# Workshop on overlap between QCD resummations

Sunday, 14 January 2024 - Wednesday, 17 January 2024

Aussois, Centre Paul Langevin

# Book of Abstracts

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# Lipatov's EFT as a computational tool

**Author:** Maxim Nefedov[1]

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The talk will cover recent results for one-loop impact-factors involving quarkonium states, obtained using Lipatov's Gauge-Invariant EFT for Multi-Regge processes in QCD.

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# Power corrections in TMD factorization

**Author:** Alexey Vladimirov[1]

[1] *Universidad Complutense de Madrid*

**Corresponding Author:** alexeyvl@ucm.es

I discuss different types of power corrections in the TMD factorization, their theoretical and practical aspects. I provide overview of the current status and perspectives in this field. The special emphasis is done on the kinematic power corrections and their importance to reach the consistent factorization formula.

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# Complete NLO Calculation of Forward Single-Inclusive Hadron Production in Proton-Nucleus Collisions

**Authors:** Heikki Mäntysaari[1]; Yossathorn Tawabutr[1]

[1] *University of Jyväskylä*

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We study the single-inclusive particle production from proton-nucleus collisions in the dilute-dense framework of the color glass condensate (CGC) at next-to-leading order (NLO) accuracy. In this regime, the cross section factorizes into hard impact factors and dipole-target scattering amplitude describing the eikonal interaction of the partons in the target color field. For the first time, we combine the NLO impact factors with the dipole amplitude evolved consistently using the NLO Balitsky-Kovchegov (BK) equation with the initial conditions fitted to HERA structure function data.

The resulting neutral pion cross section with all parton channels included are qualitatively consistent with the recent LHCb measurement. In particular, the NLO evolution coupled to the leading order impact factor is shown to produce a large Cronin peak that is not visible in the data, demonstrating the importance of consistently including NLO corrections to all the ingredients. Furthermore, the transverse momentum spectrum is found to be sensitive to the resummation scheme and the running coupling prescription in the BK evolution. This demonstrates how additional constraints for the initial condition of the BK evolution can be obtained from global analyses including both the HERA and LHC data. In light of the upcoming upgrades to the LHC, the dependence of our results on rapidity will also be discussed.

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## NLO corrections to particle production in DIS at small x

**Author:** Jamal Jalilian-Marian[None]

**Corresponding Author:** jamal.jalilian-marian@baruch.cuny.edu

We compute the Next to Leading Order corrections to single and double inclusive hadron production in DIS at small x. We show that rapidity divergences can be absorbed in to Leading Log evolution of dipoles and quadrupoles that describe the target.

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## Towards NLO for forward Drell-Yan production at small transverse momentum in the CGC

**Author:** Pieter Taels[1]

[1] *University of Antwerp*

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In 2308.02449, I have performed the NLO calculation for forward virtual photon plus jet production in the hybrid dilute-dense Color Glass Condensate framework. I give an outline how this calculation can be extended to compute the inclusive forward Drell-Yan cross section at low transverse momentum.

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## Small-x resummation of photon impact factors and virtual photon scattering at high energies

**Author:** Dimitri Colferai[1]

**Co-authors:** Anna Maria Stasto [2]; Wanchen Li

[1] *University of Florence (Italy)*

[2] *Pennsylvania State University (US)*

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After a brief introduction on the peculiarities of QCD in the high-energy regime and the bFKL approach for its description, we proceed to the theoretical
analysis of virtual photon scattering.
Here, the crucial theoretical objects are the photon impact factors and the BFKL gluon Green's function, which up to now are known in leading and
next-to-leading logarithmic approximation.

We improve the theoretical description of the virtual photon cross section by performing the renormalization group improved collinear resummation
of impact factors and Green's function.

Our analysis is consistent with previous impact factor
calculations at NLO, apart from a new term proportional to CF that we find for the longitudinal polarization.

Finally, we use the resummed cross section to compare with the LEP data
and with previous calculations. The resummed result is lower than the leading logarithmic approximation but higher
than the pure next-to-leading one, and is consistent with the experimental data.

arXiv: hep-ph 2311.07443

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## Rapidity-only evolution of TMDs

**Author:** Giovanni Antonio Chirilli[None]

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The most known scheme to regulate the rapidity/UV divergences of the Transverse Momentum Distribution operators due to the infinite light-like gauge links is the Collis Soper Sterman formalism or the Soft Collinear Effective Theory formalism. An alternative procedure is provided by the scheme used in the small-x physics. The corresponding evolution equations differ already in leading order. In view of the future Electron-Ion Collider accelerator, which will probe the TMDs at values of the Bjorken x in the region between small-x to $x \sim 1$, the different formalisms need to be reconciled. I will discuss the conformal properties of TMD operators and present the result of the conformal rapidity evolution of TMD operators in the Sudakov region.
In particular, I will present the calculation of the scale of the coupling constant obtained using the BLM procedure.

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## Single inclusive particle production in pA collisions at forward rapidities at NLO

**Author:** Tolga Altinoluk[None]

**Co-authors:** Nestor Armesto Perez [1]; Michael Lublinsky ; Alexander Kovner

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We revisit the calculation of the cross section for forward inclusive single hadron production in pA collisions within the hybrid approach. We show that the proper framework to perform this calculation beyond leading order is not the collinear factorization, as has been assumed so far, but the TMD factorized framework. Within the TMD factorized approach we show that all the large transverse logarithms appearing in the fixed order calculation, are resummed into the evolution of the TMD PDFs and TMD FFs with factorization scale. The resulting expressions, when written in terms of TMDs evolved to the appropriate, physically well understood factorization scale, contain no additional large logarithms. The absence of any large logarithms in the resummed result should ensure positivity of the cross section and eradicate the persistent problem that have plagued the previous attempts at calculating this observable in the hybrid approach.

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## Inclusive back-to-back dijet in DIS: Sudakov vs high-energy resummation of the WW TMD

**Author:** Paul Caucal[1]

[1] *Subatech, IN2P3*

**Corresponding Author:** paul.caucal@gmail.com

In this talk, I will present a recent computation of the back-to-back dijet cross-section in deep inelastic scattering (DIS) at small $x$ to next-to-leading order (NLO) in the Color Glass Condensate effective field theory [1]. I will show that the result can be factorized into a convolution of the Weizsäcker-Williams gluon transverse momentum dependent distribution function (WW gluon TMD) with a universal soft factor and an NLO coefficient function. The soft factor includes both double and single logarithms in the ratio of the relative transverse momentum $P_\perp$ of the dijet pair to the dijet momentum imbalance $q_\perp$. Likewise, the WW TMD obeys a nonlinear RG equation in $x$ that is kinematically constrained to satisfy both lifetime and rapidity ordering of the projectile. Exact analytical expressions are obtained for the NLO coefficient function of transversely and longitudinally polarized photons. Our results allow for a quantitative separation of the dynamics of Sudakov suppression from that of gluon saturation.

[1] Caucal, Salazar, Schenke, Stebel, Venugopalan, arXiv:2308.00022

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## Walking the path of NNLL corrections to BFKL

**Author:** vittorio del Duca[1]

[1] *INFN LNF*

**Corresponding Author:** vittorio.del.duca@cern.ch

I discuss the results of 2111.14265 on the 3-loop Regge trajectory as well as the ones of 2204.12459 on the central-emission vertex of two gluons

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## Rethinking running coupling in JIMWLK

**Author:** Vladimir Skokov[None]

**Corresponding Author:** vskokov@ncsu.edu

This talk reexamines the running coupling prescription for the small x evolution equations. Our analysis is based on the NLO JIMWLK, which enabled us to identify potentially large logarithms associated with the running coupling contributions. We show that past analyses performed in the framework of BK and JIMWLK attributed several DGLAP-like logarithms to the running coupling corrections. We discuss the DGLAP-like contribution and its resumation; we also propose a resumed expression for the running coupling. The resulting prescription significantly differs from those put forward by Balitsky, and Kovchegov/Weigert.

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## Transverse momentum dependent factorization theorem

**Author:** Alexey Vladimirov[1]

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**Corresponding Author:** alexeyvl@ucm.es

I review the derivation of TMD factorization theorem and the main properties of TMD distributions

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## On the high-energy amplitudes for forward Higgs production in the infinite-top-mass limit

**Authors:** ALESSANDRO PAPA[1]; Maxim Nefedov[2]; Michael Fucilla[None]; Victor S. Fadin[None]

[1] *Università della Calabria & INFN-Cosenza*

[2] *IJClab, Orsay*

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We consider the one-loop effective vertex for the interaction of a gluon with a Reggeized gluon and a Higgs boson in the infinite-top-mass limit. This vertex enters the calculation of differential cross sections for the forward inclusive production of a Higgs boson in high-energy proton-proton collisions, possibly in association with a backward jet or identified hadron, in a framework where next-to-leading logarithms of the energy are resummed to all orders. It is extracted from the high-energy behavior of two-to-two amplitudes for the Higgs production in parton-parton collisions and relies on the validity of the Regge form for these amplitudes. However, the latter assumption if far from obvious in the infinite-top mass limit if the Standard Model gluon-Higgs interaction is described by a 5-dimensional non-renormalizable operator. This issue is carefully discussed. We examine also the applicability of the high-energy calculation technique, based on the separation of rapidity regions, for the extraction of the vertex and the comparison with the calculation based on the Lipatov effective action.

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## Power corrections to back-to-back DIS dijets: Next-to-Eikonal versus twist 3

**Corresponding Author:** guillaume.beuf@gmail.com

For the DIS dijet cross section at low x, Next-to-Eikonal power corrections with respect to the Shockwave/CGC result have been calculated (at LO in alpha_s). In this talk, we will present the expansion of that result in the back-to-back dijet limit, keeping terms of twist 2 or 3. This allows us to check the consistency between the Shockwave/CGC formalism and the TMD factorization formalism beyond leading power in both ways: beyond eikonal accuracy in the Regge limit and beyond twist 2 in the Bjorken limit for back-to-back dijet.

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## QSC approach to BFKL eigenvalue in N=4 SYM

**Corresponding Author:** nikgromov@gmail.com

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## Integrability of planar N=4 SYM and BFKL

**Corresponding Author:** kazakov@lpt.ens.fr

I will review the origins and the formalism of quantum spectral curve (QSC) computing the anomalous dimensions of operators at any coupling in maximally sypersymmetric (N=4) Yang-Mills theory in the planar limit. Then I will demonstrate how to extract from QSC the Regge limit (small coupling, spin close to -1) for the dimension of twist-2 operator and to reproduce the LO BFKL formula.

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## Double logs in the Regge limit

**Corresponding Author:** a.sabio.vera@gmail.com

We will review some aspects of collinear resummations in the BFKL formalism, showing some phenomenological applications and more recent developments from the formal side.

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## Three-loop gluon Regge trajectory in QCD

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## Transverse momentum dependent factorization theorem

**Author:** Alexey Vladimirov[1]

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I review the derivation of TMD factorization theorem and the main properties of TMD distributions

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## Closing discussion