WW gluon distributions and the azimuthal asymmetries of quark pair in eA collisions

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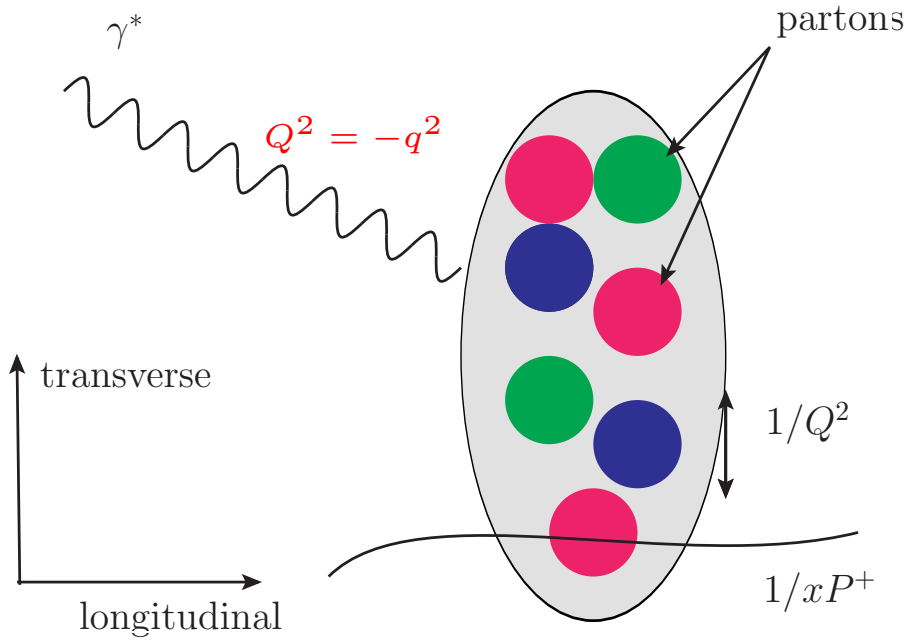
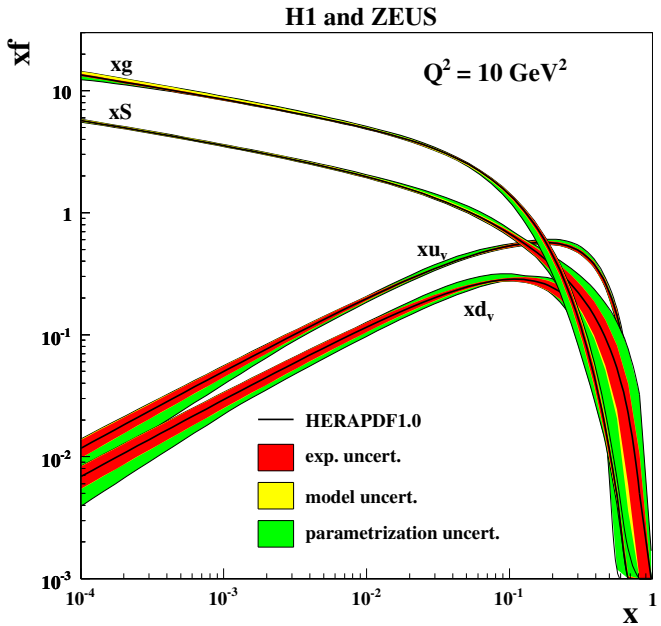
Outline

1. Motivation
2. WW gluon distribution can be probed in EIC
3. Summary

The structure of a proton: PDFs (Longitudinal)

- x: the fraction of longitudinal momentum, $k^+ = xP^+$.
- Q^2: Transverse resolution. Probe area $\Delta S_\perp \sim 1/Q^2$

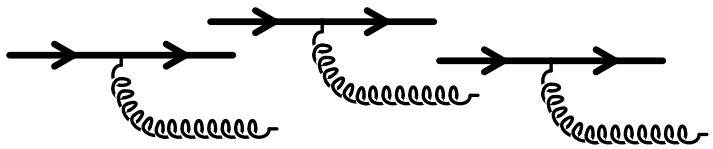


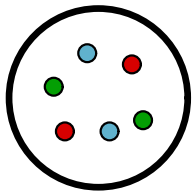


[JHEP 2010,109]

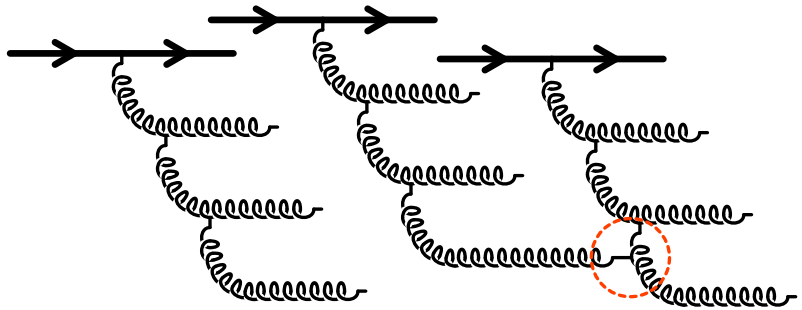
At small-x region, the dominant components are not valence quarks, but GLUONS.

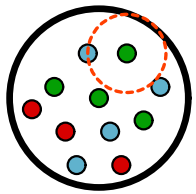
Two processes of emission and recombination: Saturation





— BFKL





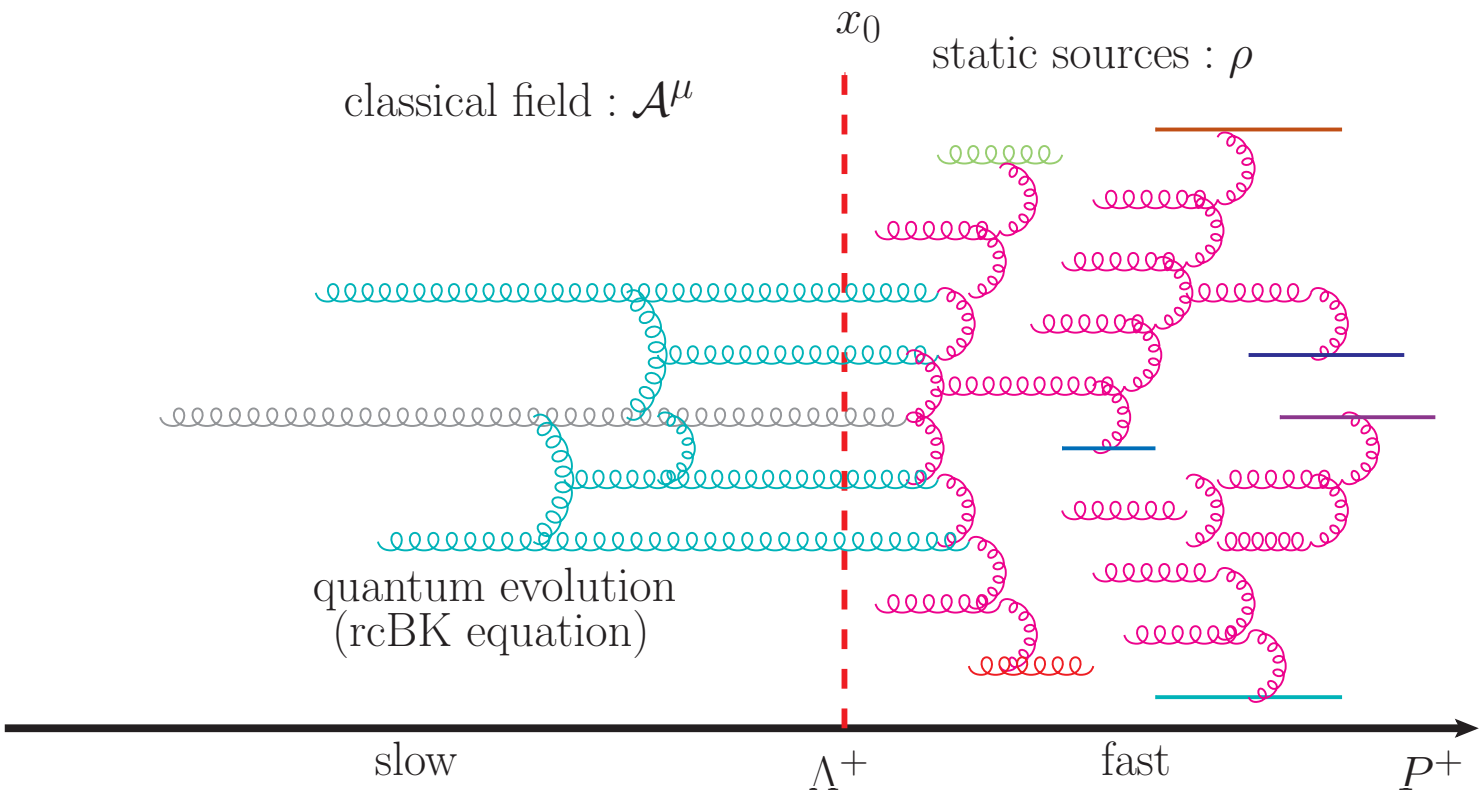
— BK

- Transverse density of gluons $\rho \sim \frac{1}{S_\perp} xg(x, Q^2)$
- Recombination cross section $\sigma_{gg\to g} \sim \frac{\alpha_s(Q^2)}{Q^2}$

Saturation condition: $\rho\sigma_{gg\to g} \geq 1 \Longrightarrow \frac{xg(x,Q_s^2)}{S_\perp Q_s^2} = \frac{1}{\alpha_s(Q_s^2)}$:max. density.

The degree freedom of partons in a hadron

Most advanced (and still developing) theoretical picture of high energy scattering in QCD



Partons are divided into:

- Fast (large-x) partons $\longrightarrow$ static source ρ
- Slow (small-x) partons $\longrightarrow$ field $\mathcal{A}$ $\Longleftarrow$ CYM

How to probe: EIC

- Directly test CGC/gluon saturation.

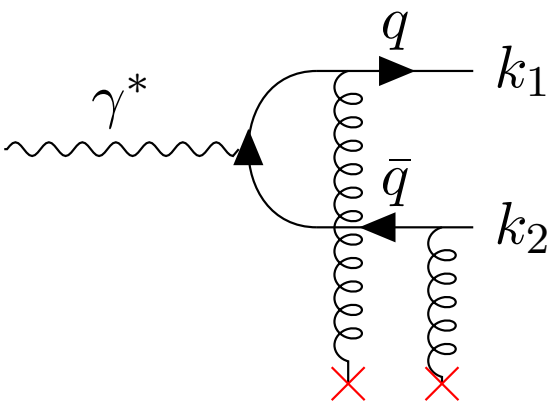
Go back to the inner structure of proton/nucleus,

- Precise, detailed information (distribution) of quark (gluon) inside the proton/nuclear
- 1D PDFs $\rightarrow$ 3D PDFs (TMDs) $\rightarrow$ 5D PDFs (Wigner distribution)
- A typical TMDs, Weizsäcker-Williams distribution(less known) can be directly measured in EIC.

Quark-antiquark pair production in EIC

In partonic level, considering a process

$$\gamma^* + p(A) \to q + \bar{q} + X$$



$$k_\perp = k_{1\perp} + k_{2\perp},$$
$$P_\perp = (1-z)k_{1\perp} - zk_{2\perp}$$

In correlation limit, $|P_\perp| \gg |k_\perp|$ [Metz-Zhou, 2011, Dominguez-Marquet-Xiao-Yuan 2011,Xie-Chen 2013, Dumitru-Lappi-Skokov 2015, Xiao-Zhou 2017]

$$\frac{d\sigma_T}{d\mathcal{P}.\mathcal{S}.} \sim \left[\left(z^2+(1-z)^2\right)\left(P_\perp^4+\epsilon_f^4\right)+2m_q^2P_\perp^2\right] \underbrace{xG(x_g,k_\perp,P_\perp)}_{\text{unpolarized WW}}$$

$$-\left[2\left(z^2+(1-z)^2\right)P_\perp^2\epsilon_f^2-2m_q^2P_\perp^2\right]\cos(2\Delta\phi)\,\underbrace{xH(x_g,k_\perp,P_\perp)}_{\text{Linear polarized WW}}$$

WW gluon distributions with Sudakov resummations

In MV model,

$$\widetilde{xG}(x_g,k_\perp,P_\perp) = \frac{2C_F S_\perp}{\alpha_s \pi^2}\int \frac{\mathrm{d}^2 r_\perp}{(2\pi)^2} e^{ik_\perp\cdot r_\perp} e^{-S_{\rm Sud}(P_\perp,r_\perp)} \times \frac{1}{r_\perp^2}\left[1-\exp\left(-\frac{1}{4}r_\perp^2 Q_{sg}^2 \ln\frac{1}{|r_\perp|\Lambda}\right)\right]$$

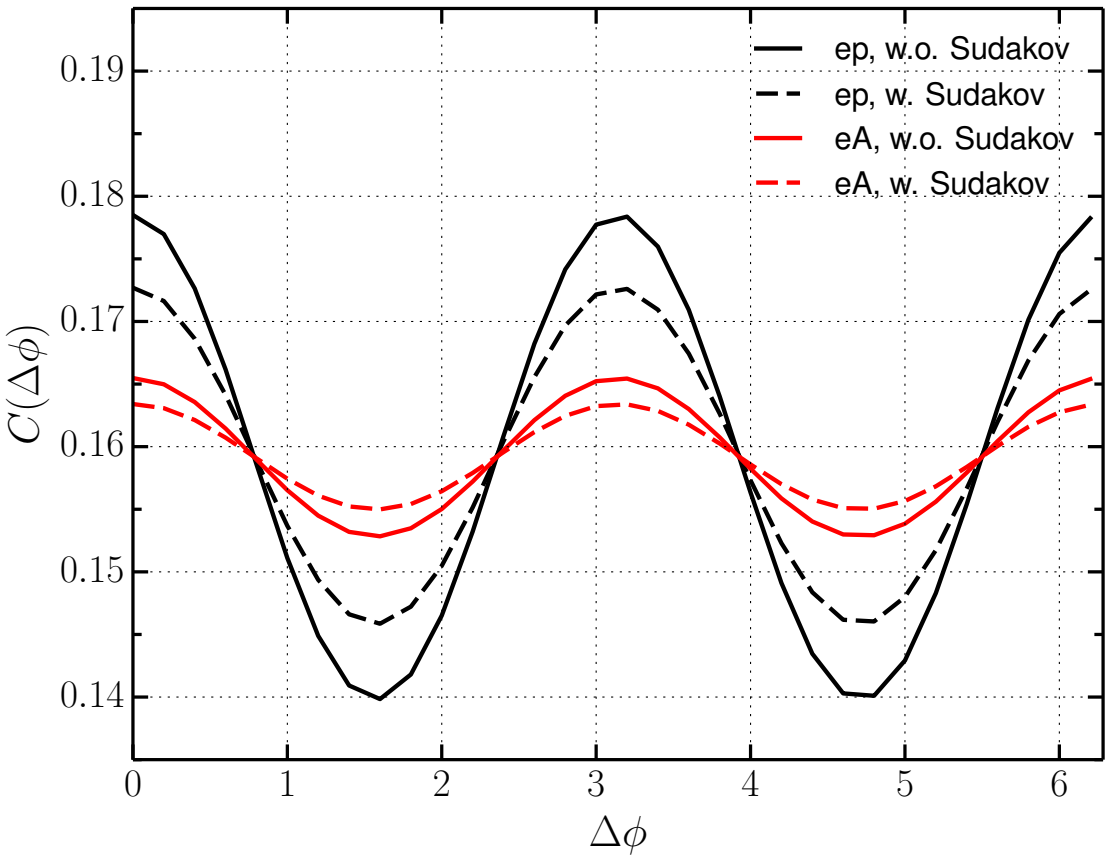
$$\widetilde{xH}(x_g,k_\perp,P_\perp) = \frac{C_F S_\perp}{2\alpha_s \pi^3}\int \mathrm{d}|r_\perp| \frac{J_2(|k_\perp||r_\perp|)}{|r_\perp|\ln\frac{1}{|r_\perp|\Lambda}} e^{-S_{\rm Sud}(P_\perp,r_\perp)} \times \left[1-\exp\left(-\frac{1}{4}r_\perp^2 Q_{sg}^2 \ln\frac{1}{|r_\perp|\Lambda}\right)\right]$$

in which [Mueller, Xiao and Yuan 2013, Xiao and Zhou, 2017]

$$S_{\rm sud}(P_\perp,r_\perp) = \int_{c_0^2/r_\perp^2}^{P_\perp^2} \frac{\mathrm{d}\mu^2}{\mu^2}\frac{N_c}{2}\frac{\alpha_s}{\pi}\ln\frac{P_\perp^2}{\mu^2}$$

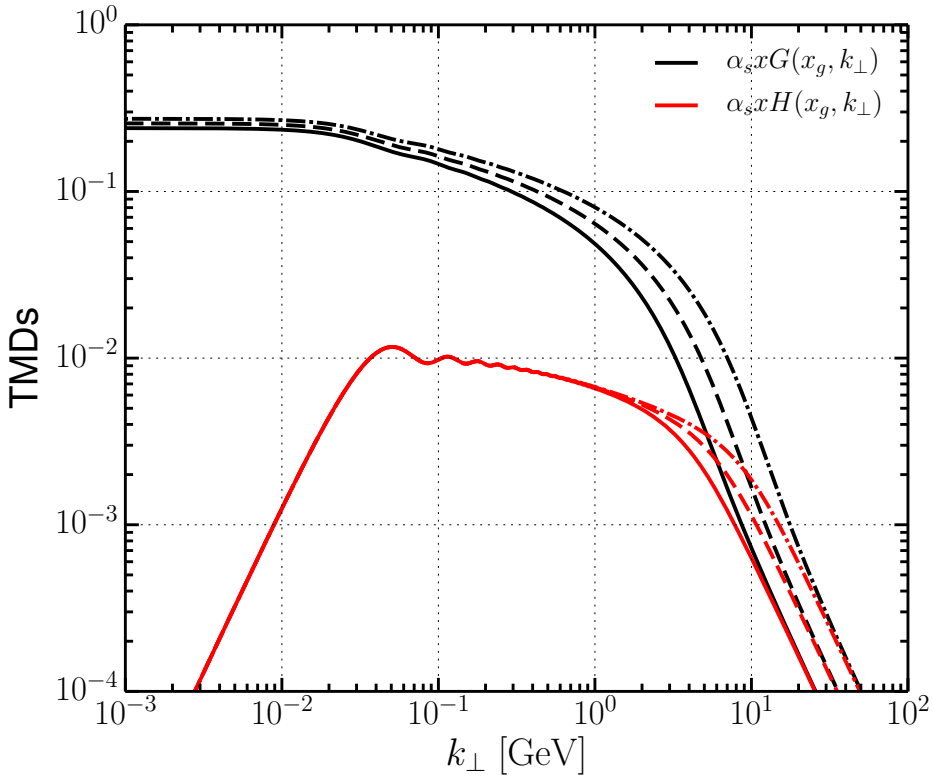
The azimuthal correlation of quark-antiquark pair

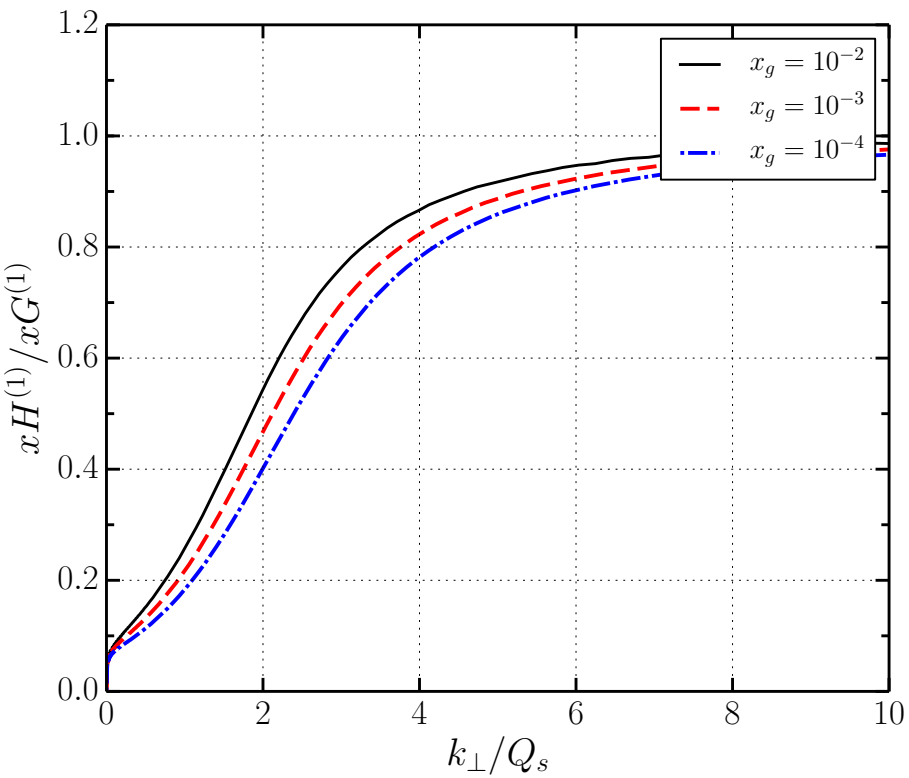
$$W = 100\ \mathrm{GeV}, k_\perp = 1\ \mathrm{GeV}, P_\perp = 2\ \mathrm{GeV}$$



- Suppression $\Longleftarrow$ Sudakov effect(parton shower)
- ep VS eA, suppression $\Longleftarrow$ nuclear saturation effects.

Unpolarized and linearly polarized WW gluon distribution





Remark

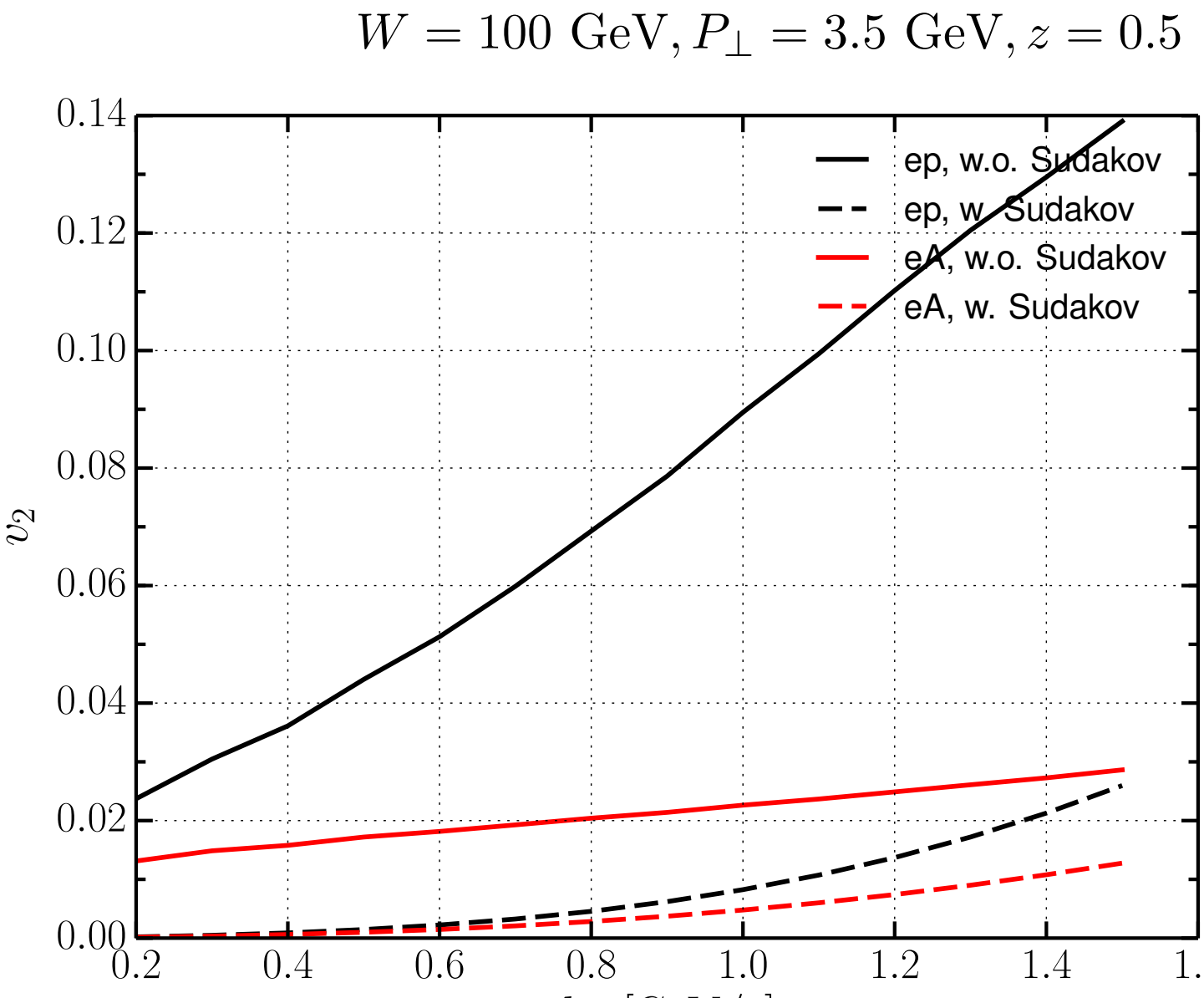
- Should be re-examined/tested in EIC.

The summary

- CGC/gluon saturation can be further tested in EIC.
- WW-type gluon distributions can be probed in EIC.
- The Sudakov and saturation effect can suppress the azimuthal correlation of the pair
- Saturation effect strongly suppress the azimuthal distribution when the target becomes heavier.

Thank you very much!

v_2 of the pair



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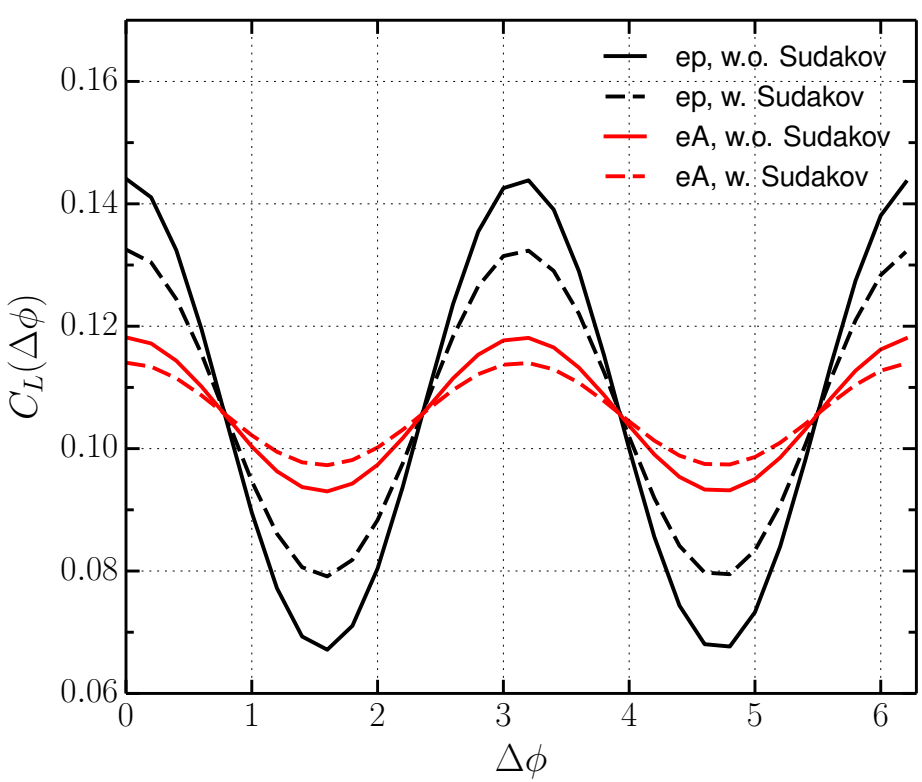
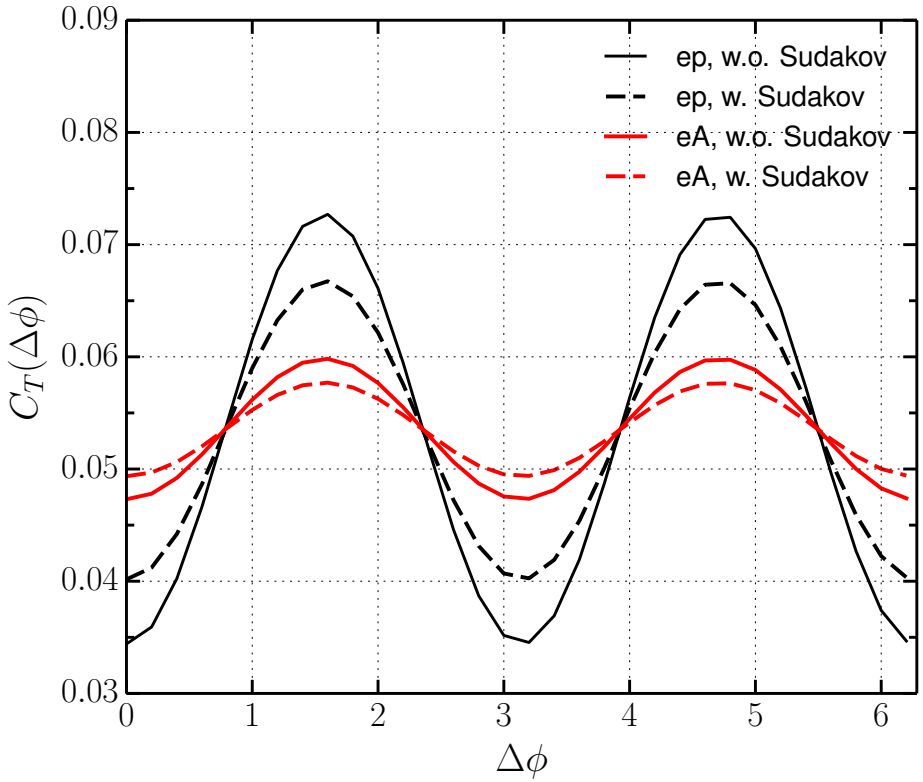
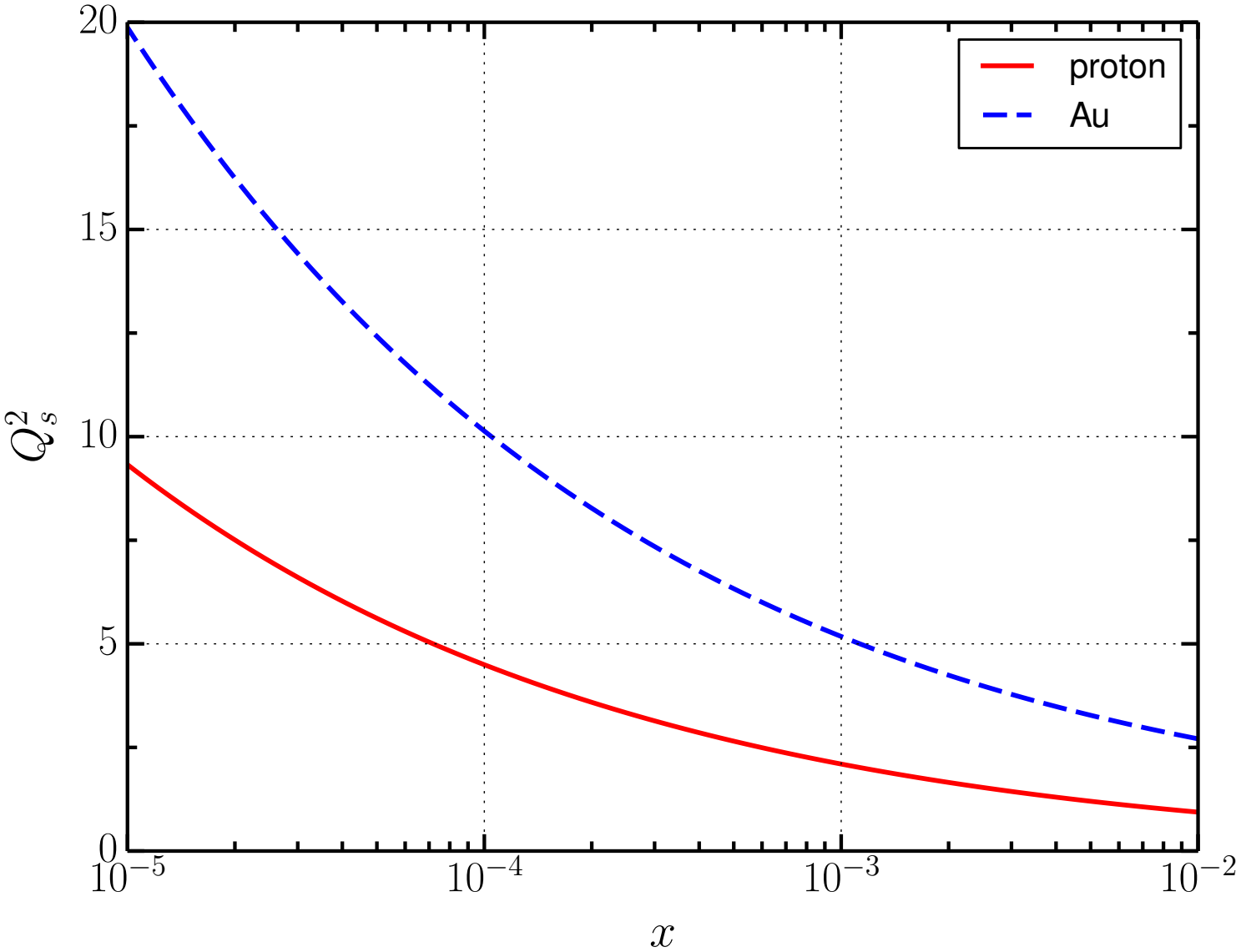
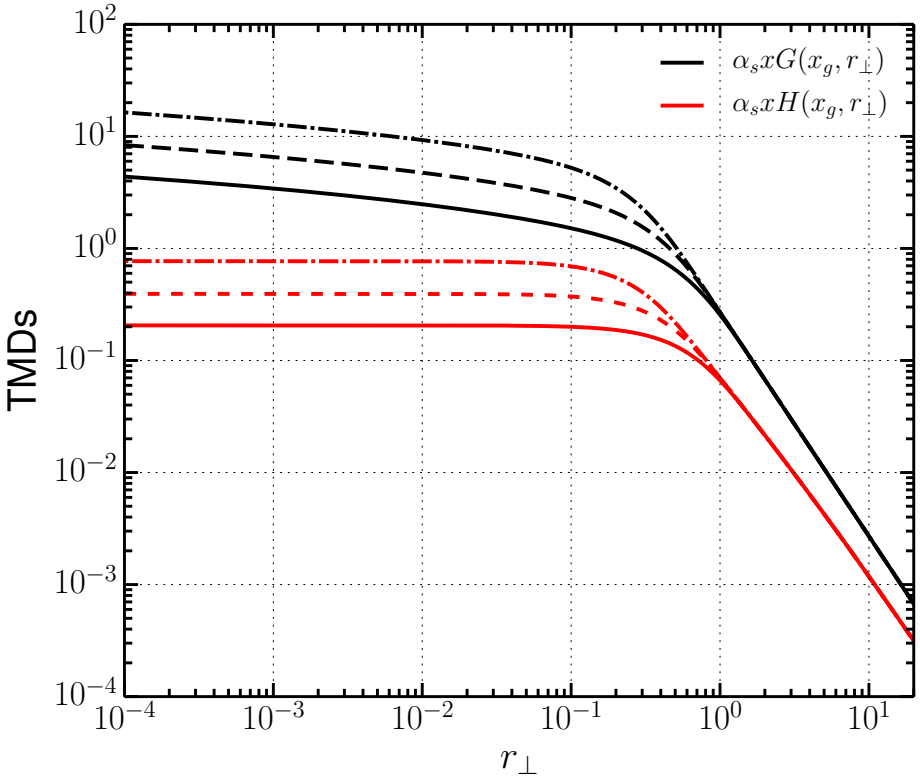


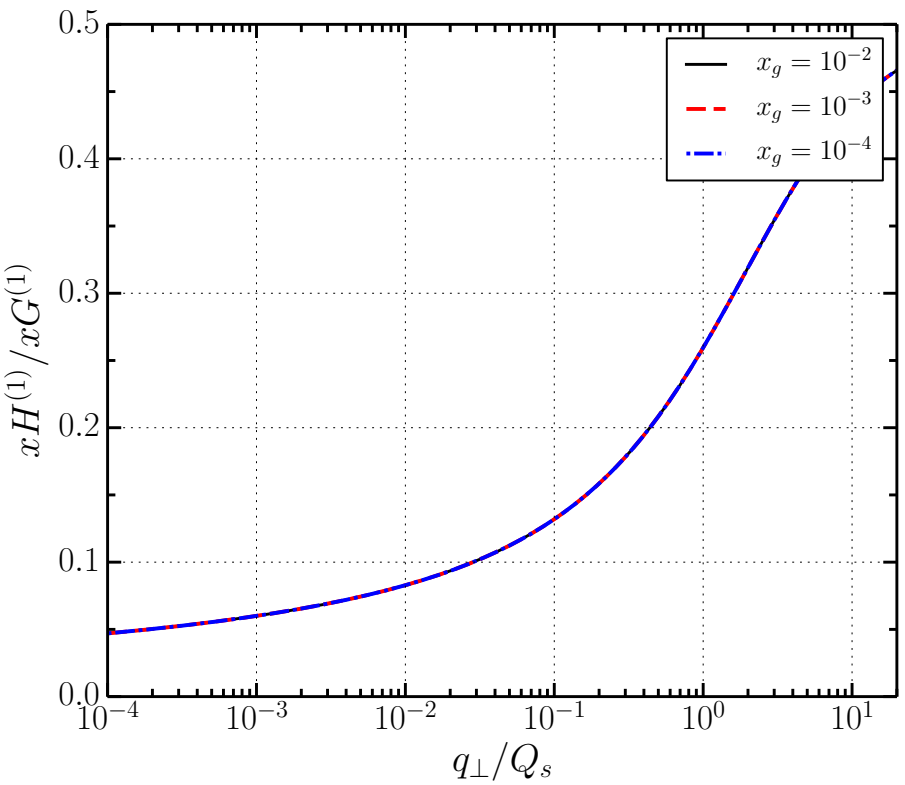


Gluon saturation scale towards small-x



WW gluon distribution in coordinate space





WW gluon distributions in momentum space