Exclusive Double Drell-Yan Factorization and GTMDs

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Universidad Complutense de Madrid - PANIC2021, 5-10 Sept

Objectives

The goal of this project is to use Soft Collinear Effective Theory (SCET) to obtain a cross-section in terms of Generalized Transverse Momentum Dependent Distributions (GTMDs). For this we:

- Choose the Exclusive Double Drell-Yan process.
- Use the factorization theorem of SCET applying color algebra.
- Remove overlapping regions and obtain functions without rapidity divergences at NLO.

Introduction

An important goal within the QCD community is to understand the inner structure of hadrons and hadronic structures in multiple dimensions. GTMDs are considered mother distributions of both GPDs and TMDs and give broader information about the hadron structure.
In our present work we consider an exclusive process, namely $\Pi N \to N'\gamma^*\gamma^* X \to N'(\ell^+\ell^-)(\ell^+\ell^-)X$ and we show that the SCET factorization theorem gives access to generalized transverse momentum dependent distributions (GTMD), thanks to the particular configuration of soft radiation and power ordering.

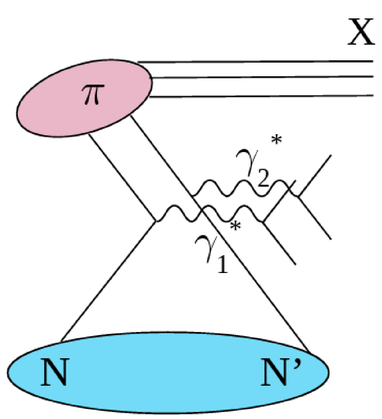

Figure 1:Exclusive DDY at leading power

Hadronic tensor

Hadronic tensor of the exclusive Double Drell-Yan process given by:

$$W_{\mu\nu\alpha\beta} = \sum_X \int dz_{1,2,3} e^{-iq_1\cdot z_1 - iq_2\cdot z_2 + iq_1\cdot z_3} \times \langle \Pi N | J^\dagger_{\alpha,z_1} J^\dagger_{\beta,z_2} | X N' \rangle \langle X N' | J_{\mu,z_3} J_{\nu,0} | \Pi N \rangle \quad (1)$$

SCET

Light-cone coordinates with $n \cdot \bar{n} = 2$.
Matching of the full QCD electromagnetic current:

$$J^{ad}_\mu = \sum_q e_q C(Q^2/\mu^2) \bar{\chi}^{q,d}_{\bar{n}} S^{\dagger dc}_{\bar{n}} \gamma_\mu S^{ca}_n \chi^{q,a}_n \quad (2)$$

Zero-bin subtraction and rapidity divergences

At operator level, the zero-bin subtraction is equivalent to subtracting the relevant soft function to the function of consideration.

$$w_{N'N} = \frac{\hat{w}_{N'N}(x, \vec{b}_\perp)}{S_{DY}(\vec{b}_\perp)} \quad (5)$$

The subtraction of arising rapidity divergences is equivalent to multiplying the functions after zero-bin subtraction by the square root of the relevant soft factor. To this end, one can split the soft factors of Eq. (3) into the product of two square roots and re-arrange factors. This results in the appearance of a new Soft Factor:

$$\Phi(\{\vec{b}_\perp\}) = \frac{\sqrt{S(\{\vec{b}_\perp\})}}{\sqrt{S_{DY}(\vec{b}_{1\perp}, \vec{b}_{2\perp})}\sqrt{S_{DY}(0, \vec{b}_{3\perp})}} \quad (6)$$

Factorized Cross-section

The hadronic tensor in b-space is split as:

$$W_{\mu\nu\alpha\beta} \propto f_\Pi(\{\vec{b}_\perp\}) S(\{\vec{b}_\perp\}) w_{NN'}(\vec{b}_{1\perp}, \vec{b}_{2\perp}) w_{N'N}(\vec{b}_{3\perp}, 0) \quad (3)$$

where:

- $f_\Pi(\{\vec{b}_\perp\})$ is a double parton distribution with four fermion fields.
- $S(\{\vec{b}_\perp\})$ is a soft function with eight Wilson lines.
- $w_{NN'}$ and $w_{N'N}$ are two GTMD correlators.

$$w^{sub}_{N'\cdot N,\mu}(P, \Delta, x, \vec{k}_{n\perp}) = \int \frac{dr^- d^2\vec{r}_\perp}{2(2\pi)^3} e^{-i(-r^- x p^+_a/2 - \vec{r}_\perp\cdot\vec{k}_{\bar{n}_\perp})} \times S^{1/2}_{DY} \langle N' | \bar{\chi}^{a_3}_n(r) \Gamma_\mu \chi^{a_4}_n(0) | N \rangle |_{r^+=0} \quad (4)$$

Color Algebra

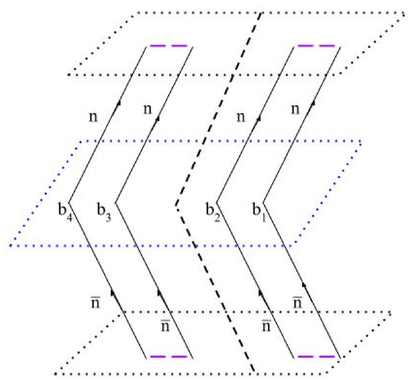

Figure 2:Double Drell-Yan Soft Factor

We make a choice of projectors to obtain color singlets in each function. This leads to a matrix form of the cross-section with the soft factor in terms of a 2x2 matrix and the collinear and anti collinear functions in terms of a column and a row.

Important Result

The factorized cross-section gets a resulting ratio between the square root of the remaining soft factors. This is a new term that has not been shown to exist before and is one of the main conclusions of our study so far.

Conclusion

The present study shows that a factorized cross-section sensitive to the **GTMD** is also dependent on the same soft factor appearing in double parton scattering processes. The factorization theorem depends on several non-perturbative functions. More theoretical work is so necessary for a viable extraction of GTMD.

Additional Information

The rapidity evolution kernel of the two processes coincides for identical color factors. The anomalous dimensions can be found in [1] for the GTMDs and in [2] for the double parton distribution.

References

[1] Miguel G. Echevarria, Ahmad Idilbi, Koichi Kanazawa, Cédric Lorcé, Andreas Metz, Barbara Pasquini, and Marc Schlegel.
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Acknowledgements

The authors are supported by the Spanish Ministry grant PID2019-106080GB-C21, by the European Union Horizon2020 research and innovation program under grant agreement Num. 824093 (STRONG-2020) and by the Community of Madrid and UAH joint grant CM/BG/2021-002 (MultiNuS) within the agreement to fund *Beatriz Galindo* researchers.

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