LO three-jet and NLO di-jet correlations in DIS at small x

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Road Map of QCD Phase Space
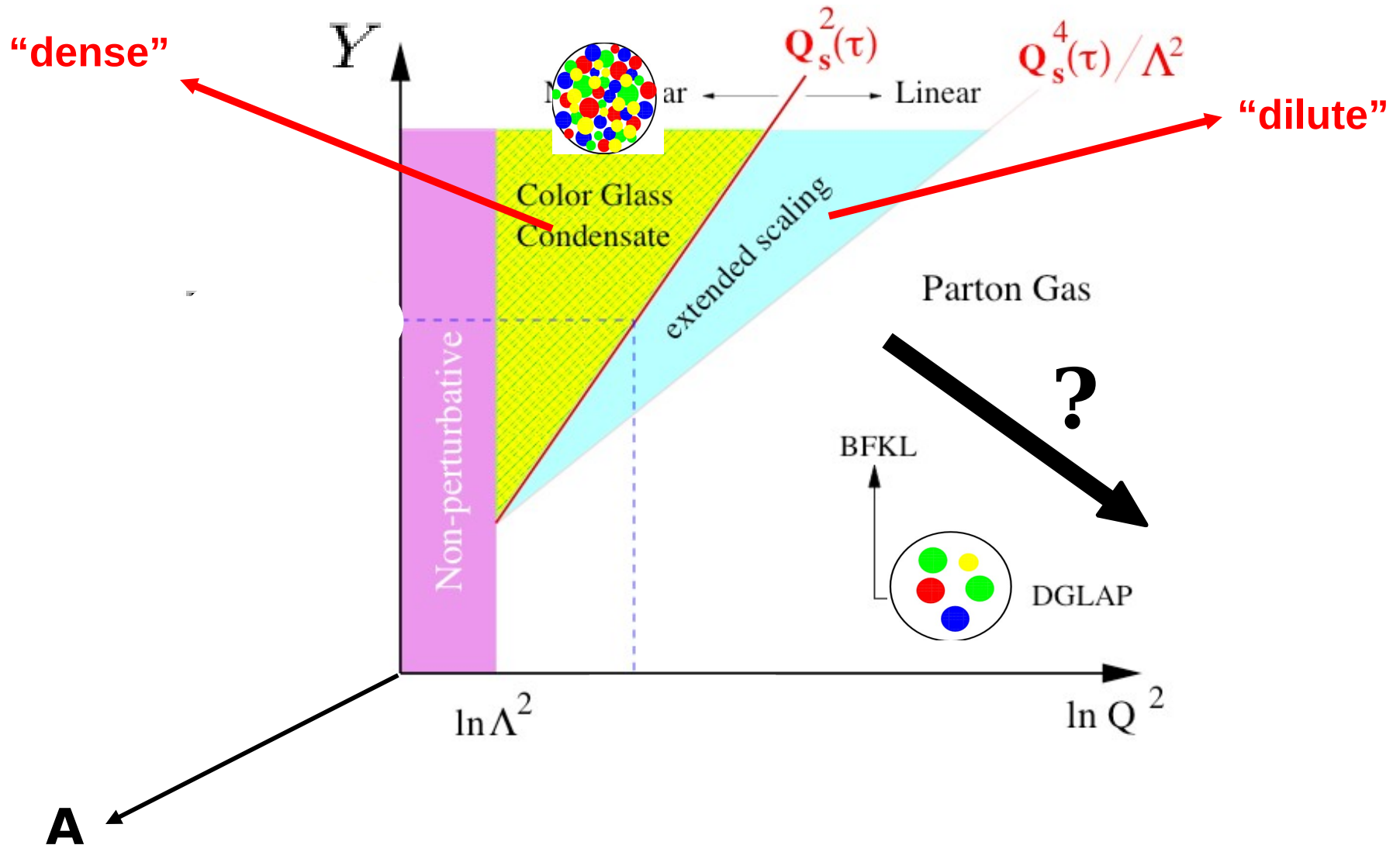
Probing CGC: observables

dense-dense (AA, pA, pp) collisions

dilute-dense (pA, forward pp) collisions

DIS

structure functions (diffraction)
particle production
single inclusive
double inclusive
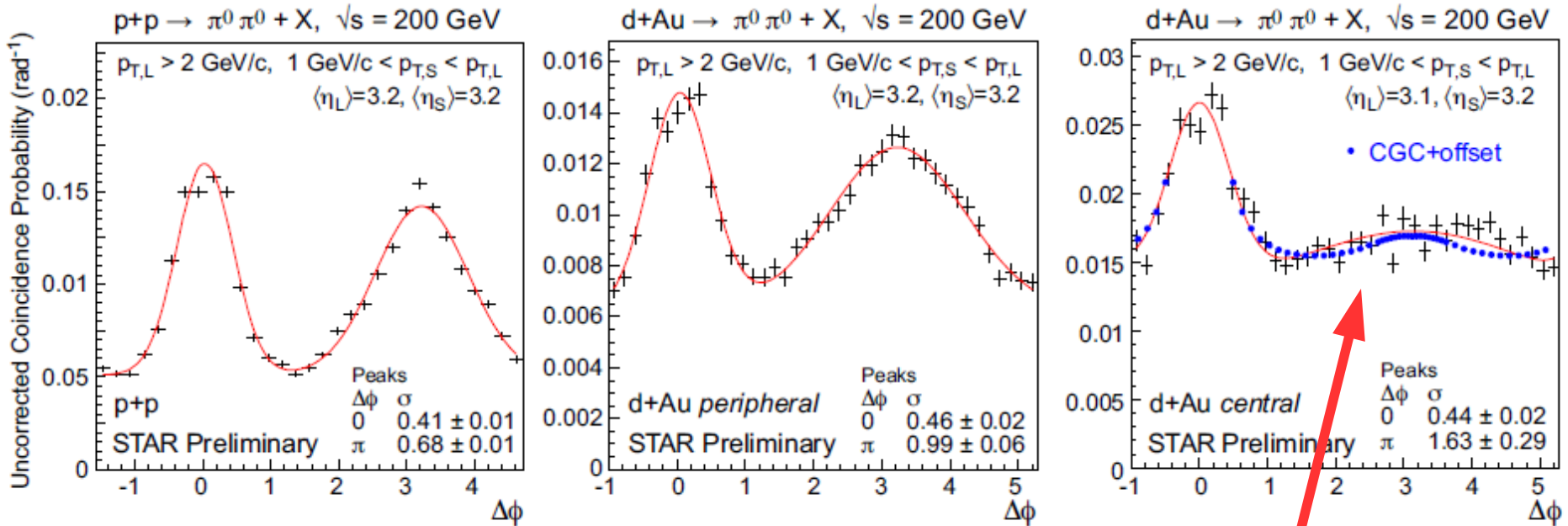**triple inclusive**

related work by:
Boussarie, Grabovsky, Szymanowski, Wallon, JHEP1409, 026 (2014)
Balitsky, Chirilli, PRD83 (2011) 031502, PRD88 (2013) 111501
Beuf, PRD85, (2012) 034039

Azimuthal correlations in pA

Recent STAR measurement (arXiv:1008.3989v1):

Marquet, NPA (2007), Albacete + Marquet, PRL (2010)
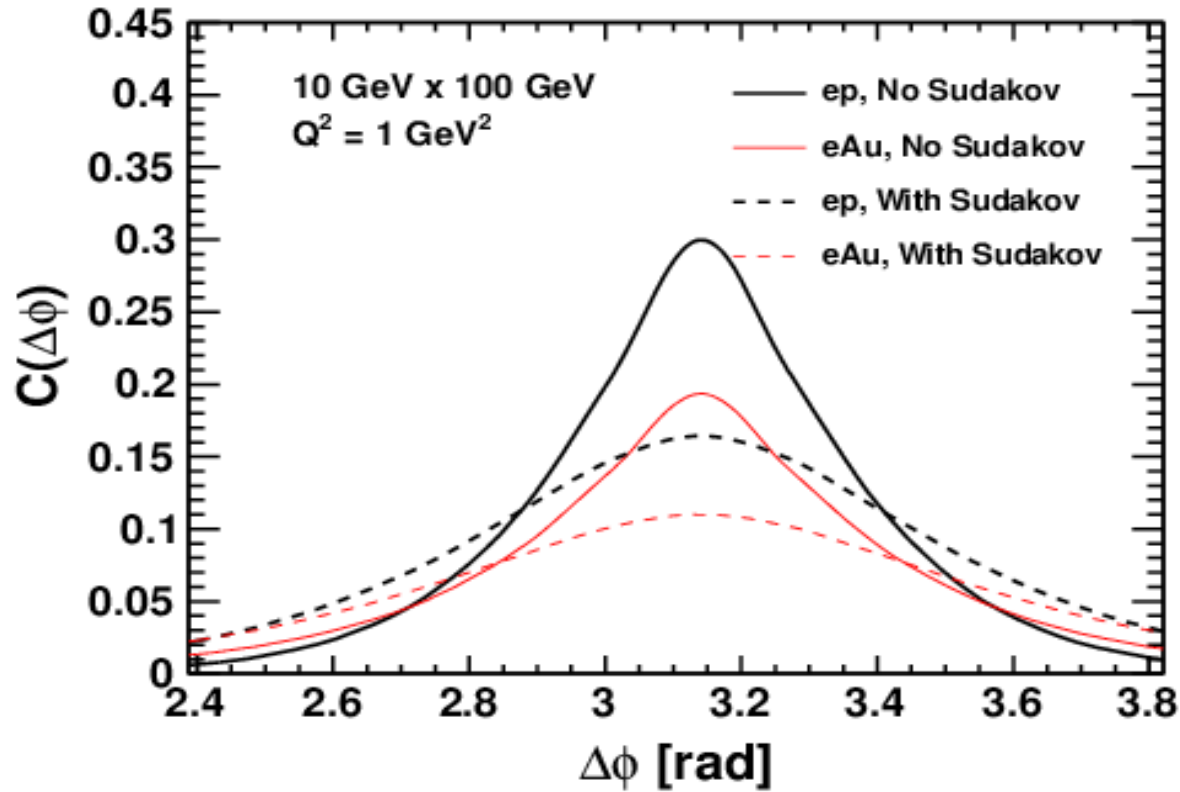Tuchin, NPA846 (2010)
A. Stasto + B-W. Xiao + F. Yuan, PLB716 (2012)
T. Lappi + H. Mantysaari, NPA908 (2013)

shadowing+energy loss: Z. Kang, I. Vitev, H. Xing, PRD85 (2012) 054024

multiple scatterings de-correlate the hadrons
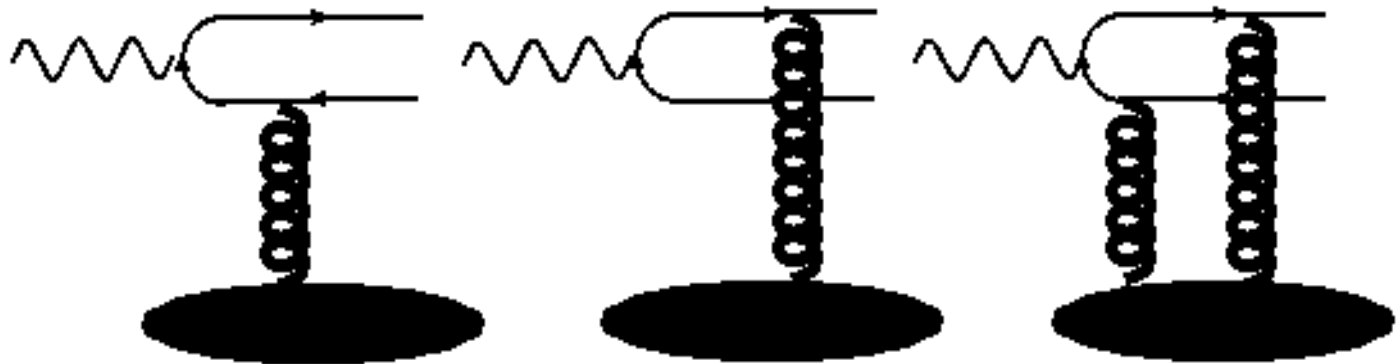
Azimuthal correlations in DIS

Zheng + Aschenauer + Lee + Xiao, PRD89 (2014)7, 074037

Azimuthal correlations in DIS

DIS total cross section (F_L, F_2): **_dipoles_** $< \mathbf{Tr\, V\, V^\dagger} >$

di-jet production in DIS: **_quadrupoles_** $< \mathbf{Tr\, V\, V^\dagger\, V\, V^\dagger} >$

LO: $\gamma^\star T \to q\, \bar{q}\, X$

Azimuthal correlations in DIS

di-jet production in DIS: **_quadrupoles_** $\quad < \mathbf{Tr\, V\, V^{\dagger}\, V\, V^{\dagger}} >$
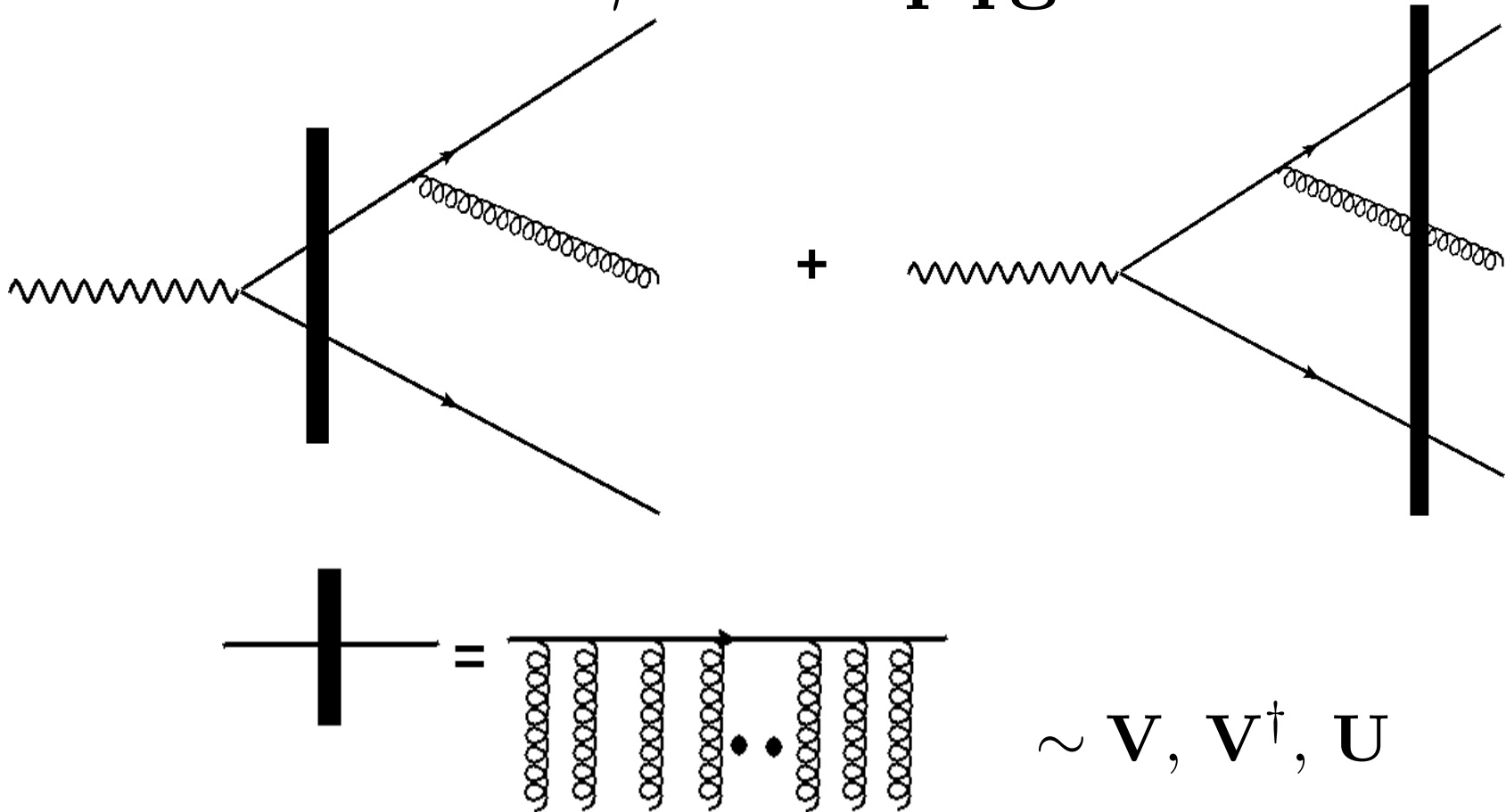
LO: $\quad \gamma^{\star}\mathbf{T} \rightarrow \mathbf{g\, g\, X}$ $\qquad$ JJM+ Y. Kovchegov, PRD (2004)

gluons widely separated in rapidity
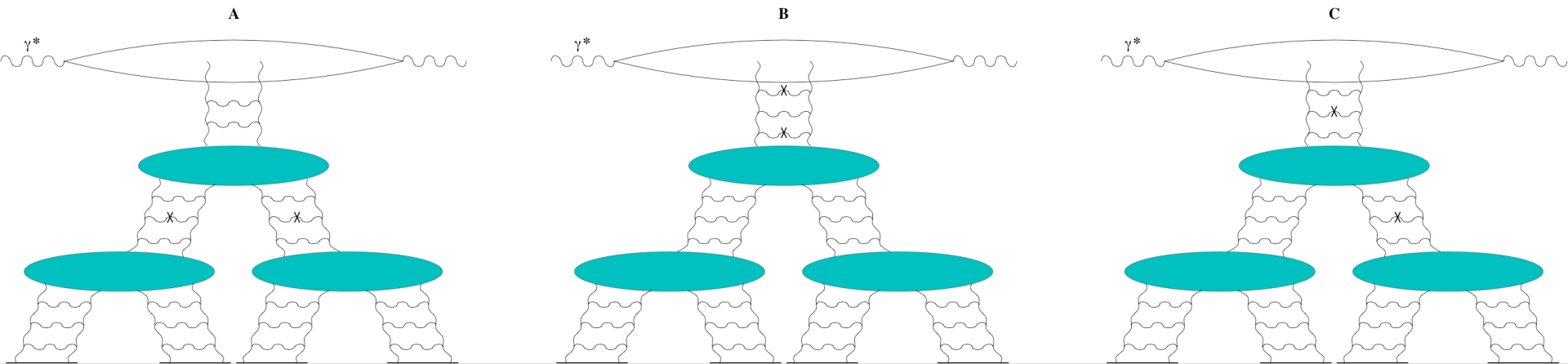
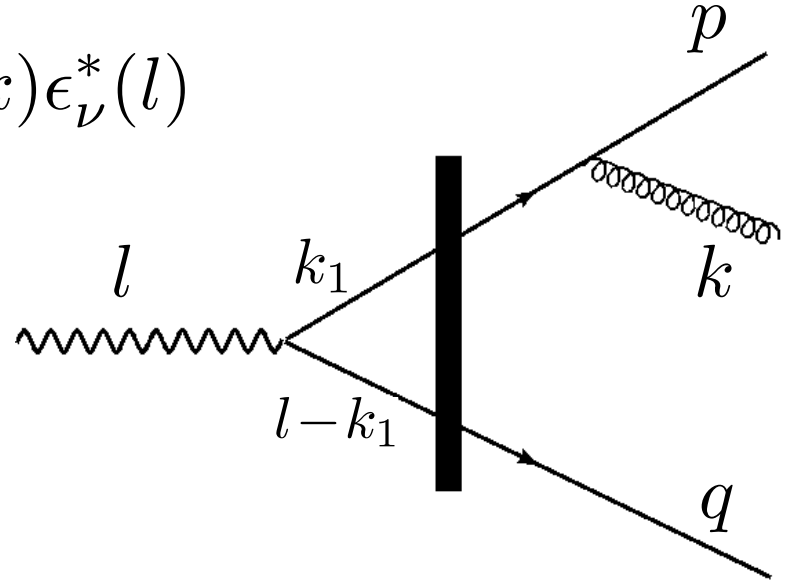# Azimuthal correlations in DIS: 3-jets
LO: $\gamma^\star \mathbf{T} \to \mathbf{q}\,\bar{\mathbf{q}}\,\mathbf{g}\,\mathbf{X}$

$$\sim \mathbf{V},\, \mathbf{V}^\dagger,\, \mathbf{U}$$

Ayala, Hentschinski, JJM, Tejeda-Yeomans, in progress

$$\mathcal{A} \equiv -eg\,\bar{u}(p)\,[A]^{\mu\nu}\,v(q)\,\epsilon_\mu\,(k)\epsilon_\nu^*(l)$$
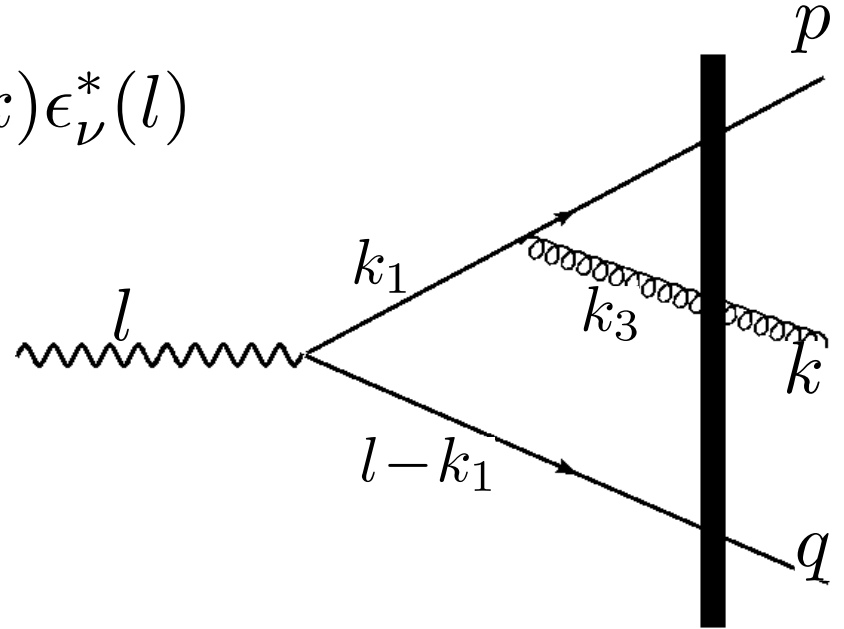

$$A_1^{\mu\nu} = \gamma^\mu\,t^a\,S_F^0(p+k)\,\tau_F(p+k,k_1)\,S_F^0(k_1)\,\gamma^\nu\,S_F^0(l-k_1)\,\tau_F(l-k_1,q)\,\frac{d^4k_1}{(2\pi)^4}$$

with interactions given by

$$\tau_F(p,q) \equiv (2\pi)\delta(p^- - q^-)\gamma^- \int d^2z_t\, e^{-i(p_t-q_t)z_t}\left[\theta(p^-)V(z_t) - \theta(-p^-)V^\dagger(z_t)\right]$$

integrations can be done and give K_0

$$\mathcal{A} \equiv -eg\,\bar{u}(p)\,[A]^{\mu\nu}\,v(q)\,\epsilon_\mu\,(k)\epsilon_\nu^*(l)$$

$$A_2^{\mu\nu} = \tau_F(p, k_1 - k_3)\,S_F^0(k_1 - k_3)\gamma^\mu\,t^a\,S_F^0(k_1)\,\gamma^\nu\,S_F^0(l - k_1)\,\tau_F(l - k_1, q)$$

$$G_\mu^{0\,\lambda}(k_3)\,\tau_g^{ac}(k_3, k)\frac{d^4 k_1}{(2\pi)^4}\,\frac{d^4 k_3}{(2\pi)^4}$$

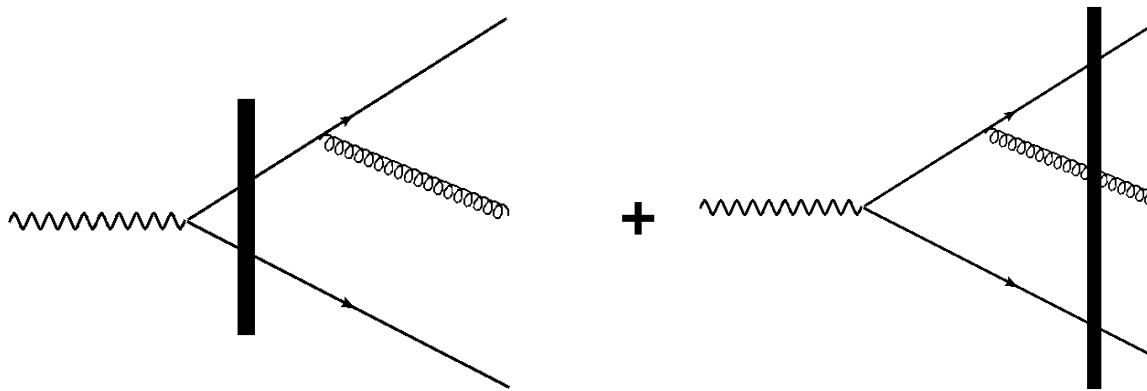all integrations (except one) can be done analytically

$$A = A_1 + A_2 \quad \text{+ radiation from anti-quark}$$

Azimuthal correlations in DIS

di-jet production in DIS: ***NLO***

real contributions: $\gamma^\star \mathbf{T} \to \mathbf{q}\,\bar{\mathbf{q}}\,\mathbf{g}\,\mathbf{X}$
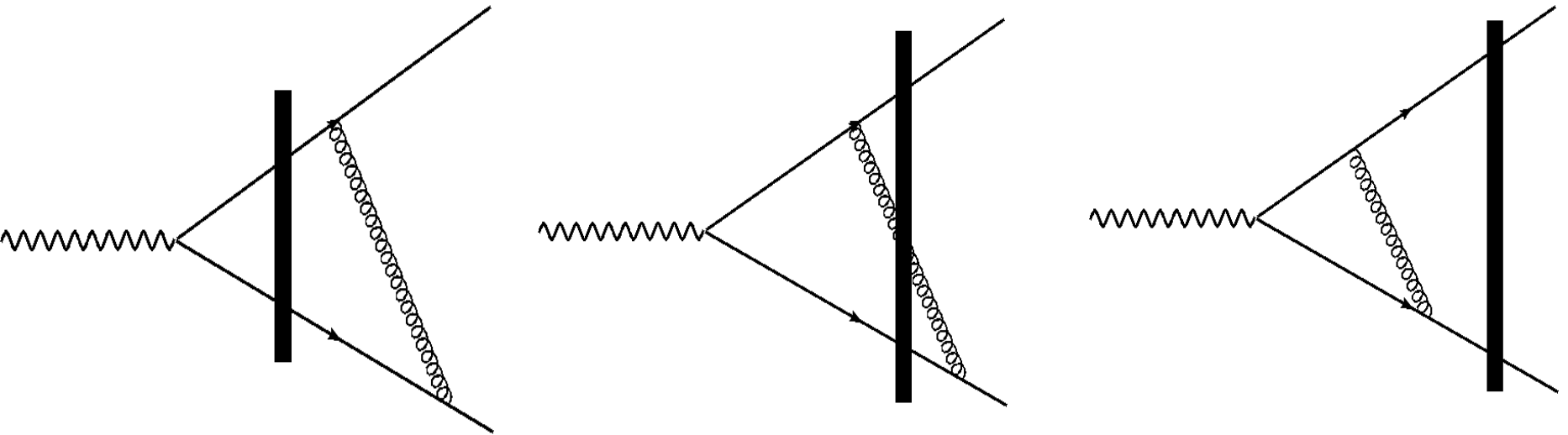
integrate out one of the produced partons

work in progress: Ayala, Hentschinski , Jalilian-Marian, Tejeda-Yeomans

di-jet azimuthal correlations in DIS

virtual contributions: $\qquad \gamma^\star T \to q\,\bar{q}\,X$

+ "self-energy" diagrams

di-jet azimuthal correlations in DIS

$$\text{NLO:} \quad \gamma^\star \mathbf{T} \to \mathbf{h\,h\,X}$$

integrate out one of the produced partons - there are divergences:

rapidity divergences: JIMWLK evolution of n-point functions

colinear divergences: DGLAP evolution of fragmentation functions

infrared divergences cancel

the finite pieces are written as a factorized cross section

work in progress: Ayala, Hentschinski , Jalilian-Marian, Tejeda-Yeomans

SUMMARY

Di-jet angular correlations offer a unique probe of CGC

3-hadron/jet correlations should be even more discriminatory

Leading Log CGC works (too) well for a qualitative/semi-quantitative description of data, NLO is needed

Need to eliminate/minimize late time/hadronization effects

an EIC is needed for precision CGC studies