Incoherent Diffractive Dijet Production in Electron DIS off Large Nuclei

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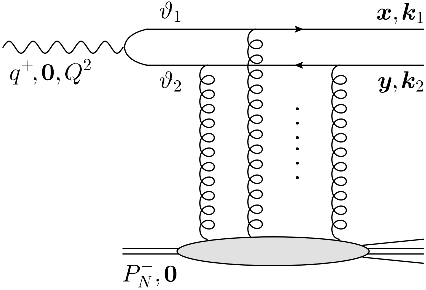
Content

- Dijets in electron DIS off nuclei
- Incoherent diffractive process
- CGC correlator at 4-gluon exchange and in correlation limit
- "Factorization" into hard $\times$ semi-hard factors
- Cross section and angular correlations
- Next to leading kinematic twists
- 2+1 jets contribution

Right moving (RM) virtual photon, left moving (LM) hadron/nucleus

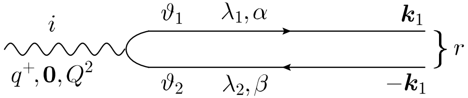
γ^* decay to RM $q\bar{q}$ pair, scattering off strong color field



Size $\boldsymbol{r} = \boldsymbol{x} - \boldsymbol{y}$, center of energy $\boldsymbol{b} = \vartheta_1 \boldsymbol{x} + \vartheta_2 \boldsymbol{y}$

Dijet imbalance $\boldsymbol{\Delta} = \boldsymbol{k}_1 + \boldsymbol{k}_2$, relative momentum $\boldsymbol{P} = \vartheta_2 \boldsymbol{k}_1 - \vartheta_1 \boldsymbol{k}_2$

No scattering $\rightsquigarrow$ no $\boldsymbol{b}$ dependence



$q\bar{q}$ component of transverse γ^* in coordinate space

$$\left|\gamma_T^i(q)\right\rangle_{q\bar{q}} = \sum_{\lambda_{1,2}=\pm 1/2} \sum_{\alpha,\beta=1}^{N_c} \delta_{\alpha\beta} \int_0^1 \mathrm{d}\vartheta_1 \mathrm{d}\vartheta_2\, \delta(1-\vartheta_1-\vartheta_2) \int \mathrm{d}^2\boldsymbol{x}\, \mathrm{d}^2\boldsymbol{y}$$
$$\times\, \widetilde{\psi}^i_{\lambda_1\lambda_2}(\vartheta_1, \boldsymbol{r}) \left|q^\alpha_{\lambda_1}(\vartheta_1, \boldsymbol{x})\, \bar{q}^\beta_{\lambda_2}(\vartheta_2, \boldsymbol{y})\right\rangle$$

with wavefunction (WF)

$$\widetilde{\psi}^i_{\lambda_1\lambda_2}(\vartheta, \boldsymbol{r}) = -\sqrt{\frac{q^+}{2}}\, \frac{iee_f}{(2\pi)^2}\, \varphi^{il}_{\lambda_1\lambda_2}(\vartheta)\, \frac{\bar{Q} r^l}{r} K_1(\bar{Q} r), \qquad \bar{Q}^2 = \vartheta_1\vartheta_2 Q^2$$

φ contains EM vertex helicity structure

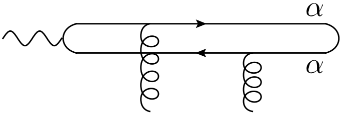
Eikonal multiple scattering of quark off target color field

$$V(\boldsymbol{x}) = \mathrm{T}\exp\left[ig\int \mathrm{d}x^+ t^a A_a^-(x^+, \boldsymbol{x})\right]$$

For the $q\bar{q}$ pair let

$$\delta_{\alpha\beta} \to \big[V(\boldsymbol{x})V^\dagger(\boldsymbol{y}) - \mathbb{1}\big]_{\alpha\beta}$$

Diffraction: close dipole color line in DA (and separately in CCA)



$$\big[V(\boldsymbol{x})V^\dagger(\boldsymbol{y}) - \mathbb{1}\big]_{\alpha\beta} \to \left\{\frac{1}{N_c}\,\mathrm{tr}\big[V(\boldsymbol{x})V^\dagger(\boldsymbol{y})\big] - 1\right\}\delta_{\alpha\beta}$$

$$\equiv \left[S(\boldsymbol{x},\boldsymbol{y}) - 1\right]\delta_{\alpha\beta} = -T(\boldsymbol{x},\boldsymbol{y})\,\delta_{\alpha\beta}$$

Diffractive Dijet Cross Section

In transverse sector

$$\frac{\mathrm{d}\sigma_{\mathrm{D}}^{\gamma_T^* A\to q\bar{q}X}}{\mathrm{d}\vartheta_1\mathrm{d}\vartheta_2\,\mathrm{d}^2\boldsymbol{P}\mathrm{d}^2\boldsymbol{\Delta}} = \frac{\alpha_{\mathrm{em}}\,N_c}{2\pi^2}\left(\sum e_f^2\right)\,\delta(1-\vartheta_1-\vartheta_2)\left(\vartheta_1^2+\vartheta_2^2\right)\int\frac{\mathrm{d}^2\boldsymbol{b}}{2\pi}\,\frac{\mathrm{d}^2\bar{\boldsymbol{b}}}{2\pi}\,\frac{\mathrm{d}^2\boldsymbol{r}}{2\pi}\,\frac{\mathrm{d}^2\bar{\boldsymbol{r}}}{2\pi}$$
$$\times\, e^{-i\boldsymbol{\Delta}\cdot(\boldsymbol{b}-\bar{\boldsymbol{b}})-i\boldsymbol{P}\cdot(\boldsymbol{r}-\bar{\boldsymbol{r}})}\,\frac{\boldsymbol{r}\cdot\bar{\boldsymbol{r}}}{r\bar{r}}\,\bar{Q}^2 K_1\big(\bar{Q}r\big)K_1\big(\bar{Q}\bar{r}\big)\langle T(\boldsymbol{x},\boldsymbol{y})T(\bar{\boldsymbol{y}},\bar{\boldsymbol{x}})\rangle$$

QCD dynamics in correlator $\langle T(\boldsymbol{x},\boldsymbol{y})T(\bar{\boldsymbol{y}},\bar{\boldsymbol{x}})\rangle$

Target average to be taken with CGC wave-function

- $\langle T(\boldsymbol{x},\boldsymbol{y})\rangle\langle T(\bar{\boldsymbol{y}},\bar{\boldsymbol{x}})\rangle \to$ Coherent diffraction
- $\langle T(\boldsymbol{x},\boldsymbol{y})T(\bar{\boldsymbol{y}},\bar{\boldsymbol{x}})\rangle - \langle T(\boldsymbol{x},\boldsymbol{y})\rangle\langle T(\bar{\boldsymbol{y}},\bar{\boldsymbol{x}})\rangle \to$ Incoherent diffraction

Homogeneous target: coherent diffraction $\sim \delta^2(\boldsymbol{\Delta})$ (smeared to $1/R_A$)

Negligible momentum transfer and dijet imbalance

Variance of scattering amplitude

$$\mathcal{W}_{\mathrm{D}} = \langle T(\boldsymbol{x},\boldsymbol{y}) T(\bar{\boldsymbol{y}},\bar{\boldsymbol{x}})\rangle - \langle T(\boldsymbol{x},\boldsymbol{y})\rangle \langle T(\bar{\boldsymbol{y}},\bar{\boldsymbol{x}})\rangle$$

- Pomeron loops: particle number fluctuations in target
- Hot spots (Mäntysaari,Schenke; Demirci, Lappi, Schlichting)
- $1/N_c^2$ color fluctuations (MV model, JIMWLK) (Marquet, Weigert)

Homogeneous target: $\boldsymbol{r}, \bar{\boldsymbol{r}}, \boldsymbol{B} \equiv \boldsymbol{b} - \bar{\boldsymbol{b}}$ independent variables

$$\frac{\mathrm{d}\sigma_{\mathrm{D}}^{\gamma_T^* A \to q\bar{q}X}}{\mathrm{d}\vartheta_1 \mathrm{d}\vartheta_2\, \mathrm{d}^2\boldsymbol{P} \mathrm{d}^2\boldsymbol{\Delta}} = \cdots \frac{S_\perp}{2\pi} \int \frac{\mathrm{d}^2\boldsymbol{B}}{2\pi}\, \frac{\mathrm{d}^2\boldsymbol{r}}{2\pi}\, \frac{\mathrm{d}^2\bar{\boldsymbol{r}}}{2\pi} e^{-i\boldsymbol{\Delta}\cdot\boldsymbol{B} - i\boldsymbol{P}\cdot(\boldsymbol{r}-\bar{\boldsymbol{r}})} \times \frac{\boldsymbol{r}\cdot\bar{\boldsymbol{r}}}{r\bar{r}}\, \bar{Q}^2\, K_1\big(\bar{Q}r\big) K_1\big(\bar{Q}\bar{r}\big) \mathcal{W}_{\mathrm{D}}(\boldsymbol{r},\bar{\boldsymbol{r}},\boldsymbol{B})$$

$\rightsquigarrow$ Non-zero momentum transfer and dijet imbalance

- Energy conservation

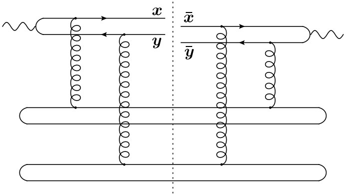
$$x_{\rm gap} P_N^- = \frac{1}{2q^+}\left(\frac{k_{1\perp}^2}{\vartheta_1} + \frac{k_{2\perp}^2}{\vartheta_2} + Q^2\right) \Longrightarrow x_{\rm gap} = \frac{Q^2}{W^2}\left(1 + \underbrace{\frac{P_\perp^2}{\bar{Q}^2}}_{\mathcal{O}(1)} + \underbrace{\frac{\Delta_\perp^2}{Q^2}}_{\ll 1}\right)$$

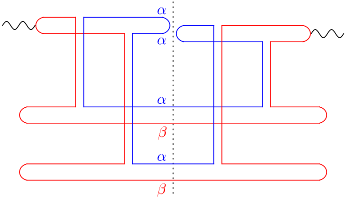
Consider $Y_{\rm gap}$ as independent of $P_\perp$

- Symmetric splitting $\vartheta_1 \sim \vartheta_2 \sim 1/2$

$$\frac{{\rm d}\sigma_{\rm D}^{\gamma_T^* A \to q\bar{q}X}}{{\rm d}\vartheta_1 {\rm d}\vartheta_2\, {\rm d}^2\boldsymbol{P} {\rm d}^2\boldsymbol{\Delta}} = \underbrace{\vartheta_1 \vartheta_2}_{\sim 1/4} \frac{{\rm d}\sigma_{\rm D}^{\gamma_T^* A \to q\bar{q}X}}{{\rm d}\eta_1 {\rm d}\eta_2\, {\rm d}^2\boldsymbol{P} {\rm d}^2\boldsymbol{\Delta}}$$

Assume Gaussian CGC WF, only pieces connecting DA with CCA survive:





$$\frac{g^4}{4N_c^2}\sum_{a,b}\langle\alpha^a_{\boldsymbol{x}}\,\alpha^b_{\bar{\boldsymbol{y}}}\rangle\langle\alpha^a_{\boldsymbol{y}}\,\alpha^b_{\bar{\boldsymbol{x}}}\rangle=\frac{g^4}{4N_c^2}\sum_{a}\langle\alpha^a_{\boldsymbol{x}}\,\alpha^a_{\bar{\boldsymbol{y}}}\rangle\langle\alpha^a_{\boldsymbol{y}}\,\alpha^a_{\bar{\boldsymbol{x}}}\rangle=\sum_{a,b}\frac{g^4}{4N_c^2(N_c^2-1)}\langle\alpha^a_{\boldsymbol{x}}\,\alpha^a_{\bar{\boldsymbol{y}}}\rangle\langle\alpha^b_{\boldsymbol{y}}\,\alpha^b_{\bar{\boldsymbol{x}}}\rangle$$

Target colorless substructures exchange only one gluon in DA (CCA)

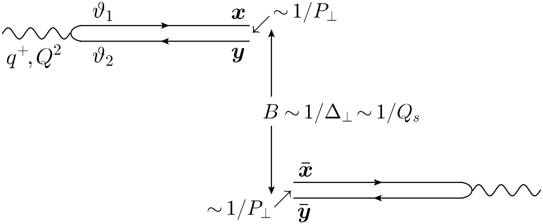
Put together all 16 terms, add/subtract “same point correlators”

$$\mathcal{W}_{\rm D}(\boldsymbol{r},\bar{\boldsymbol{r}},\boldsymbol{B})\simeq\frac{1}{2(N_c^2-1)}\,r^i\bar{r}^j r^k\bar{r}^l\partial^i\partial^j\mathcal{T}(\boldsymbol{B})\partial^k\partial^l\mathcal{T}(\boldsymbol{B})$$

Incoherent scattering $\leftrightarrow$ $1/N_c^2$ suppression

Extend above to include saturation in the correlation limit

$P_\perp \gg \Delta_\perp, Q_s \longleftrightarrow r, \bar{r} \ll B, 1/Q_s$



$\langle TT \rangle$ known at finite-N_c, expand for small $r, \bar{r}$, let B arbitrary

$$\mathcal{W}_{\mathrm{D}}(\boldsymbol{r}, \bar{\boldsymbol{r}}, \boldsymbol{B}) \simeq \frac{C_F}{2N_c^3} \underbrace{r^i \bar{r}^j r^k \bar{r}^l}_{\text{hard}} \underbrace{\Phi(\mathcal{S}_g(B)) \, [\partial^i \partial^j \ln \mathcal{S}_g(B)] \, [\partial^k \partial^l \ln \mathcal{S}_g(B)]}_{\text{semi-hard}}$$

Same structure as in 4 gluon exchange approxximation

Angular correlation between $\boldsymbol{r}$ and $\boldsymbol{B}$, hence between $\boldsymbol{P}$ and $\boldsymbol{\Delta}$

Hard integrals over $\boldsymbol{r}$,$\bar{\boldsymbol{r}}$ factorize from semi-hard over $\boldsymbol{B}$

Factorization holds at cross section (not at amplitude) level

$$\frac{\mathrm{d}\sigma_{\mathrm{D}}^{\gamma_T^* A \to q\bar{q}X}}{\mathrm{d}\vartheta_1 \mathrm{d}\vartheta_2\, \mathrm{d}^2\boldsymbol{P} \mathrm{d}^2\boldsymbol{\Delta}} = \frac{S_\perp \alpha_{\mathrm{em}}\, N_c}{4\pi^3} \left(\sum e_f^2\right) \delta(1-\vartheta_1-\vartheta_2) \left(\vartheta_1^2 + \vartheta_2^2\right) \frac{C_F}{2N_c^3} \left|\mathcal{A}_{\mathrm{D}}^T\right|^2$$

Reduced cross section

$$\boxed{\left|\mathcal{A}_{\mathrm{D}}^T\right|^2 = \underbrace{H_T^{iks}(\boldsymbol{P}, \bar{Q})\, H_T^{jls*}(\boldsymbol{P}, \bar{Q})}_{\text{hard}}\, \underbrace{\mathcal{G}_{\mathrm{D}}^{ij,kl}(\boldsymbol{\Delta})}_{\text{semi}-\text{hard}}}$$

Hard factor trivial to calculate

$$H_T^{iks}(\boldsymbol{P}, \bar{Q}) = -\frac{2i}{(P_\perp^2 + \bar{Q}^2)^2} \left(\delta^{ik} P^s + \delta^{is} P^k + \delta^{ks} P^i\right) + \frac{8i P^i P^k P^s}{(P_\perp^2 + \bar{Q}^2)^3}$$

Scales like $1/P_\perp^3$ for $\bar{Q} \sim P_\perp$

Semi-Hard Function and its Decomposition

Semi-hard factor with dimension of mass squared

$$\mathcal{G}_{\mathrm{D}}^{ij,kl}(\boldsymbol{\Delta}) = \int \frac{\mathrm{d}^2\boldsymbol{B}}{2\pi}\, e^{-i\boldsymbol{\Delta}\cdot\boldsymbol{B}}\, \Phi(\mathcal{S}_g(B))\, [\partial^i\partial^j \ln \mathcal{S}_g(B)]\, [\partial^k\partial^l \ln \mathcal{S}_g(B)]$$

Square of structure $\partial^i\partial^j \ln \mathcal{S}_g(B)$ appearing in WW gluon TMD

Tensor decomposition of $\mathcal{G}_{\mathrm{D}}^{ij,kl}(\boldsymbol{\Delta})$ decomposed into terms with δ and $\boldsymbol{\Delta}$

$\rightsquigarrow$ Four scalar coefficients $\mathcal{G}_{\mathrm{D}}^{(n)}(\Delta_\perp)$: analogs of xG and xh (unpolarized and linearly polarized dsitributions gluon distribution in inclusive dijets)

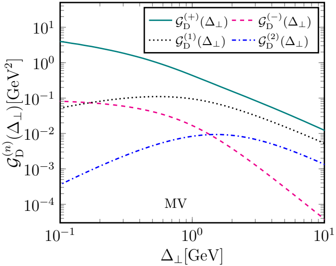
$$\mathcal{G}_{\mathrm{D}}^{[+,-,1,2]} = \int \frac{\mathrm{d}^2\boldsymbol{B}}{2\pi}\, e^{-i\boldsymbol{\Delta}\cdot\boldsymbol{B}}\, \Phi(\mathcal{S}_g(B))[F_+^2, F_-^2, F_+F_-\cos 2\phi_{\Delta B}, F_-^2\cos 4\phi_{\Delta B}]$$

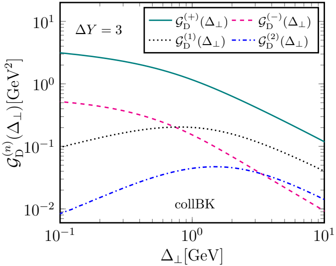
(Reduced) Cross Section

Compact analytic expression in correlation limit $P_\perp \gg \Delta_\perp, Q_s$

$$\boxed{\begin{aligned}\left|\mathcal{A}_{\mathrm{D}}^{T}\right|^2 = &\ \frac{4P_\perp^2(3\bar{Q}^4 + P_\perp^4)}{(P_\perp^2+\bar{Q}^2)^6}\,\mathcal{G}_{\mathrm{D}}^{(+)}(\Delta_\perp) + \frac{8\bar{Q}^4 P_\perp^2}{(P_\perp^2+\bar{Q}^2)^6}\,\mathcal{G}_{\mathrm{D}}^{(-)}(\Delta_\perp)\\ &+ \frac{16\bar{Q}^2 P_\perp^2(\bar{Q}^2 - P_\perp^2)\cos 2\phi}{(P_\perp^2+\bar{Q}^2)^6}\,\mathcal{G}_{\mathrm{D}}^{(1)}(\Delta_\perp) - \frac{8\bar{Q}^2 P_\perp^4 \cos 4\phi}{(P_\perp^2+\bar{Q}^2)^6}\,\mathcal{G}_{\mathrm{D}}^{(2)}(\Delta_\perp)\end{aligned}}$$

- Simple 1D integration (Bessel transform) to get $\mathcal{G}_{\mathrm{D}}^{(n)}(\Delta_\perp)$
- Dependence on $P_\perp$, $\Delta_\perp$ and also on $\phi = \angle(\boldsymbol{P}, \boldsymbol{\Delta})$
- For $\bar{Q} \sim P_\perp$ all hard factors $\sim 1/P_\perp^6$, like in exclusive dijets
- One-to-one correspondence between angles $\phi_{\Delta B}$ and ϕ: $\cos n\phi_{\Delta B} \rightsquigarrow \cos n\phi$

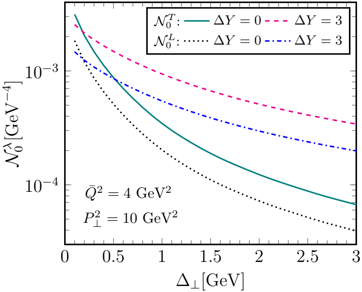


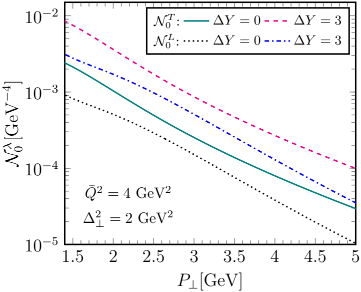


Analytic estimates in MV model $S_g(B) = \exp\left[-\frac{B^2 Q_A^2}{4} \ln \frac{4}{B^2\Lambda^2}\right]$

$$\mathcal{G}_{\rm D}^{(+)} \simeq \begin{cases} \dfrac{2Q_A^4}{\Delta_\perp^2} & \text{for} \quad \Delta_\perp \gg Q_s \\ Q_A^2 \left(\ln^2 \dfrac{Q_s^2}{\Lambda^2} - \ln^2 \dfrac{\Delta_\perp^2}{\Lambda^2}\right) & \text{for} \quad \Delta_\perp \ll Q_s \end{cases}$$

Overall $\mathcal{G}_{\rm D}^{(+)} > \mathcal{G}_{\rm D}^{(1)} \gg \mathcal{G}_{\rm D}^{(2)}$, while $\mathcal{G}_{\rm D}^{(-)}$ may be neglected

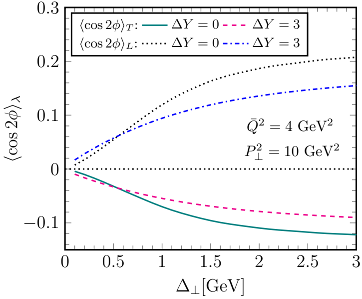


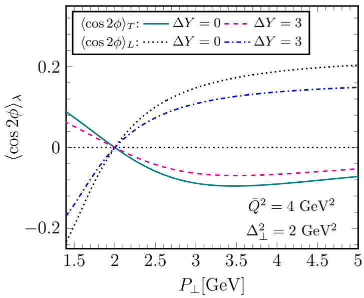


$$\boxed{\frac{\mathrm{d}\sigma_{\mathrm{D}}^{\gamma_\lambda^* A\to q\bar{q}X}}{\mathrm{d}\vartheta_1\mathrm{d}\vartheta_2\mathrm{d}^2\boldsymbol{P}\mathrm{d}^2\boldsymbol{\Delta}} \propto \frac{\alpha_{\mathrm{em}}S_\perp}{N_c}\,\frac{Q_s^2}{P_\perp^6}\,\underbrace{f(\Delta_\perp/Q_s)}_{\mathrm{dim/less}}}$$

- If $\Delta_\perp \sim Q_s$, double suppression $1/N_c^2 \times Q_s^2/P_\perp^2$ w.r.t. inclusive

Angular Correlation $\langle \cos 2\phi \rangle$

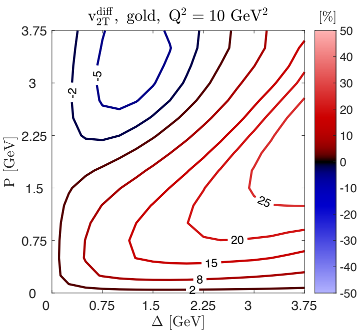


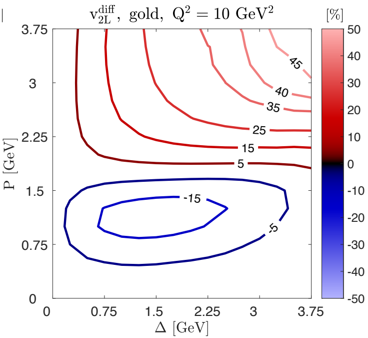


$$\langle \cos 2\phi \rangle_T \simeq \frac{2\bar{Q}^2(\bar{Q}^2 - P_\perp^2)}{3\bar{Q}^4 + P_\perp^4} \frac{\mathcal{G}_{\rm D}^{(1)}(\Delta_\perp)}{\mathcal{G}_{\rm D}^{(+)}(\Delta_\perp)}, \quad \langle \cos 2\phi \rangle_L \simeq \frac{4P_\perp^2(P_\perp^2 - \bar{Q}^2)}{\bar{Q}^4 - 2\bar{Q}^2 P_\perp^2 + 5P_\perp^4} \frac{\mathcal{G}_{\rm D}^{(1)}(\Delta_\perp)}{\mathcal{G}_{\rm D}^{(+)}(\Delta_\perp)}$$

- Saturation leads to suppression of anisotropy
- Both T and L vanish at $P_\perp = \bar{Q}$

Exact numerical solution in for arbitrary $P_\perp, \Delta_\perp$ and Q_s (Mäntysaari et al)





- Very good agreement in longitudinal sector
- Puzzling in the transverse sector:
  - zero not at $P_\perp = \bar{Q}$
  - for fixed $P_\perp > \bar{Q}$, minimum as a function of $\Delta_\perp$

Three scales, classify corrections (Altinoluk, Boussarie, Fujii, Kotko, Marquet, Mehtar-Tani, Watanabe...)

- Genuine saturation twists $(Q_s^2/P_\perp^2)^n$: numerical implementation
- Kinematic twists $(\Delta_\perp^2/P_\perp^2)^n$: resummation $\rightsquigarrow$ improved TMD
  Done for inclusive dijets (Boussarie, Mäntysaari, Salazar, Schenke)

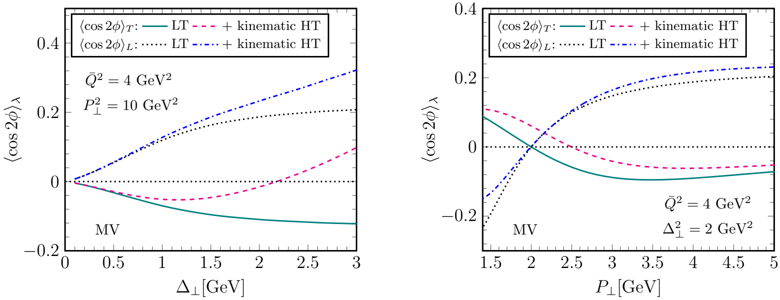
Calculate just first kinematic twist

$$\delta\left|\mathcal{A}_{\mathrm{D}}^{T}\right|^2 = \frac{1}{6}\, H_T^{ikmns}(\boldsymbol{P},\bar{Q})\, H_T^{jls*}(\boldsymbol{P},\bar{Q})\, \mathcal{G}_{\mathrm{D}}^{ij,klmn}(\boldsymbol{\Delta})$$

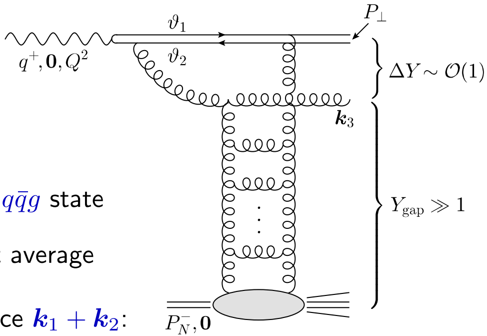
$$\mathcal{G}_{\mathrm{D}}^{ij,klmn}(\boldsymbol{\Delta}) = \int \frac{\mathrm{d}^2\boldsymbol{B}}{2\pi}\, e^{-i\boldsymbol{\Delta}\cdot\boldsymbol{B}}\, \Phi((\mathcal{S}_g(B))[\partial^i\partial^j \ln\mathcal{S}_g(B)][\partial^k\partial^l\partial^m\partial^n \ln\mathcal{S}_g(B)]$$

Next to leading kinematic twist vs leading twist

- $\delta\mathcal{W}_{\mathrm{D}}/\mathcal{W}_{\mathrm{D}} \sim r^2/B^2 \sim \Delta_\perp^2/P_\perp^2$ ✓



- No qualitative change in longitudinal sector ✓
- New features in transverse sector
  - for fixed $P_\perp$, minimum as a function of $\Delta_\perp$ ✓
  - sign change at $P_\perp$ value which increases with $\Delta_\perp$ ✓



- Diffractive projection to $q\bar{q}g$ state
- Connected part in target average

Two sources for dijet imbalance $\boldsymbol{k}_1 + \boldsymbol{k}_2$:

- Momentum transfer from nucleus
- Kick due to gluon emission $\boldsymbol{k}_3$

If $k_{3\perp} \ll P_\perp$, then gluon dipole configuration scatters

Keep $1/N_c^2$ piece of $\langle T_g T_g \rangle$ (Kovchegov, Wertepny)

- Simple, but illustrative case: $P_\perp \gg k_{3\perp} \gg \Delta_\perp, Q_s$

  $\langle T_g T_g \rangle$ simplifies, analytical calculation

$$\frac{\mathrm{d}\sigma_{\mathrm{D}}^{\gamma_T^* A \to q\bar{q}gX}}{\mathrm{d}^2\boldsymbol{P}\mathrm{d}^2\boldsymbol{\Delta}\mathrm{d}^2\boldsymbol{k}_3} \propto \frac{1}{P_\perp^4}\frac{Q_s^4}{\Delta_\perp^2}\frac{1}{k_{3\perp}^4}$$

- Gluon integration dominated by lower limit

  Eventually exact integration should be determined by $k_{3\perp} \sim \Delta_\perp$

$$\boxed{\frac{\mathrm{d}\sigma_{\mathrm{D}}^{\gamma_T^* A \to q\bar{q}gX}}{\mathrm{d}^2\boldsymbol{P}\mathrm{d}^2\boldsymbol{\Delta}} \propto \frac{1}{P_\perp^4}\frac{Q_s^4}{\Delta_\perp^4}}$$

  Larger than $q\bar{q}$ component

Conclusion

- Incoherent diffractive dijet production
- Color fluctuations source of incoherency
- Correlation limit jet momenta $P_\perp \gg$ momentum transfer $\Delta_\perp$
- Power-law tail at high $\Delta_\perp$, saturation at small $\Delta_\perp$
- Process with extra gluon dominates in twist expansion in hard jet momentum

Some General Questions

- CGC (small-x) vs Collinear Factorization
- Odderon, perturbative vs non-perturbative
- Measuring di-jets and di-hadrons at the EIC
- Relevant value of Q_s at the EIC, especially for exclusive processes
- Coherent vs Incoherent Diffraction