NLO Corrections to Di-Hadron Production in DIS Using the Color Glass Condensate Formalism

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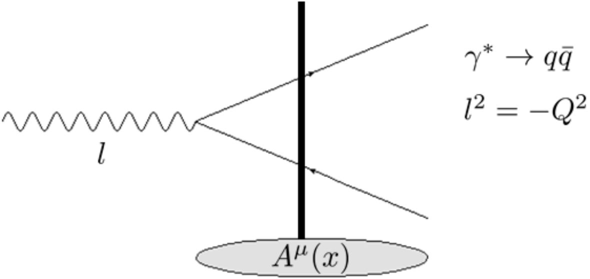
Outline

Di-hadron angular correlations are a sensitive probe of small x saturation physics in the color glass condensate (CGC). The leading order di-hadron production cross section is well known, but future experiments will be sensitive to next-to-leading order (NLO) effects. Here we calculate the NLO corrections to the di-hadron production cross section in DIS.

Leading Order Di-Hadron Production in DIS

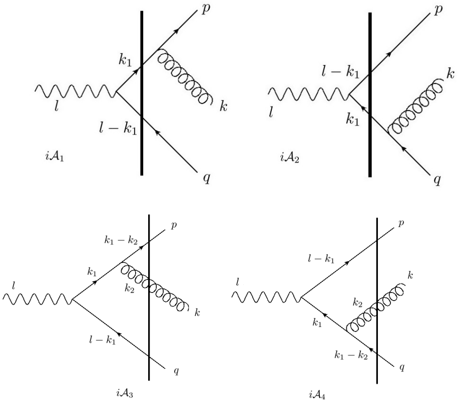
- At high energy, we use the Color Glass Condensate (CGC) effective theory of QCD. This allows us to treat the heavy nucleus as a **classical** background (color) field A^μ.
- The leading order (LO) diagram has the photon split into a $q\bar{q}$ pair which then interacts with the CGC.



- The LO result is well understood [Gelis and Jalilian-Marian, 2003]. Interaction with the background field is via **multiple scattering**.

Real Corrections

- There are four real diagrams to consider in the eikonal limit using the shockwave approximation. [Ayala et al., 2017]



- We need to integrate over the phase space of the outgoing gluon.

Real Corrections

- Results for real corrections using longitudinally polarized photons.

$$\int_k \left\langle \mathcal{A}_{11}^L \right\rangle = \frac{32e^2g^2Q^2N_c^2z_2^3(1-z_2)^2(z_1^2+(1-z_2)^2)}{(2\pi)^2 z_1} \int \mathrm{d}^8x \left[S_{122'1'} - S_{12} - S_{1'2'} + 1\right] e^{ip(x_1'-x_1)} e^{iq(x_2'-x_2)}$$
$$K_0(|x_{12}|Q_2)K_0(|x_{1'2'}|Q_2)G(x_1'-x_1).$$

$$\int_k \left\langle A_{33}^L \right\rangle = \frac{32e^2g^2Q^2N_c^2z_1z_2^3(z_1^2+(1-z_2)^2)}{(2\pi)^4} \int \mathrm{d}^{10}x \left[S_{11'}S_{22'} - S_{13}S_{23} - S_{1'3}S_{2'3} + 1\right] e^{ip(x_1'-x_1)} e^{iq(x_2'-x_2)}$$
$$K_0(QX)K_0(QX')\frac{(\mathbf{x}_3-\mathbf{x}_1)\cdot(\mathbf{x}_3-\mathbf{x}_1')}{(x_3-x_1)^2(x_3-x_1')^2}.$$

$$\int_k \left\langle A_{24}^L \right\rangle = \frac{32e^2g^2Q^2N_c^2z_1^3(1-z_1)(z_2^2+(1-z_1)^2)}{(2\pi)^4} \int \mathrm{d}^{10}x \left[S_{211'3}S_{2'3} - S_{1'3}S_{2'3} - S_{12} + 1\right] e^{ip(x_1'-x_1)} e^{iq(x_2'-x_2)}$$
$$K_0(|x_{12}|Q_1)K_0(QX')\frac{(\mathbf{x}_3-\mathbf{x}_2)\cdot(\mathbf{x}_3-\mathbf{x}_2')}{(x_3-x_2)^2(x_3-x_2')^2}.$$

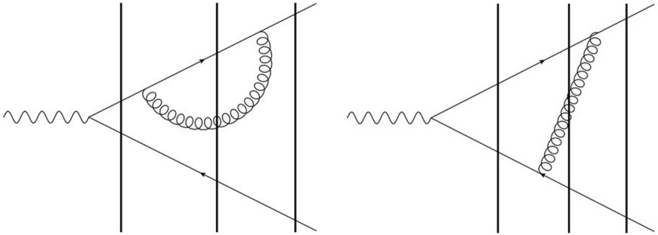
$$Q_i = \sqrt{z_i(1-z_i)}Q, \qquad X = \sqrt{z_2z_1x_{12}^2 + z_3z_1x_{13}^2 + z_3z_2x_{23}^2},$$

$$S_{ij} = \frac{1}{N_c}\mathrm{Tr}_c\left\langle V(x_i)V^\dagger(x_j)\right\rangle, \qquad S_{ijkl} = \frac{1}{N_c}\mathrm{Tr}_c\left\langle V(x_i)V^\dagger(x_j)V(x_k)V^\dagger(x_l)\right\rangle,$$

$$G(x_i-x_j) = \int \frac{\mathrm{d}^2\mathbf{k}}{(2\pi)^2}\frac{e^{i\mathbf{k}\cdot(\mathbf{x}_1-\mathbf{x}_j)}}{\mathbf{k}^2} = \frac{1}{2\pi}\left(\frac{1}{\epsilon} + \gamma_E - \log\left(\pi\mu|x_i-x_j|\right)\right).$$

Virtual Corrections

- There are several virtual diagrams to consider in the eikonal limit using the shockwave approximation. (Here each vertical line indicates a separate diagram)



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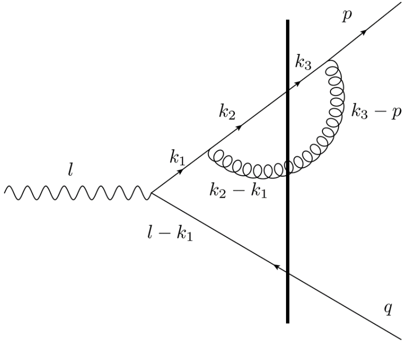
- Some of these diagrams can be handled by inserting standard loop corrections to propagators and vertices. Others need to be worked out in full.



$$\int \frac{\mathrm{d}^4 k_1}{(2\pi)^4} \frac{\mathrm{d}^4 k_2}{(2\pi)^2} \frac{\mathrm{d}^4 k_3}{(2\pi)^4} \bar{u}(p)(ig\gamma^{\mu} t^a) S(k_3, k_2)(ig\gamma^{\nu} t^b) S^0(k_1)(ie\not{\epsilon}(l)) S(k_1 - l, -q) S^0(q)^{-1} v(q)$$
$$G^{ba}_{\nu\mu}(k_2 - k_1, k_3 - p)$$

Ongoing Work

- Derive all NLO contributions to the di-hadron cross section.
- Establish factorization (or lack thereof) in NLO corrections to di-hadron production in DIS.

Thank You

- Thank you for listening!
- We gratefully acknowledge support from the DOE Office of Nuclear Physics through Grant No. DE-FG02-09ER41620 and by PSC-CUNY through grant No. 62185-0050.

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From deep inelastic scattering to proton-nucleus collisions in the color glass condensate model.
Physical Review D, 67(7).