Inclusive photon+di-jet production in p+A and e+A collisions at small x

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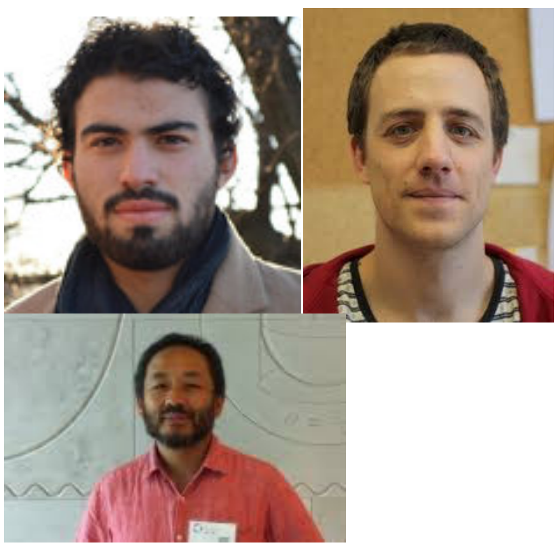
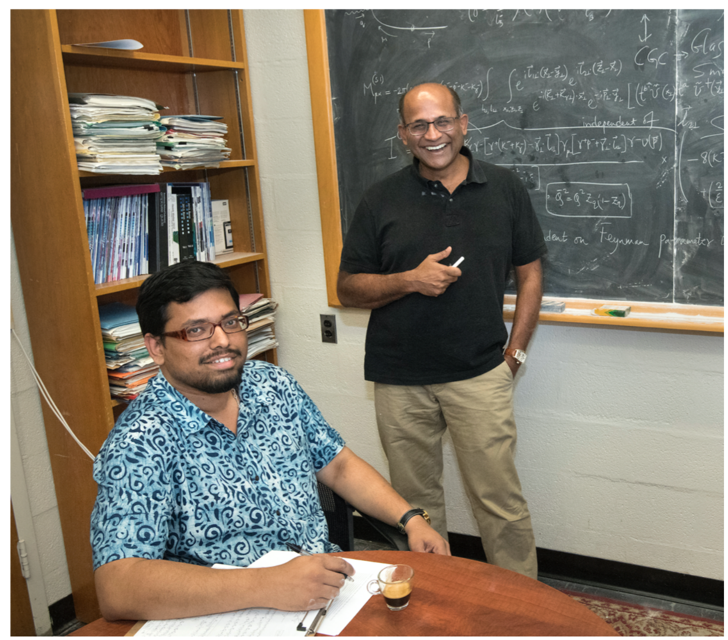
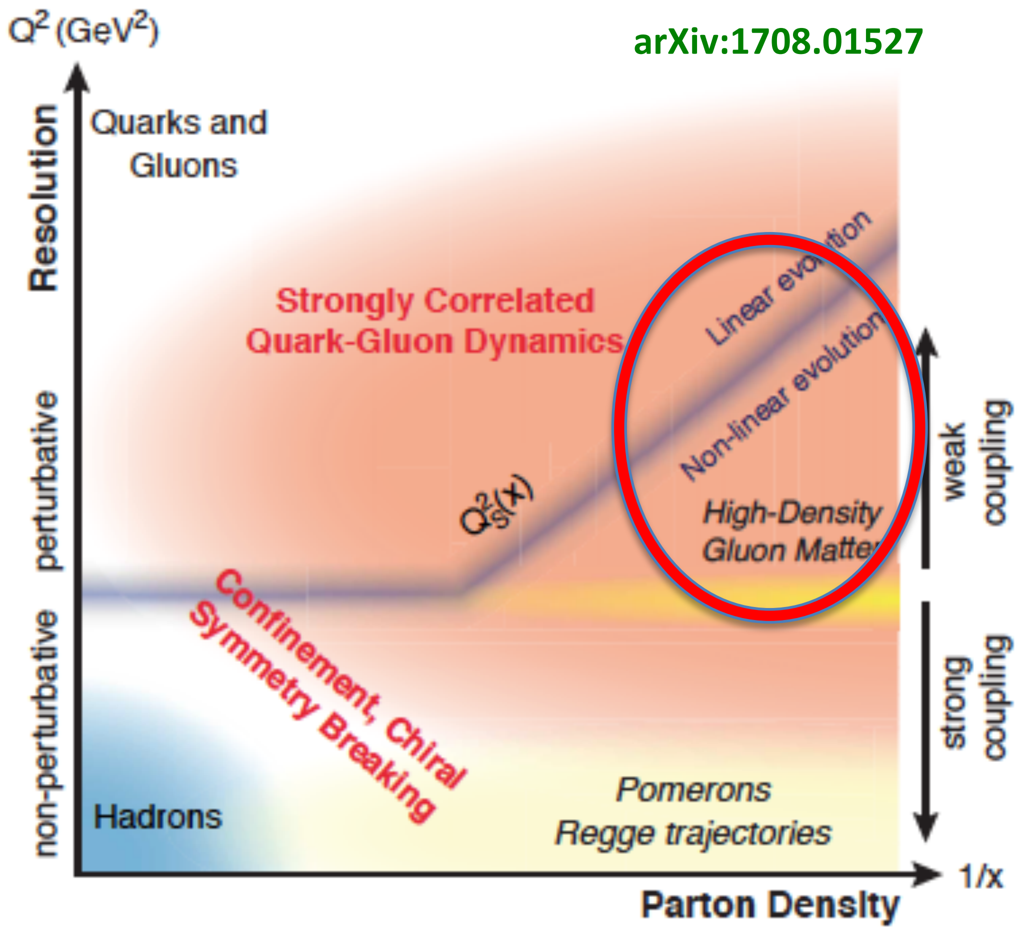




Hard Probes 2018, Aix-les-Bains, October 1-5, 2018

The CGC EFT

arXiv:1708.01527



EFT in the Regge limit of $Q^2 >> \Lambda_{QCD}^2$ to study QCD matter at high parton densities

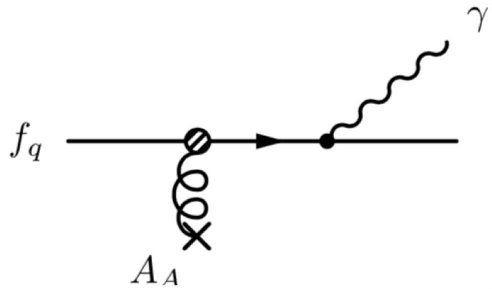
Photons are clean probes of dynamical many-body gluon correlations

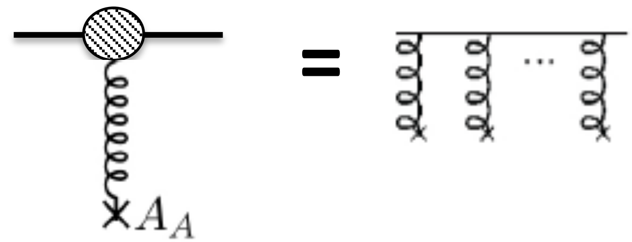
Uncover universal structures from p+A and e+A collisions

Dilute-dense CGC framework for p+p/p+A collisions

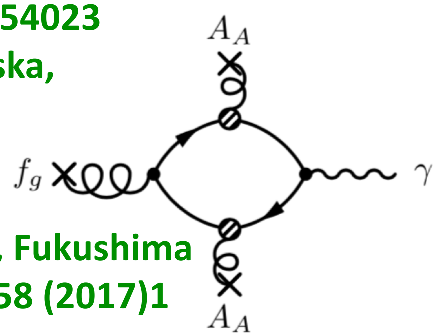
LO contribution:
computed previously

Gelis,Jalilian-Marian,PRD66 (2002) 014021
Ducloue,Lappi,Mantysaari, PRD97 (2018)054023
Altinoluk,Armesto,Kovner,Lublinsky,Petreska, JHEP1804(2018)063

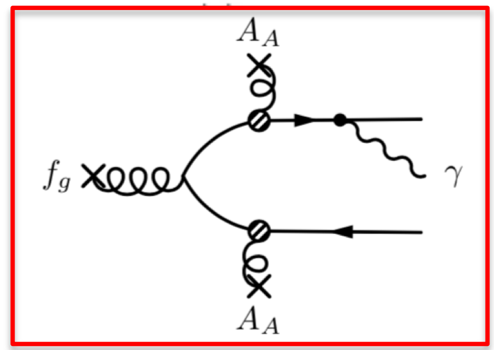




NLO contributions:



Benic, Fukushima NPA958 (2017)1



Benic,Fukushima, Garcia-Montero,RV, JHEP 1701(2017) 115

QCD Yang-Mills Eqns: $$[D_\mu, F^{\mu\nu}](x) = g\delta^{\nu+}\delta(x^-)\rho_p(\boldsymbol{x}_\perp) + g\delta^{\nu-}\delta(x^+)\rho_A(\boldsymbol{x}_\perp)$$

Solve for gauge fields and propagators in the dilute-dense approximation: $\frac{\rho_p}{k_{\perp 1}^2} << 1 \quad \frac{\rho_A}{k_{\perp 2}^2} \sim 1$

Blaizot,Gelis,RV, hep-ph/0402257

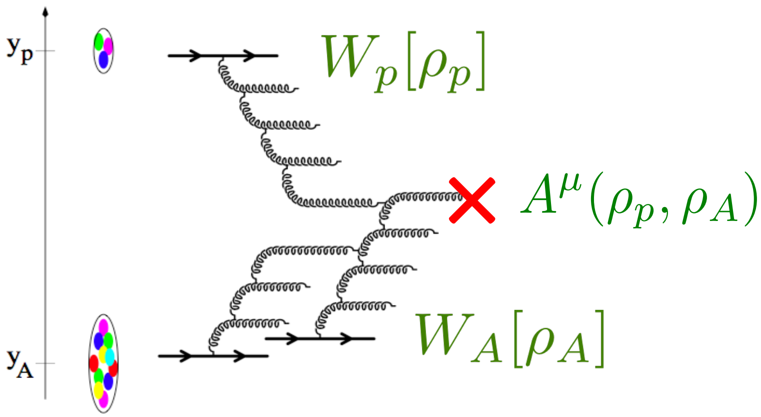
Inclusive photon+di-jet amplitude at NLO

$$\mathcal{M}^\mu(\boldsymbol{p},\boldsymbol{q},\boldsymbol{k}_\gamma) = -q_f e g^2 \int_{\boldsymbol{k}_\perp \boldsymbol{k}_{1\perp}} \int_{\boldsymbol{x}_\perp \boldsymbol{y}_\perp} \frac{\rho_p^a(\boldsymbol{k}_{1\perp})}{\boldsymbol{k}_{1\perp}^2} \mathrm{e}^{\mathrm{i}\boldsymbol{k}_\perp\cdot\boldsymbol{x}_\perp + \mathrm{i}(\boldsymbol{P}_\perp - \boldsymbol{k}_\perp - \boldsymbol{k}_{1\perp})\cdot\boldsymbol{y}_\perp}$$
$$\times\, \bar{u}(\boldsymbol{q})\{T_g^\mu(\boldsymbol{k}_{1\perp})U(\boldsymbol{x}_\perp)^{ba}t^b + T_{q\bar{q}}^\mu(\boldsymbol{k}_\perp,\boldsymbol{k}_{1\perp})\tilde{U}(\boldsymbol{x}_\perp)t^a\tilde{U}^\dagger(\boldsymbol{y}_\perp)\}v(\boldsymbol{p})$$

Lightlike Wilson lines $\tilde{U}(\boldsymbol{x}_\perp) = \mathcal{P}_+ \exp\left[-\mathrm{i}g^2\int_{-\infty}^{\infty} \mathrm{d}z^+ \frac{1}{\nabla_\perp^2}\rho_A(z^+,\boldsymbol{x}_\perp)\cdot t\right]$

Dirac structures $T_g^\mu(\boldsymbol{k}_{1\perp})$ & $T_{q\bar{q}}^\mu$

Inclusive photon cross-section



Color distributions evolved in rapidity via the JIMWLK functional RG equation

$$\langle \mathcal{O} \rangle = \int [d\rho_A][d\rho_B] W_p[\rho_p]\, W_A[\rho_A]\, \mathcal{O}[\rho_p,\rho_A]$$

unintegrated gluon distribution

Target forward dipole amplitude

$$\frac{\mathrm{d}\sigma^{\mathrm{NLO}}}{\mathrm{d}^2\boldsymbol{k}_{\gamma\perp}\mathrm{d}\eta_\gamma} = S_\perp \sum_f \frac{\alpha_e\alpha_S N_c^2 q_f^2}{64\pi^4(N_c^2-1)} \int_{\eta_q\eta_p}\int_{\boldsymbol{q}_\perp\boldsymbol{p}_\perp\boldsymbol{k}_{1\perp}\boldsymbol{k}_\perp} \frac{\varphi_p(Y_p,\boldsymbol{k}_{1\perp})}{\boldsymbol{k}_{1\perp}^2} \tilde{N}_{t,Y_t}(\boldsymbol{k}_\perp)\tilde{N}_{t,Y_t}(\boldsymbol{P}_\perp-\boldsymbol{k}_{1\perp}-\boldsymbol{k}_\perp)$$
$$\times \left[2\tau_{g,g}(\boldsymbol{k}_{1\perp};\boldsymbol{k}_{1\perp}) + 4\tau_{g,q\bar{q}}(\boldsymbol{k}_{1\perp};\boldsymbol{k}_\perp,\boldsymbol{k}_{1\perp}) + 2\tau_{q\bar{q},q\bar{q}}(\boldsymbol{k}_\perp,\boldsymbol{k}_{1\perp};\boldsymbol{k}_\perp,\boldsymbol{k}_{1\perp})\right],$$

Results obtained by solving the rcBK equation

Benic, Fukushima, Garcia-Montero, RV, JHEP 1701(2017) 115

For $k_{\perp\gamma} >> Q_S$ recover kt-factorization

$$\frac{\mathrm{d}\sigma^\gamma}{\mathrm{d}^6K_\perp\mathrm{d}^3\eta_K} = \frac{\alpha_e\alpha_S^2 q_f^2}{256\pi^8 N_c(N_c^2-1)} \int_{\boldsymbol{k}_{1\perp}\boldsymbol{k}_{2\perp}} (2\pi)^2\delta^{(2)}(\boldsymbol{P}_\perp-\boldsymbol{k}_{1\perp}-\boldsymbol{k}_{2\perp}) \frac{\varphi_p(Y_p,\boldsymbol{k}_{1\perp})\varphi_A(Y_A,\boldsymbol{k}_{2\perp})}{\boldsymbol{k}_{1\perp}^2\boldsymbol{k}_{2\perp}^2}\Theta(\boldsymbol{k}_{1\perp},\boldsymbol{k}_{2\perp})$$

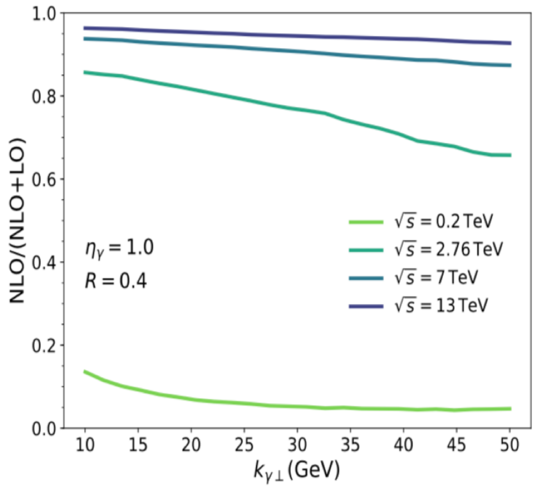
… and collinear factorization

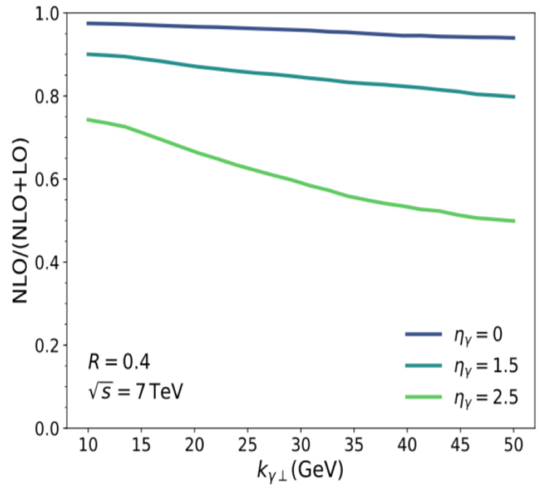
$$\frac{d\sigma^\gamma}{d^2\boldsymbol{k}_\gamma d\eta_{k_\gamma}} = \frac{1}{16}\int_0^\infty \frac{\mathrm{d}q^+}{q^+}\frac{\mathrm{d}p^+}{p^+}\int_{\boldsymbol{q}_\perp\boldsymbol{p}_\perp}(2\pi)^2\delta^{(2)}(\boldsymbol{p}_\perp+\boldsymbol{q}_\perp+\boldsymbol{k}_{\gamma\perp})\, x_p f_{g,p}(x_p,Q^2)\, x_A f_{g,A}(x_A,Q^2)\, |\mathcal{M}_{gg\to q\bar{q}\gamma}|^2$$

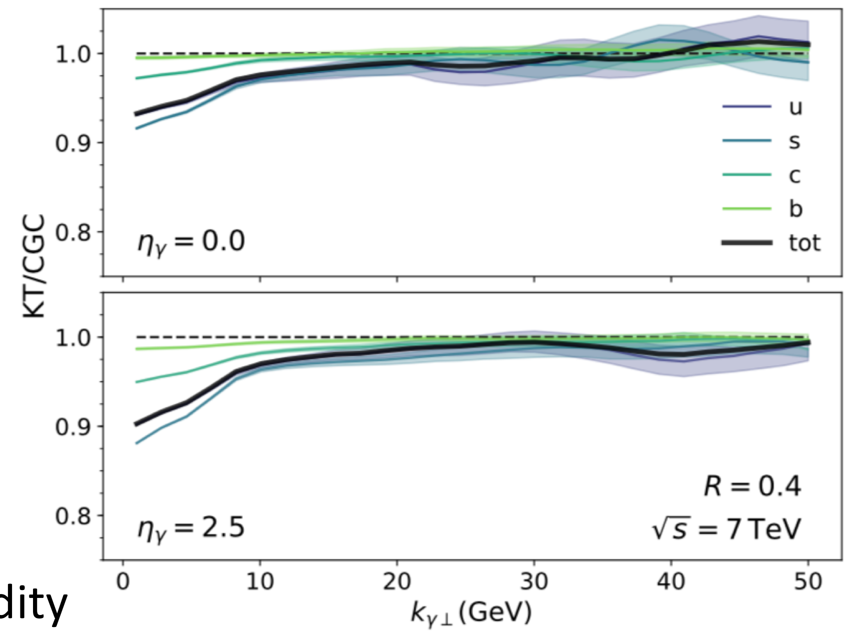
$$|\mathcal{M}_{gg\to q\bar{q}\gamma}|^2 \equiv \lim_{\substack{\boldsymbol{k}_{1\perp}\to 0\\ \boldsymbol{k}_{2\perp}\to 0}} \frac{q_f^2\,\alpha_e\,\alpha_S^2}{N_c(N_c^2-1)}\frac{\Theta(\boldsymbol{k}_{1\perp},\boldsymbol{k}_{2\perp})}{\boldsymbol{k}_{1\perp}^2\boldsymbol{k}_{2\perp}^2}$$

Small x nuclear gluon distribution

Results for inclusive photon production in p+p

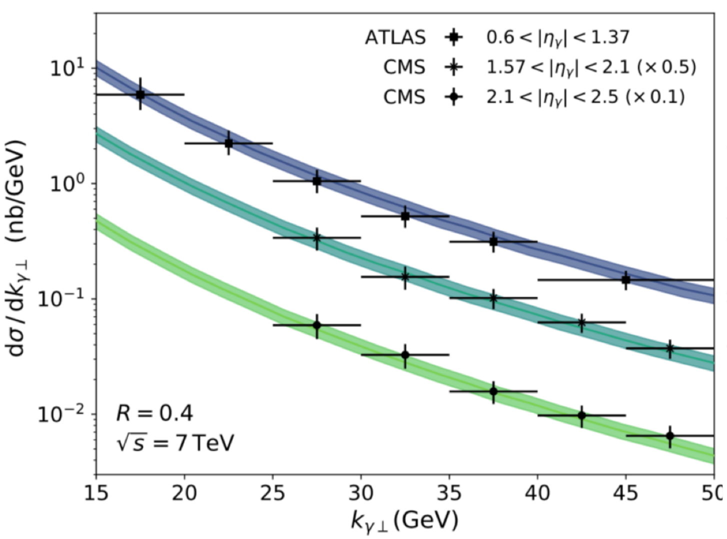


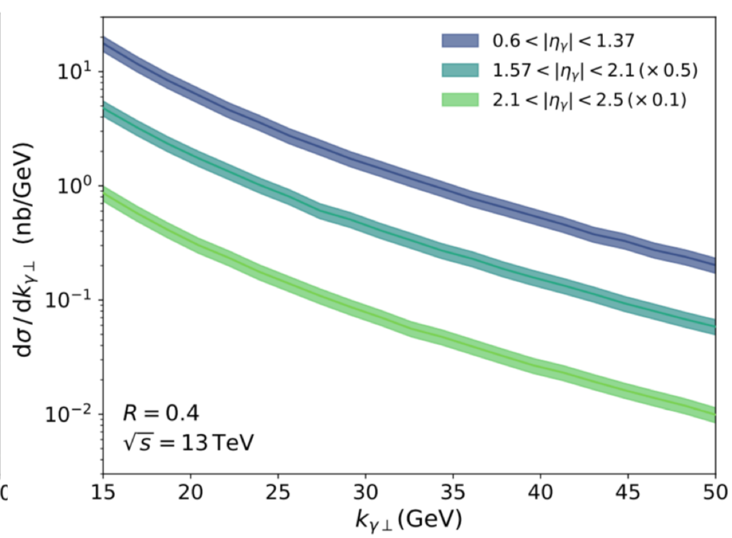




- NLO dominates with increasing energy for fixed rapidity
- At LHC, LO fraction increases towards fragmentation region
- Dilute-dense framework includes ***both*** small x –resummation and saturation effects. However latter in p+p at most ~ 10%

Benic,Fukushima, Garcia-Montero, Venugopalan, arXiv:1807.03806



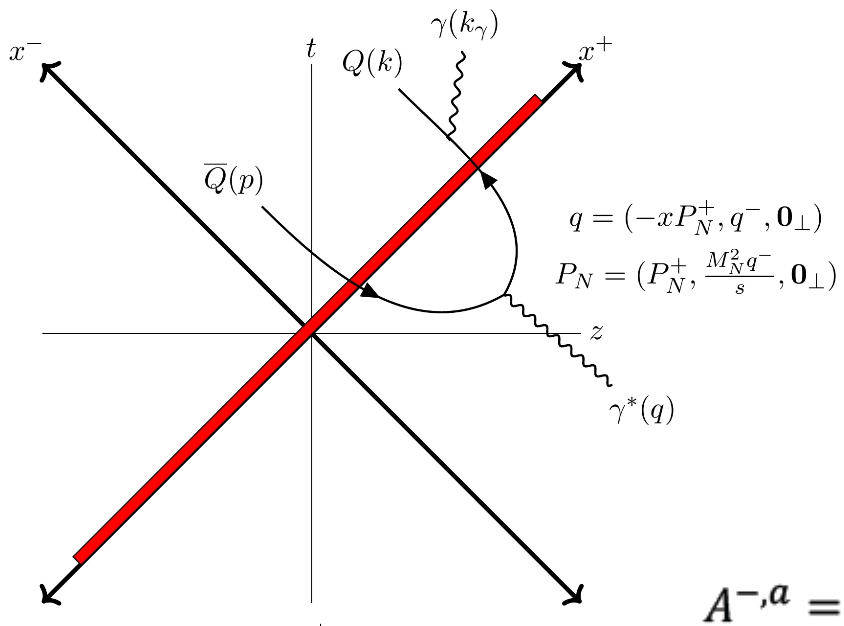


Expect p+A to be more sensitive to saturation effects

K factor of 2.4 - need to go to "NNLO" in this framework

Easier to first look at DIS…

Inclusive photon+dijet production in e+A DIS

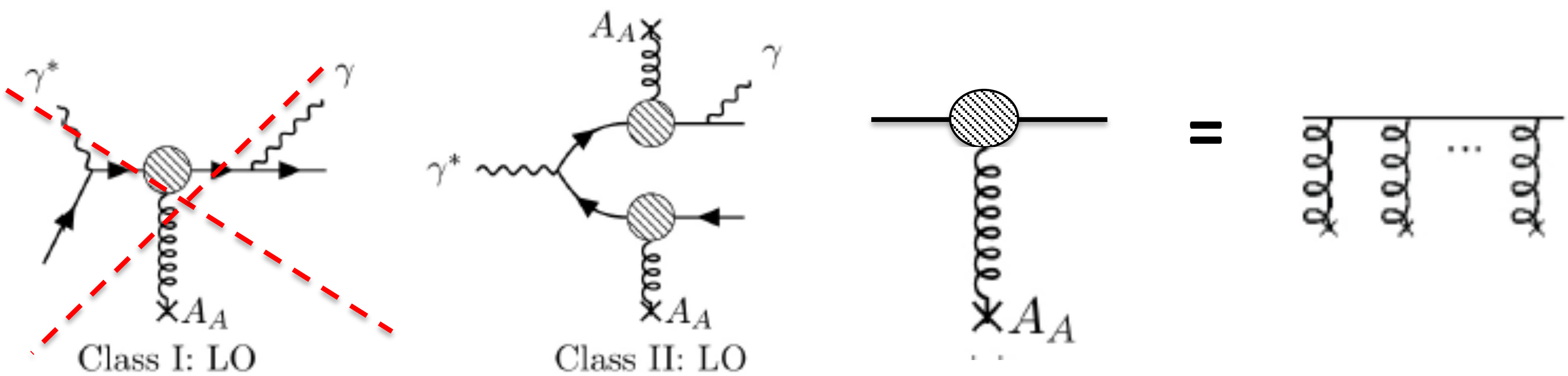


Right moving nucleus with momentum P_N^+ is Lorentz contracted in x^- direction

Glue fields satisfy Yang-Mills eqns.

$$[D_\mu, F^{\mu\nu}](x) = g\delta^{\nu +}\delta(x^-)\rho_A(x_\perp)$$

$A^{-,a} = 0$, $F_{ij}^a = 0$ with $A^{+,a}, A^{i,a}$ static (independent of x^+)



Suppressed at small x

Inclusive photon+dijet production in DIS at LO

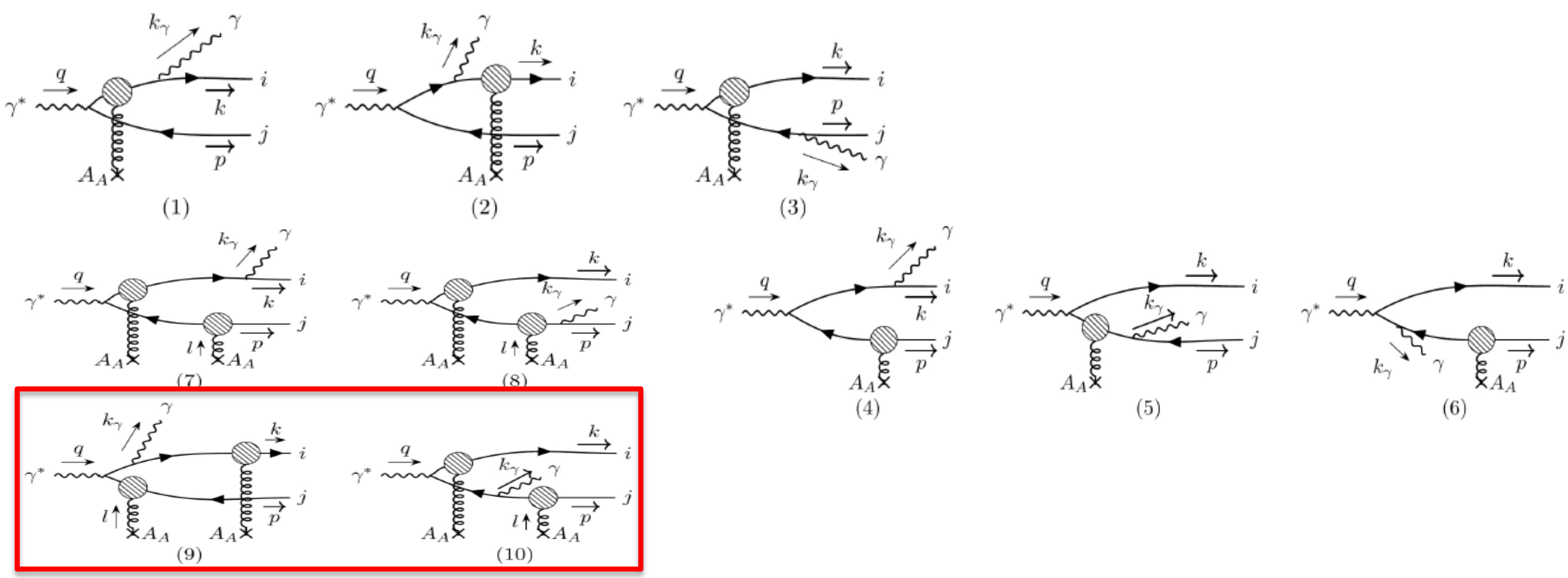
$$e(\tilde{l}) + A(P) \longrightarrow e(\tilde{l}') + Q(k) + \bar{Q}(p) + \gamma(k_\gamma) + X$$

Roy, RV; JHEP 1805 (2018) 013

$$\frac{\mathrm{d}\sigma}{\mathrm{d}x\mathrm{d}Q^2} = \frac{2\pi y^2}{64\pi^3 Q^2}\frac{\mathrm{d}^3\mathbf{k}}{(2\pi)^3 2E_k}\frac{\mathrm{d}^3\mathbf{p}}{(2\pi)^3 2E_p}\frac{\mathrm{d}^3\mathbf{k}_\gamma}{(2\pi)^3 2E_{k_\gamma}}\frac{1}{2q^-}\left(\frac{1}{2}\sum_{\mathrm{spins},\lambda}\left\langle|\tilde{\mathcal{M}}|^2\right\rangle_{Y_A}\right)(2\pi)\delta(P^- - q^-)$$

$$\frac{1}{2}\sum_{\mathrm{spins},\lambda}\langle|\tilde{\mathcal{M}}|^2\rangle_{Y_A} = L_{\mu\nu}X^{\mu\nu}$$

$L_{\mu\nu}$ is well known-the lepton tensor
$X^{\mu\nu}$ - the hadron tensor for inclusive photon +dijet production is what we compute



DIS inclusive cross-section at LO

Roy, RV; JHEP 1805 (2018) 013

$$\frac{d\sigma}{dx dQ^2 d^2\mathbf{k}_{\gamma\perp} d\eta_{k_\gamma}} = \frac{\alpha^2 q_f^4 y^2 N_c}{512\pi^5 Q^2} \frac{1}{2q^-} \int_0^{+\infty} \frac{dk^-}{k^-} \int_0^{+\infty} \frac{dp^-}{p^-} \int_{\mathbf{k}_\perp, \mathbf{p}_\perp} L^{\mu\nu} \widetilde{X}_{\mu\nu} (2\pi) \delta(P^- - q^-)$$

$$L^{\mu\nu} = \frac{2e^2}{Q^4} \left[(\widetilde{l^\mu} \widetilde{l'^\nu} + \widetilde{l^\nu} \widetilde{l'^\mu}) - \frac{Q^2}{2} g^{\mu\nu} \right]$$

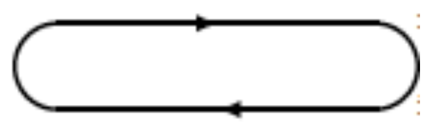
Includes Dirac trace

$$\widetilde{X}_{\mu\nu} = \int_{\mathbf{x}_\perp, \mathbf{y}_\perp, \mathbf{x'}_\perp, \mathbf{y'}_\perp, \mathbf{l}_\perp, \mathbf{l'}_\perp} e^{-i(\mathbf{P}_\perp - \mathbf{l}_\perp).\mathbf{x}_\perp - i\mathbf{l}_\perp.\mathbf{y}_\perp + i(\mathbf{P}_\perp - \mathbf{l'}_\perp).\mathbf{x'}_\perp + i\mathbf{l'}_\perp.\mathbf{y'}_\perp} \tau_{\mu\nu}{}^{q\bar{q}, q\bar{q}}(\mathbf{l}_\perp, \mathbf{l'}_\perp | \mathbf{P}_\perp) \, \Xi(\mathbf{x}_\perp, \mathbf{y}_\perp; \mathbf{x'}_\perp, \mathbf{y'}_\perp)$$

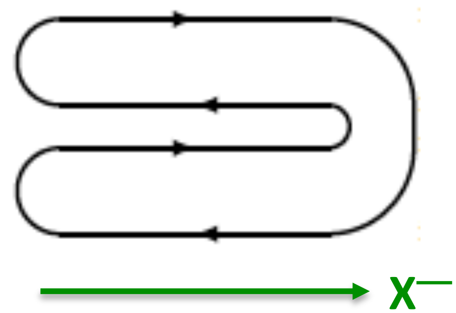
All the nonperturbative info about strongly correlated gluons is in

$$\Xi(\mathbf{x}_\perp, \mathbf{y}_\perp; \mathbf{x'}_\perp, \mathbf{y'}_\perp) = 1 - D(\mathbf{x}_\perp, \mathbf{y}_\perp) - D(\mathbf{y'}_\perp, \mathbf{x'}_\perp) + Q(\mathbf{x}_\perp, \mathbf{y}_\perp; \mathbf{y'}_\perp, \mathbf{x'}_\perp)$$

Dipoles: $D(x_\perp, y_\perp) = \frac{1}{N_c} \langle \mathrm{Tr} \left(\tilde{U}(x_\perp) \tilde{U}^\dagger(y_\perp) \right) \rangle_{Y_A}$



Quadrupoles: $Q(x_\perp, y_\perp) = \frac{1}{N_c} \langle \mathrm{Tr} \left(\tilde{U}(y'_\perp) \tilde{U}^\dagger(x'_\perp) \tilde{U}(x_\perp) \tilde{U}^\dagger(y_\perp) \right) \rangle_{Y_A}$

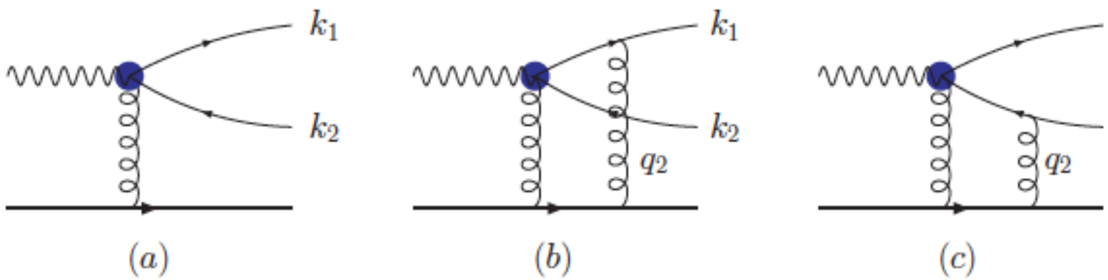


Interesting limits

When $k_\gamma \rightarrow 0$, the amplitude satisfies the Low-Burnett-Kroll theorem:

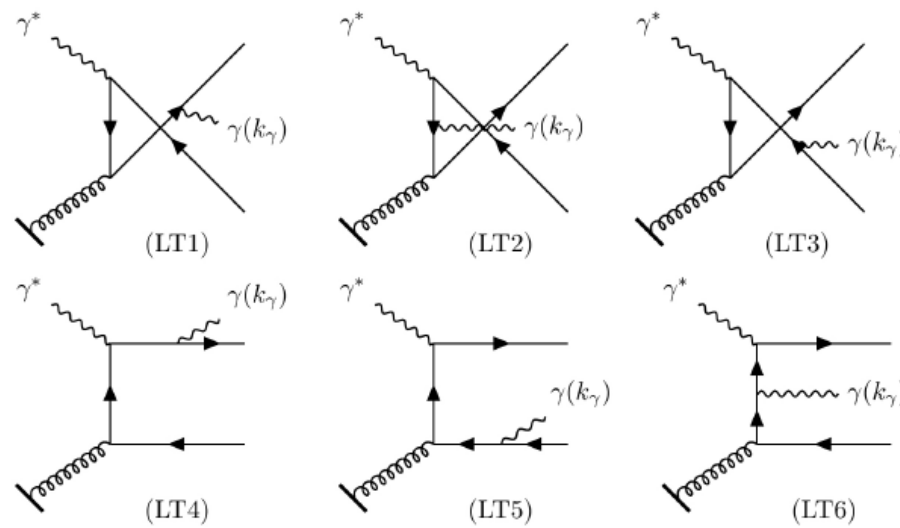
$$\mathcal{M}_\mu(\mathbf{q},\mathbf{k},\mathbf{p},\mathbf{k}_\gamma) \to -(eq_f)\epsilon^*_\alpha(\mathbf{k}_\gamma,\lambda)\Big(\frac{p^\alpha}{p.k_\gamma} - \frac{k^\alpha}{k.k_\gamma}\Big)\mathcal{M}^{NR}_\mu(\mathbf{q},\mathbf{k},\mathbf{p})$$

Polarization vector × Vectorial structure depending only on momenta of emitted particles × Non-radiative DIS amplitude



Recover results in soft photon limit for di-jet production
- sensitive to the gluon Weizsäcker-Williams distribution for large pair momenta

Dominguez,Marquet,Xiao,Yuan, PRD83 (2011)105005



As for p+A, recover in DIS
kt-factorization & collinear factorization
small x limits
(sensitivity to leading twist gluon distribution)

Aurenche et al., Z. Phys. C24, 309 (1984)

Structure of higher order computations: Shockwave propagators

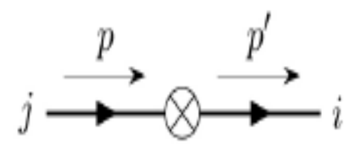
Convenient to work in the wrong light cone gauge $A^-=0$ for this problem (Gauge links in pdf definitions are unity in the right LC gauge $A^+=0$)

Dressed quark and gluon propagators: remarkably simple forms in $A^-=0$ gauge

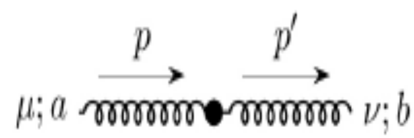
$$S(p,p') = (2\pi)^4\delta^{(4)}(p-p')S_0(p) + S_0(p)\mathcal{T}(p,p')S_0(p')$$

$$G^{\mu\nu;ab}(p,p') = (2\pi)^4\delta^{(4)}(p-p')G_0^{\mu\nu;ab} + G_0^{\mu\rho;ac}\mathcal{T}_{\rho\sigma;cd}G_0^{\sigma\nu;db}(p')$$

McLerran, RV; hep-ph/9402335
Ayala,Jalilian-Marian,McLerran, RV; hep-ph/9508302
Balitsky, Belitsky, hep-ph/0110158



$$\mathcal{T}_{ij}(p,p') = (2\pi)\delta(p^- - p'^-)\gamma^-\,\mathrm{sign}(p^-)\int d^2\mathbf{z}_\perp e^{i(\mathbf{p}_\perp-\mathbf{p}'_\perp).\mathbf{z}_\perp}\tilde{U}^{\mathrm{sign}(p^-)}(\mathbf{z}_\perp)_{ij}$$

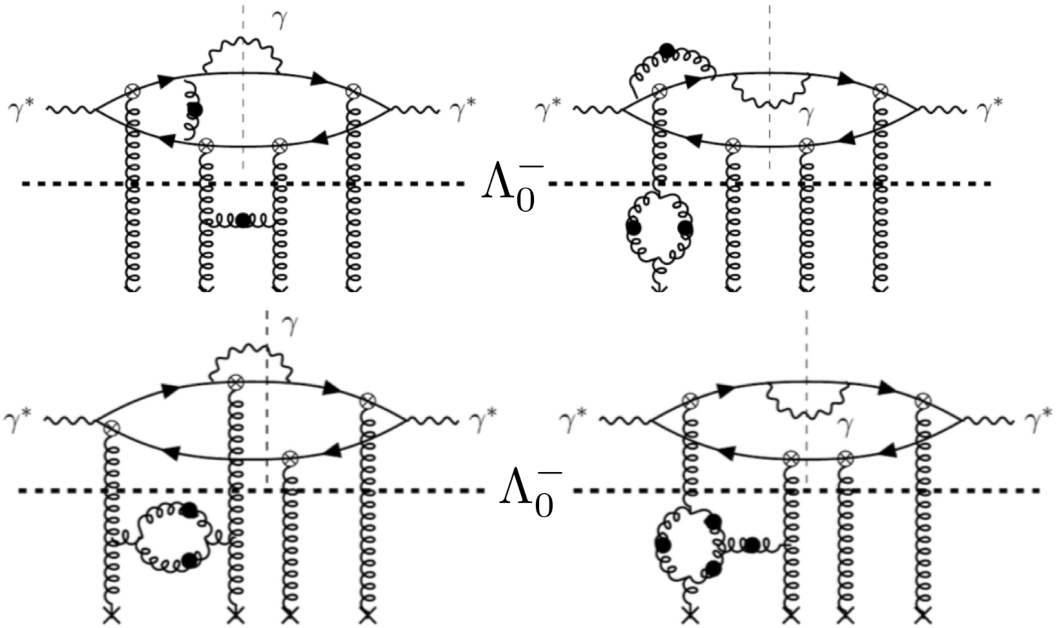


$$\mathcal{T}_{\mu\nu;ab}(p,p') = -2\pi\delta(p^- - p'^-)\times(2p^-)g_{\mu\nu}\ \mathrm{sign}(p^-)\int d^2\mathbf{z}_\perp e^{i(\mathbf{p}_\perp-\mathbf{p}'_\perp).\mathbf{z}_\perp}U_{ab}^{\mathrm{sign}(p^-)}(\mathbf{z}_\perp)$$

Structure of vertices identical to quark-quark-reggion and gluon-gluon-reggeon in Lipatov's Reggeon EFT

Bondarenko,Lipatov,Pozdnyakov, Prygarin, arXiv:1708.05183
Hentschinski, arXiv:1802.06755

DIS inclusive photo+dijet production at NLO+NLLx



Roy, RV: in preparation

Formally NNLO: but collect NLO pieces in the photon+dijet impact factor + leading log pieces $\alpha_S \log(\Lambda^- / \Lambda_0^-)$

Formally NNLO: but collect LO pieces in the photon+dijet impact factor + NLL leading log pieces $\alpha_S^2 \log(\Lambda^- / \Lambda_0^-)$

$$\langle \mathrm{d}\sigma_{NLO+NLLx} \rangle = \int [\mathcal{D}\rho_A] \left\{ W^{NLLx}[\rho_A]\, \mathrm{d}\hat{\sigma}_{LO}[\rho_A] + W^{LLx}[\rho_A]\, \mathrm{d}\hat{\sigma}_{NLO}[\rho_A] \right\}$$

$$= \int [\mathcal{D}\rho_A] \left(W^{NLLx}[\rho_A] \left\{ \mathrm{d}\hat{\sigma}_{LO}[\rho_A] + \boxed{\mathrm{d}\hat{\sigma}_{NLO}[\rho_A]} \right\} + O(\alpha_S^3 \ln(\Lambda_1^- / \Lambda_0^-)) \right)$$

$$\ln(\Lambda_1^- / \Lambda_0^-)(\mathcal{H}_{LO} + \mathcal{H}_{NLO})$$

NLO photon+dijet impact factor

Leading order JIMWLK Hamiltonian computed 20 years ago: 1997-2001
NLO JIMWLK Hamiltonian: 2013-2016

Balitsky, Chirilli, arXiv:1309.7644, Grabovsky, arXiv:1307.5414
Caron-Huot, arXiv:1309.6521, Kovner,Lublinsky,Mulian, arXiv:1310.0378, Lublinsky, Mulian, arXiv:1610.03453

The NLO inclusive photon impact factor

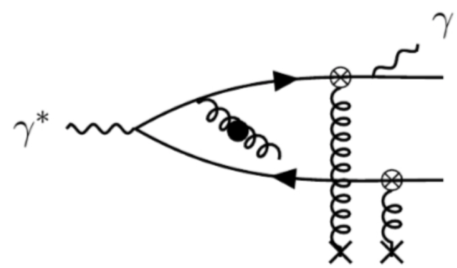
Several computations exist for inclusive DIS – subtleties in choice of scheme, etc.

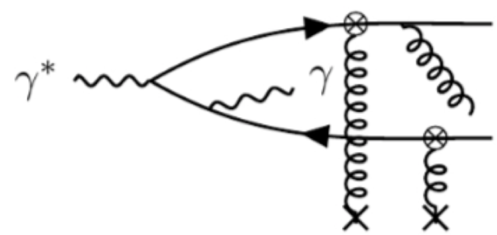
Balitsky,Chirilli, arXiv:1009.4729
Beuf, arXiv:1606.00777, 1708.06557
Hanninen, Lappi, Paatelainen, 1711.08207
Dijet: Boussarie, Grabovsky, Szymanowski, Wallon,1606.00419

First computation discussed here of photon+dijet:

Roy, RV, in preparation

I) Real contributions:
(20 $\times$ 20 diagrams)



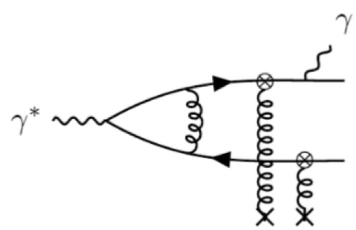


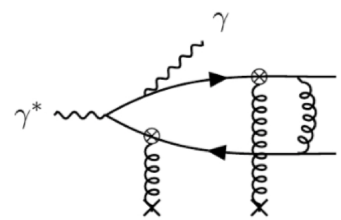
Gluon rescatters (or not) along with quarks

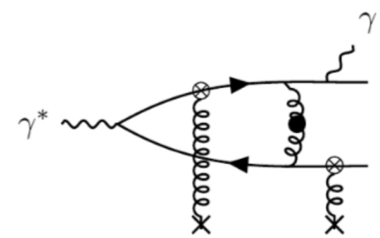
Gluon emitted after rescattering

II) Interference contributions:

A) Vertex corrections

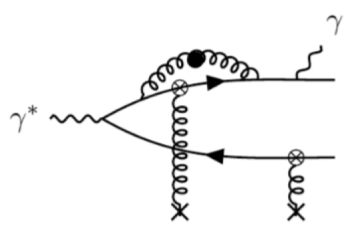


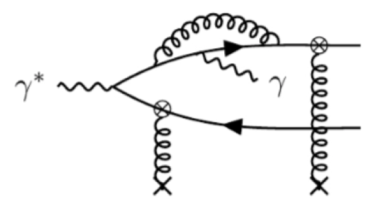


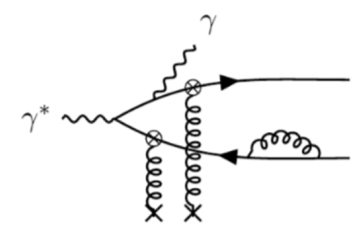


●●● and 21 more permutations

B) Self-energy corrections:







●●● and likewise, 21 more

Coda: A nontrivial derivation of JIMWLK evolution

coda *: something that serves to round out, conclude, or summarize and usually has its own interest.*

Roy, RV, in preparation

Recall $X^{\rm LO}_{\mu\nu} = \mathcal{C}^{\rm LO}_{\mu\nu} \otimes \Xi(\boldsymbol{x}_\perp, \boldsymbol{y}_\perp; \boldsymbol{y}'_\perp, \boldsymbol{x}'_\perp | \Lambda_0^-)$ $\quad \Xi(\boldsymbol{x}_\perp, \boldsymbol{y}_\perp; \boldsymbol{y}'_\perp, \boldsymbol{x}'_\perp | \Lambda_0^-) = 1 - D_{xy} - D_{y'x'} + Q_{y'x';xy}$

In the "soft gluon limit" that generates logs in x, our NLO hadron tensor gives

$$X^{\rm NLO}_{\mu\nu;LLx} = C^{\rm LO}_{\mu\nu} \otimes \ln(\Lambda_1^-/\Lambda_0^-) \Bigg[\frac{\alpha_S N_c}{2\pi^2} \Big\{ \mathcal{K}_B(\boldsymbol{x}_\perp, \boldsymbol{y}_\perp; \boldsymbol{z}_\perp) D_{xy} + \begin{pmatrix} \boldsymbol{x}_\perp \to \boldsymbol{y}'_\perp \\ \boldsymbol{y}_\perp \to \boldsymbol{x}'_\perp \end{pmatrix} \Big\} - \frac{\alpha_S N_c}{(2\pi)^2} \mathcal{K}_1(\boldsymbol{x}_\perp, \boldsymbol{y}_\perp, \boldsymbol{y}'_\perp, \boldsymbol{x}'_\perp; \boldsymbol{z}_\perp) Q_{xy;y'x'}$$
$$- \frac{\alpha_S N_c}{2\pi^2} \Big\{ \mathcal{K}_B(\boldsymbol{x}_\perp, \boldsymbol{y}_\perp; \boldsymbol{z}_\perp) D_{xz} D_{zy} + \begin{pmatrix} \boldsymbol{x}_\perp \to \boldsymbol{y}'_\perp \\ \boldsymbol{y}_\perp \to \boldsymbol{x}'_\perp \end{pmatrix} \Big\} + \frac{\alpha_S N_c}{(2\pi)^2} \Bigg(\Big\{ \mathcal{A}(\boldsymbol{x}_\perp, \boldsymbol{y}'_\perp, \boldsymbol{y}_\perp, \boldsymbol{x}'_\perp; \boldsymbol{z}_\perp) D_{xx'} D_{y'y} + \boldsymbol{x}_\perp \leftrightarrow \boldsymbol{y}'_\perp \Big\}$$
$$+ \Big\{ \mathcal{K}_2(\boldsymbol{x}_\perp, \boldsymbol{y}_\perp, \boldsymbol{x}'_\perp; \boldsymbol{z}_\perp) D_{xz} Q_{zy;y'x'} + \begin{pmatrix} \boldsymbol{x}_\perp \to \boldsymbol{y}'_\perp \\ \boldsymbol{y}_\perp \to \boldsymbol{x}'_\perp \end{pmatrix} \Big\} + \Big\{ \mathcal{K}_2(\boldsymbol{x}'_\perp, \boldsymbol{x}_\perp, \boldsymbol{y}'_\perp; \boldsymbol{z}_\perp) D_{zx'} Q_{y'z;xy'} + \begin{pmatrix} \boldsymbol{x}_\perp \to \boldsymbol{y}'_\perp \\ \boldsymbol{y}_\perp \to \boldsymbol{x}'_\perp \end{pmatrix} \Big\} \Bigg) \Bigg],$$

Nontrivial combinations of dipole and quadrupole operators

Dominguez,Mueller,Munier,Xiao, PLB705(2011)106

Remarkably, this can be reexpressed as $X^{\rm NLO}_{\mu\nu;LLx} = C^{\rm LO}_{\mu\nu} \otimes \ln\left(\frac{\Lambda_1^-}{\Lambda_0^-}\right) H^{\rm LO}_{\rm JIMWLK}\, \Xi(\boldsymbol{x}_\perp, \boldsymbol{y}_\perp; \boldsymbol{y}'_\perp, \boldsymbol{x}'_\perp | \Lambda_0^-)$

This immediately leads to the JIMWLK RG equation for the rapidity evolution of many-body gluon correlators

$$W_{\Lambda_1^-}[\rho_A] = \left(1 + \ln\left(\frac{\Lambda_1^-}{\Lambda_0^-}\right) H^{\rm LO}_{\rm JIMWLK}\right) W_{\Lambda_0^-}[\rho_A]$$

Summary and Outlook

- **Discussed inclusive photon production in p+p/A collisions. Good agreement with data in p+p but sensitivity to saturation effects small in min. bias. Compute p+A. Need NNLO to improve accuracy**

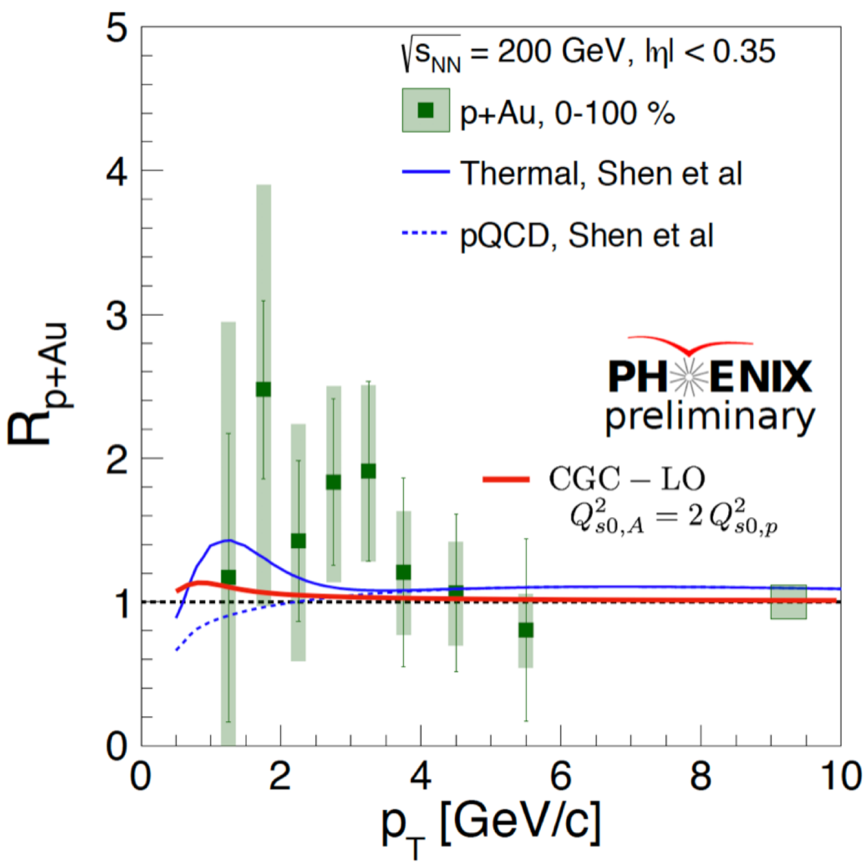
- **First computation of inclusive photon+dijet in e+A collisions. Rich structure in terms of 2-point and 4-point Wilson line correlators. Well-known result for Weizsäcker-Williams gluon distribution recovered in the soft photon limit. In leading twist, the cross-section is directly proportional to the nuclear gluon distribution**

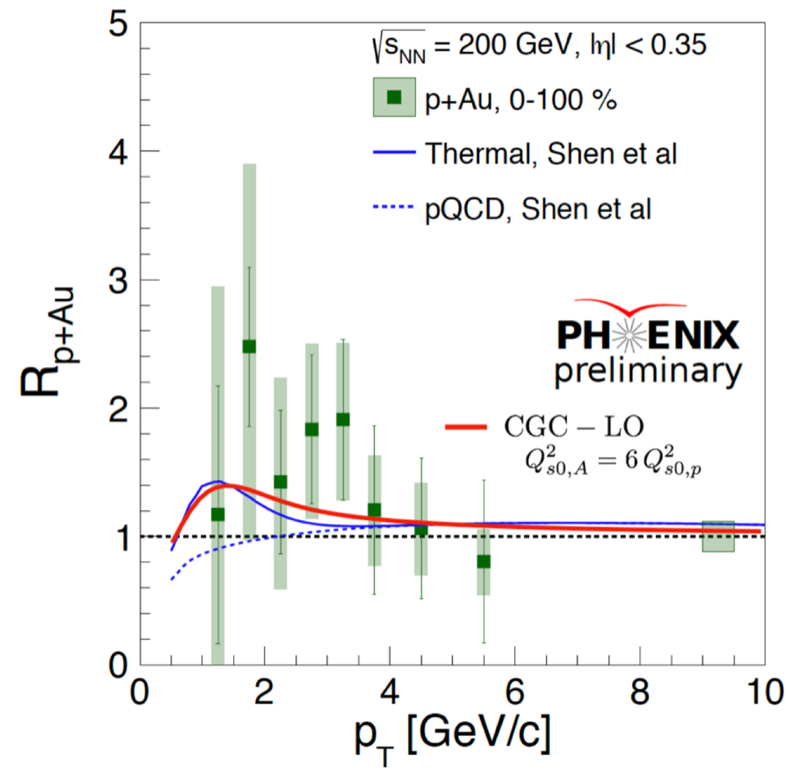
- **The structure of dressed quark and gluon propagators in the "wrong" light cone gauge $A^{-}=0$ is remarkably simple and *facilitates higher order computations in momentum space* (using standard techniques in pQCD)**

- **Outlined first computation of the NLO inclusive photon+dijet impact factor. Nontrivial derivation of JIMWLK functional RG equation**

Backup slides

Inclusive photon production in p+A





Preliminary (theory) results courtesy of Oscar Garcia-Montero

The NLO inclusive photon impact factor

Inclusive photon cross-section: NLO-real * NLO*real + LO * NLO virtual

Wilson line factor	Real emission	Virtual: Vertex	Virtual: Self-energy
$\frac{N_c^2}{2}\Big(1 - D_{xz}D_{zy} - D_{y'z}D_{zx'} + D_{y'y}D_{xx'}\Big) - \frac{1}{2}\Xi(x_\perp, y_\perp; y'_\perp, x'_\perp)$	$T_R^{(1)*}T_R^{(1)}$		
$C_F N_c \Xi(x_\perp, y_\perp; y'_\perp, x'_\perp)$	$T_R^{(2)*}T_R^{(2)} + T_R^{(3)*}T_R^{(3)}$	$T_{LO}^* T_V^{(3)} + c.c$	$T_{LO}^* T_S^{(3)} + c.c$
$\frac{N_c^2}{2}[(1 - D_{xy})(1 - D_{y'x'})] - \frac{1}{2}\Xi(x_\perp, y_\perp; y'_\perp, x'_\perp)$	$T_R^{(2)*}T_R^{(3)} + c.c$	$T_{LO}^* T_V^{(4)} + c.c$	
$\frac{N_c^2}{2}\Big(1 + (Q_{zy;y'x'} - D_{zy})D_{xz} - D_{y'x'}\Big) - \frac{1}{2}\Xi(x_\perp, y_\perp; y'_\perp, x'_\perp)$	$T_R^{(2)*}T_R^{(1)}$	$T_{LO}^* T_V^{(1)}$	$T_{LO}^* T_S^{(1)}$
$\frac{N_c^2}{2}\Big(1 + (Q_{xy;y'z} - D_{y'z})D_{zx'} - D_{xy}\Big) - \frac{1}{2}\Xi(x_\perp, y_\perp; y'_\perp, x'_\perp)$	$T_R^{(1)*}T_R^{(2)}$	$T_V^{(1)*}T_{LO}$	$T_S^{(1)*}T_{LO}$
$\frac{N_c^2}{2}\Big(1 + (Q_{y'x';xz} - D_{xz})D_{zy} - D_{y'x'}\Big) - \frac{1}{2}\Xi(x_\perp, y_\perp; y'_\perp, x'_\perp)$	$T_R^{(3)*}T_R^{(1)}$	$T_{LO}^* T_V^{(2)}$	$T_{LO}^* T_S^{(2)}$
$\frac{N_c^2}{2}\Big(1 + (Q_{xy;zx'} - D_{zx'})D_{y'z} - D_{xy}\Big) - \frac{1}{2}\Xi(x_\perp, y_\perp; y'_\perp, x'_\perp)$	$T_R^{(1)*}T_R^{(3)}$	$T_V^{(2)*}T_{LO}$	$T_S^{(2)*}T_{LO}$

For each Wilson line structure, collinear divergences cancel between real and Interference contributions

Rapidity and UV divergent pieces: these can be absorbed, in a subtraction scheme, into the NLLx JIMWLK expressions.

Roy, RV, in preparation