holes thermodynamics**

  Stefano Giusto

- **Conformal filed theories**

  Andrea Amoretti

- **Introduction to Deep Learning**

  Maurizio Pierini

  On-line course organized by Università Milano-Bicocca

Schools and conferences

I attended the following schools and conferences:

- **School**: *CTEQ-MCnet Summer School 2021*,
  due to COVID-19 restriction this school has been held in a virtual format;
  from 6^{th} to 16^{th} September 2021;
  link to school's website: https://indico.cern.ch/event/1005703/.

- **Conference**: *Cortona young 2021*,
  online conference;
  from 9^{th} to 11^{th} June 2021;
  link to conference's website: https://www.ggi.infn.it/showevent.pl?id=404.

  During the *Cortona Young 2021* conference I presented a videoposter. My contribution is available at: https://l.infn.it/gd.

Bibliography

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[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].