



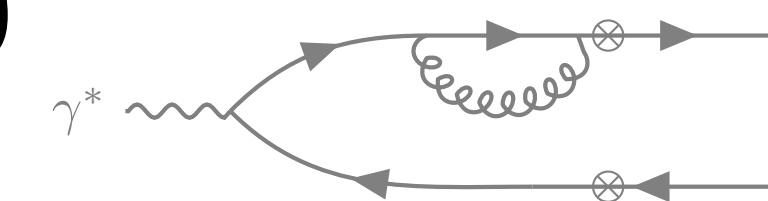
Stony Brook **University**



Inclusive prompt photon-jet correlations as a probe of gluon saturation

Semi-inclusive WG EIC YR (virtual talk)

August 17th, 2020



Farid Salazar



Kolb  , Roy, FS, Schenke, Venugopalan. [2008.04372](#)

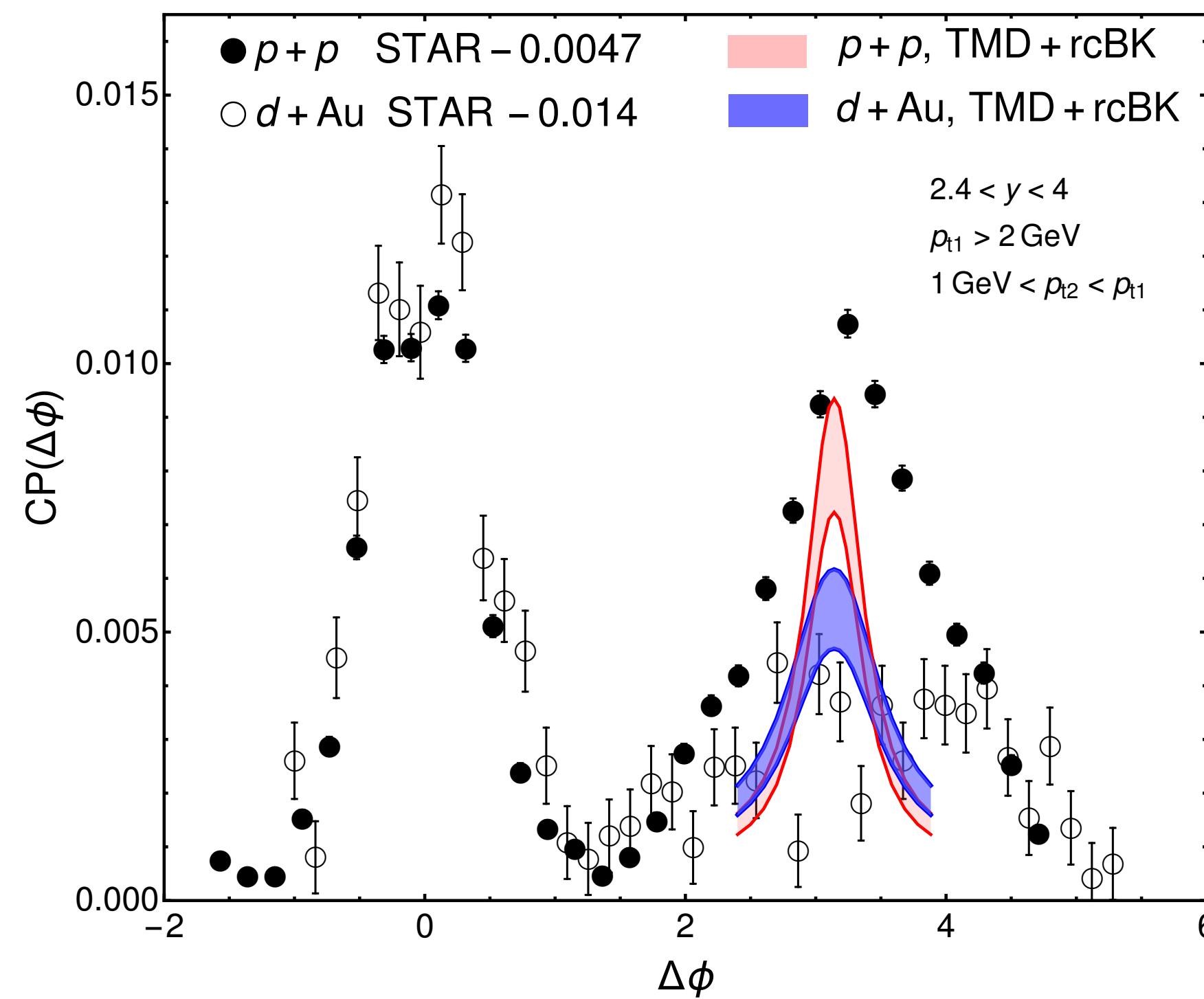
Outline

- Prompt photon+quark production from CGC
- Numerical results: azimuthal angle correlations at EIC
- Summary and Outlook

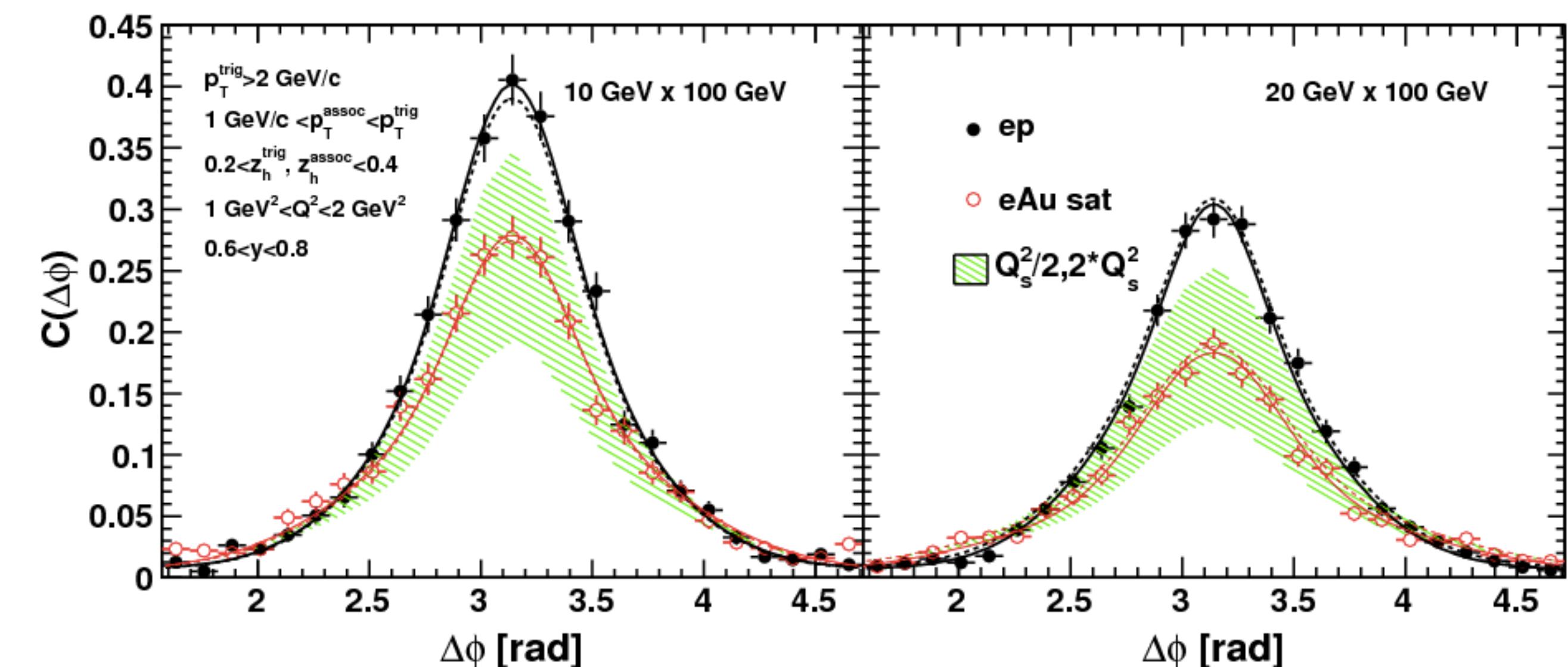
Dihadron correlations

Dihadron back-to-back suppression as a probe of gluon saturation

p+p / d+Au collisions



e+p/A collisions



Zheng, Aschenauer, Lee, Xiao. Phys. Rev. D 89, 074037 (2014)

Albacete, Giacalone, Marquet, Matas. Phys. Rev. D 99, 014002 (2019)

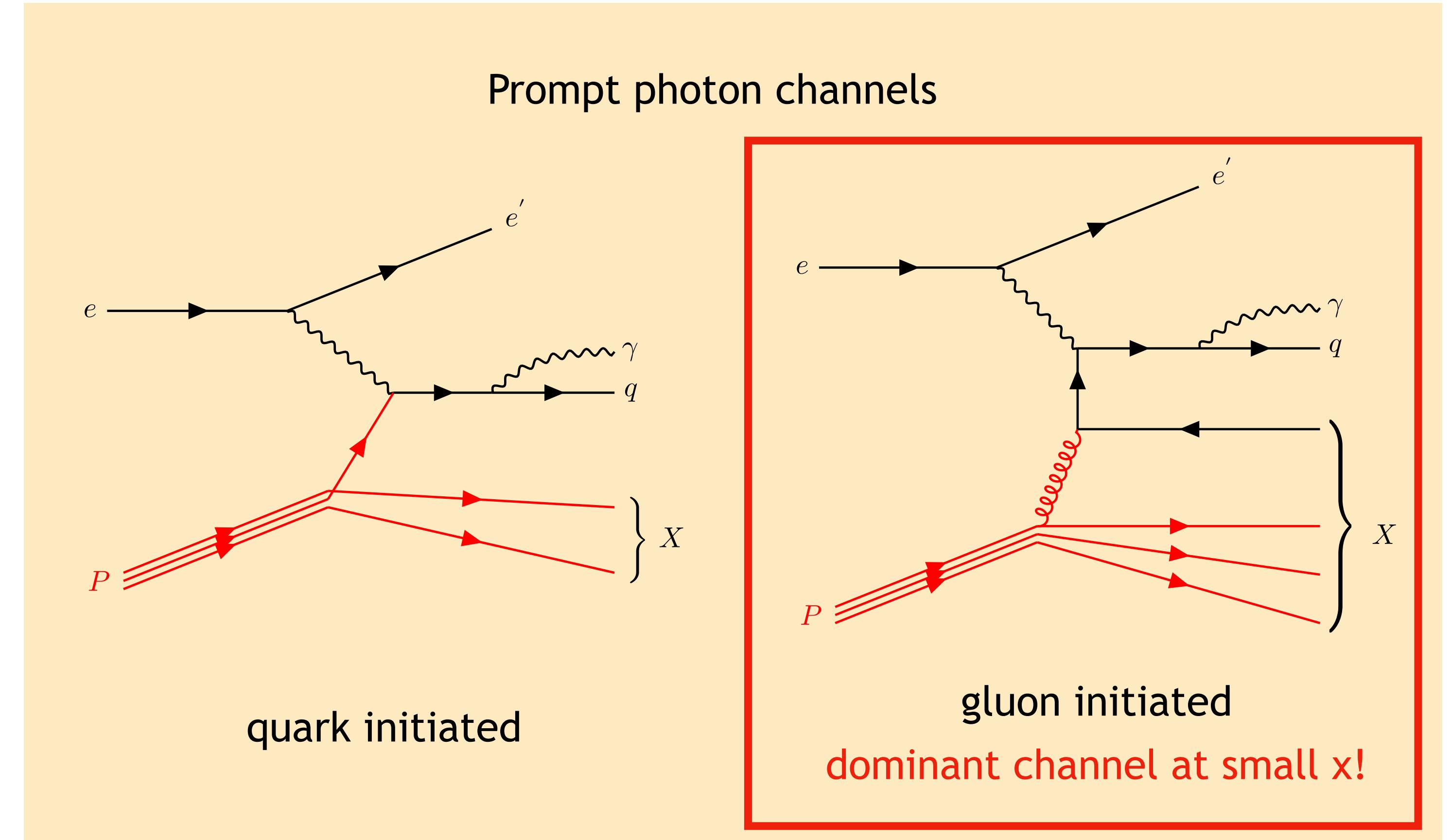
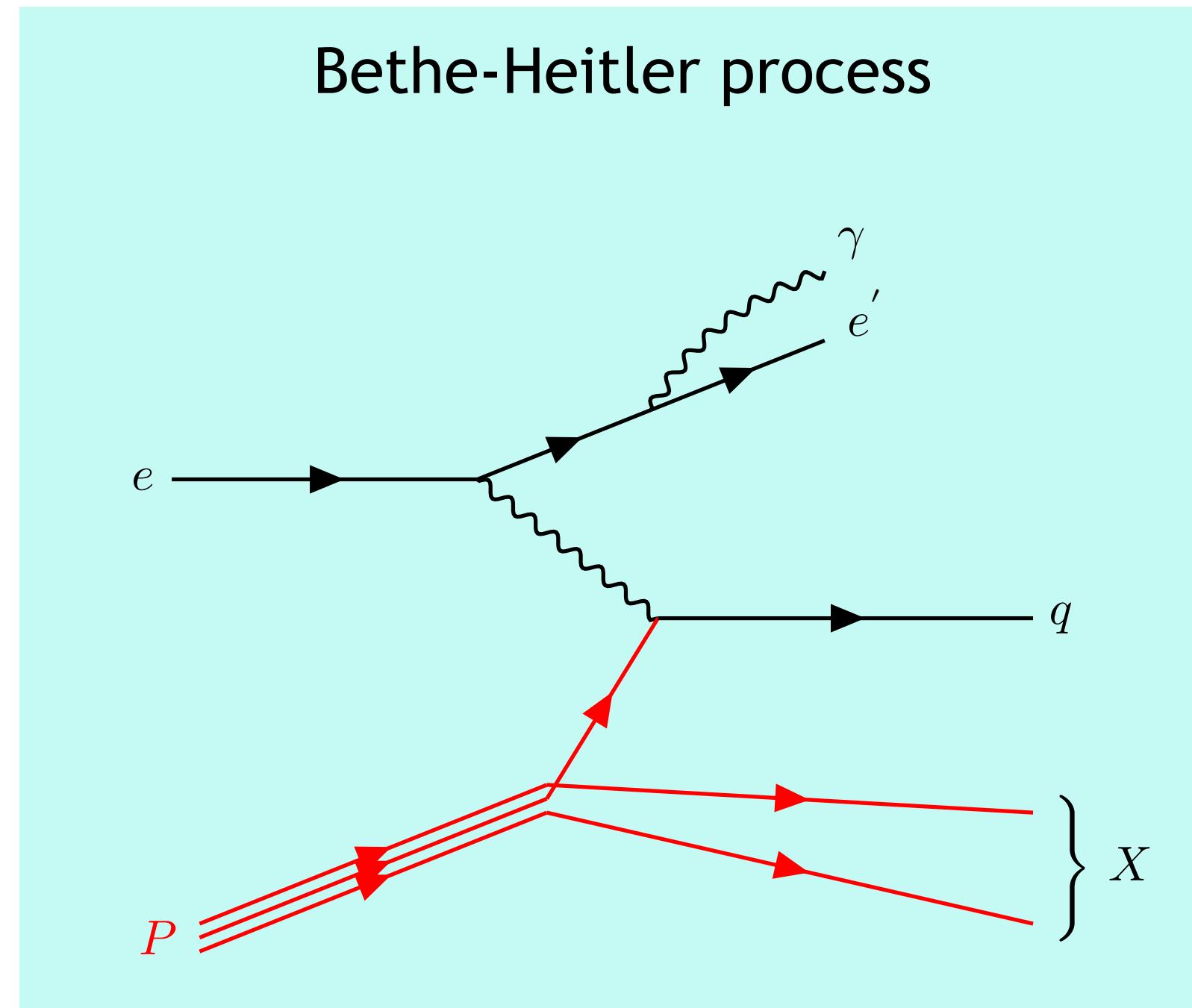
see also: Mäntysaari, Lappi. Nucl.Phys. A908 (2013) 51-72

Inclusive prompt-photon+jet in ep-eA: collinear pQCD and CGC

Inclusive photon + jet from collinear pQCD

Prompt photon: quark initiated vs gluon initiated

$$e + p/A \rightarrow \gamma + q + X$$

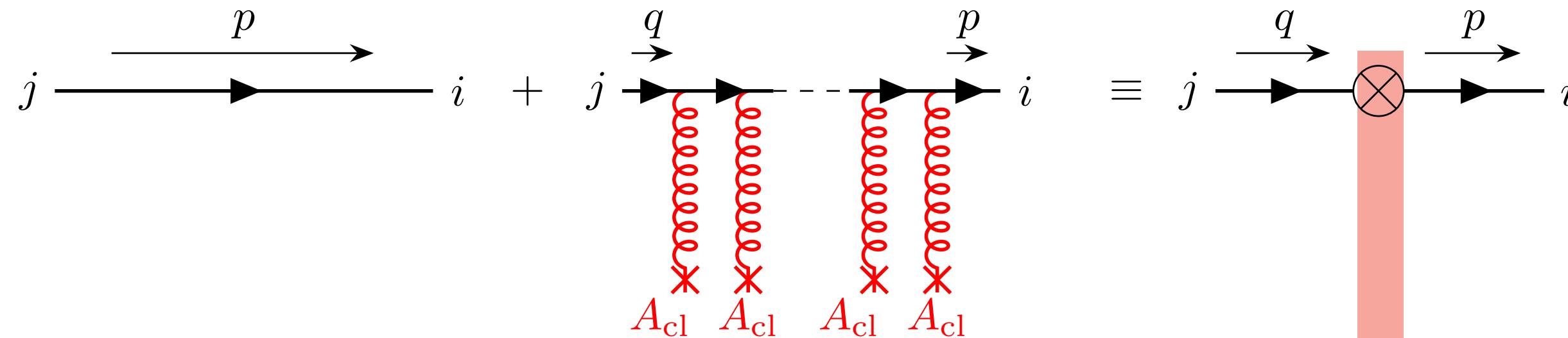


Inclusive prompt photon + jet from CGC

Multiple scattering and Wilson line correlators

McLerran, Venugopalan.
Phys. Rev. D 49 (1994) 2233-2241
Phys. Rev. D 49 (1994) 3352-3355

Dense gluon field $A_{cl} \sim 1/g$ needs resummation of multiple gluon interactions



Light-like Wilson line:

$$V_{ij}(\mathbf{x}) = P \exp \left\{ ig \int dx^- A_{cl}^{+,a}(\mathbf{x}, x^-) t^a \right\}$$

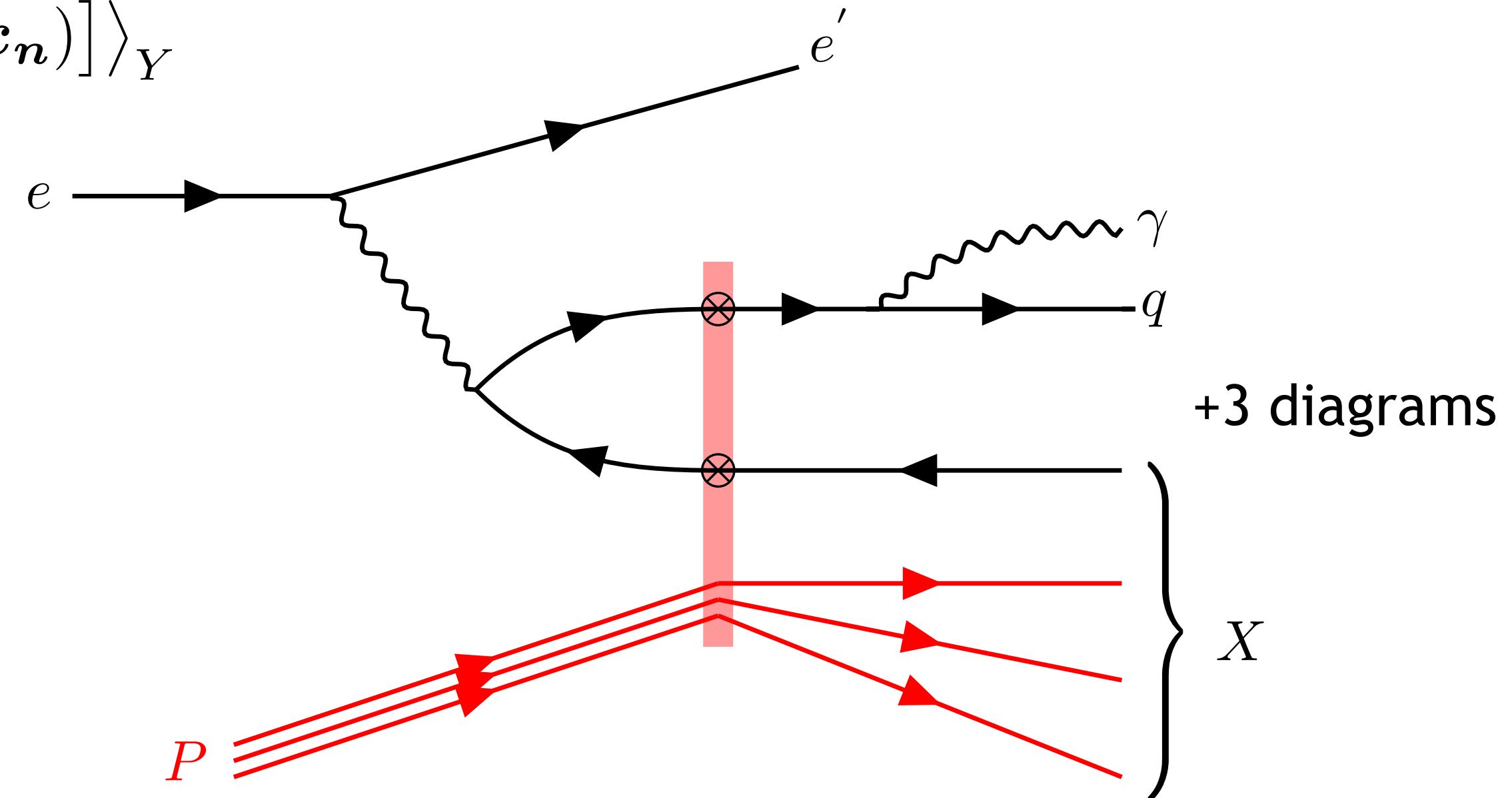
$$S_{x_1 x_2 \dots x_{n-1} x_n}^{(n)} = \frac{1}{N_c} \langle \text{Tr}_c [V(x_1)V^\dagger(x_2)\dots V(x_{n-1})V^\dagger(x_n)] \rangle_Y$$

dipole ($n = 2$), quadrupole ($n = 4$) ...

Leading order (in CGC power counting) contribution
prompt photon+quark production

$$d\sigma_{LO}^{\gamma^* + A \rightarrow q + \gamma + X} = H^{q\gamma} \otimes \Xi$$

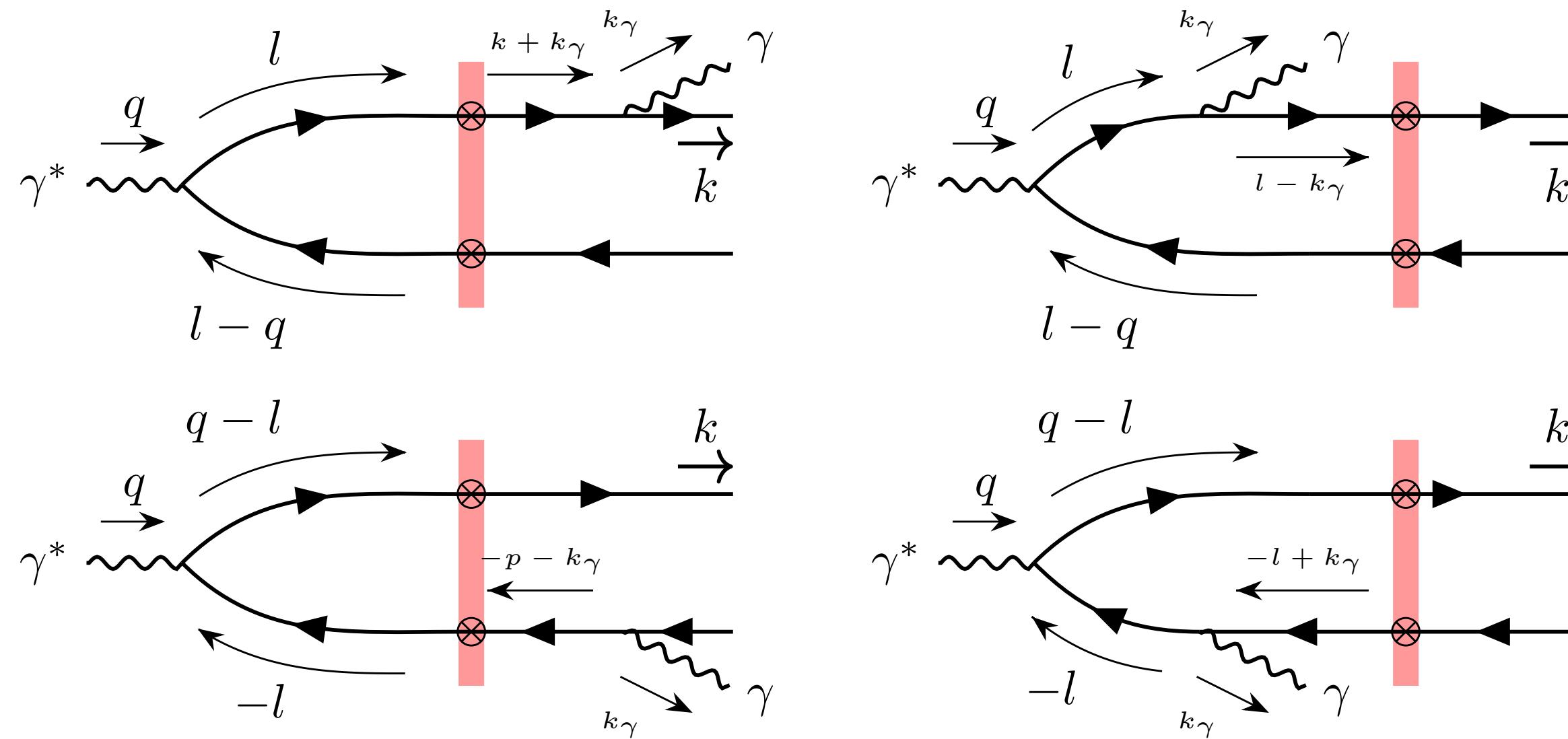
hard part Wilson line
correlators



Inclusive prompt photon + jet from CGC

From prompt photon + dijet to prompt photon + jet

Start from dijet+photon derived in Roy, Venugopalan. *JHEP* 05 (2018) 013



dijet+photon LO contributions (in CGC power counting)

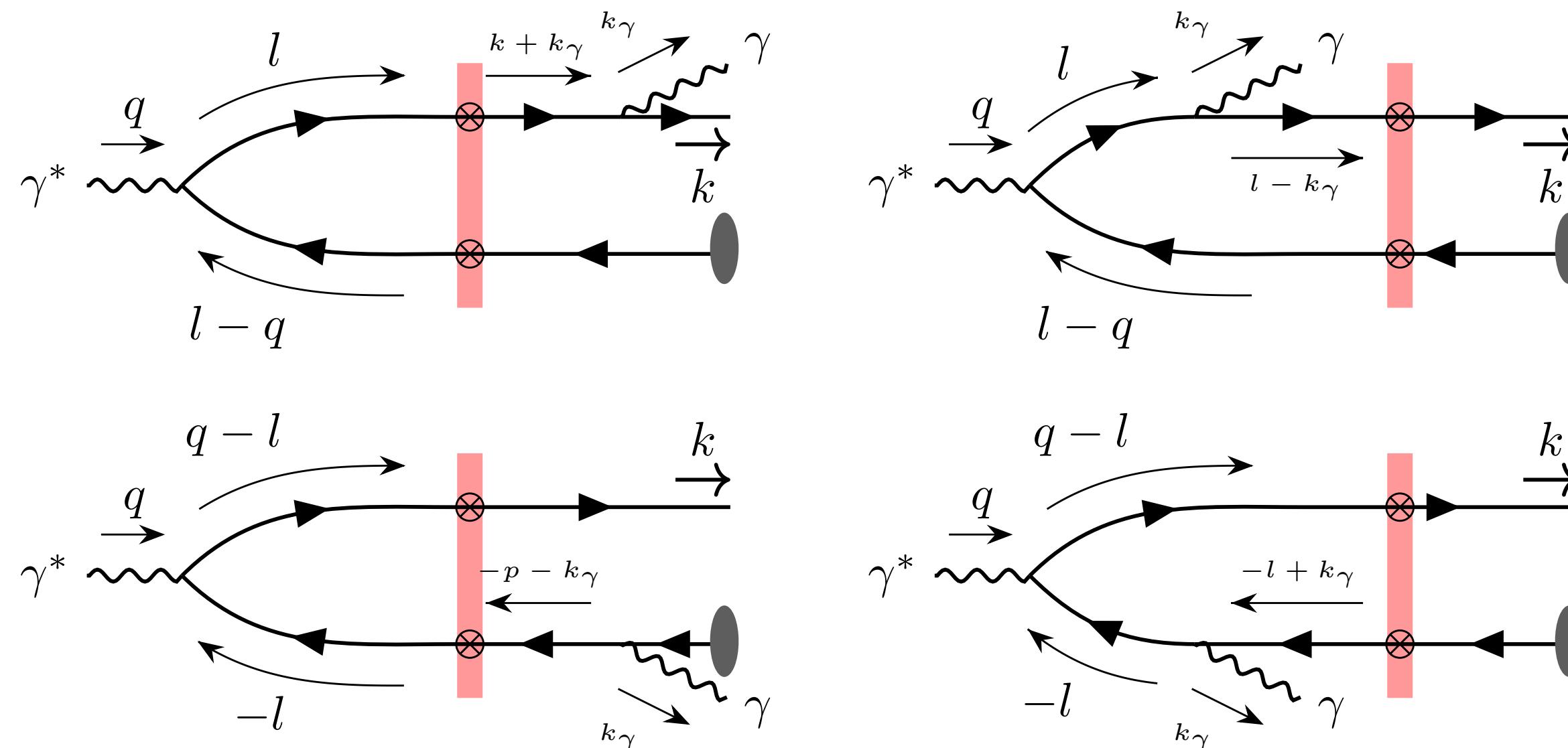
Integrate phase-space of anti-quark (**analytically**):

- Consider separately **longitudinally and transversely** polarized virtual photon γ^* contributions
- Fully work out **Dirac structure** of all contributions to cross-section
- Isolate **collinear singularity**

Kolb , Roy, FS, Schenke, Venugopalan. 2008.04372

Inclusive prompt photon + jet from CGC

Direct and fragmentation contributions



Fragmentation contribution matched to collinear singularity, includes both **dipoles** and **quadrupole**

$$d\sigma_F^{q\gamma} \propto H^{q\bar{q}} \otimes \Xi \otimes \mathcal{D}_{\bar{q} \rightarrow \gamma}$$

The **leading term of direct contribution** (dominant for $k_{\gamma,\perp} \gtrsim Q_s$) contains only **dipoles**

$$d\sigma_D^{q\gamma} \propto H^{q\gamma}(l_\perp; k, k_\gamma) \otimes C(l_\perp)$$

subleading contributions in powers of $Q_s/k_{\gamma,\perp}$ contain correlators with derivatives of Wilson lines

Kolb  , Roy, FS, Schenke, Venugopalan. 2008.04372

indicates integrated over phase space

Dominguez, Marquet, Xiao, Yuan. Phys.Rev.D 83 (2011)

quadrupole \longleftrightarrow Weizs  cker-Williams gluon TMD
dipole \longleftrightarrow dipole gluon TMD

Numerical results for azimuthal angle correlations in prompt photon+jet at EIC

Setup for prompt photon+quark production from CGC

Kinematics:

$\sqrt{s} = 90$ GeV

c.o.m. energy

$y = 0.9$

inelasticity

$Q^2 = 1, 2, 4$ GeV 2 virtuality of photon probe

photon and quark kinematics

$2.0 \text{ GeV} < k_{\perp}, k_{\gamma, \perp} < 3.0 \text{ GeV}$

$1.2 < \eta_q, \eta_{\gamma} < 1.7$

Observable:

$$\mathcal{C}(\Delta\phi_{q\gamma}) = \frac{dN_{q\gamma}(\Delta\phi_{q\gamma})}{dQ^2 dW^2} / \frac{dN_q}{dQ^2 dW^2}$$

correlation coefficient of direct photons
(associated yield) for a quark/jet trigger

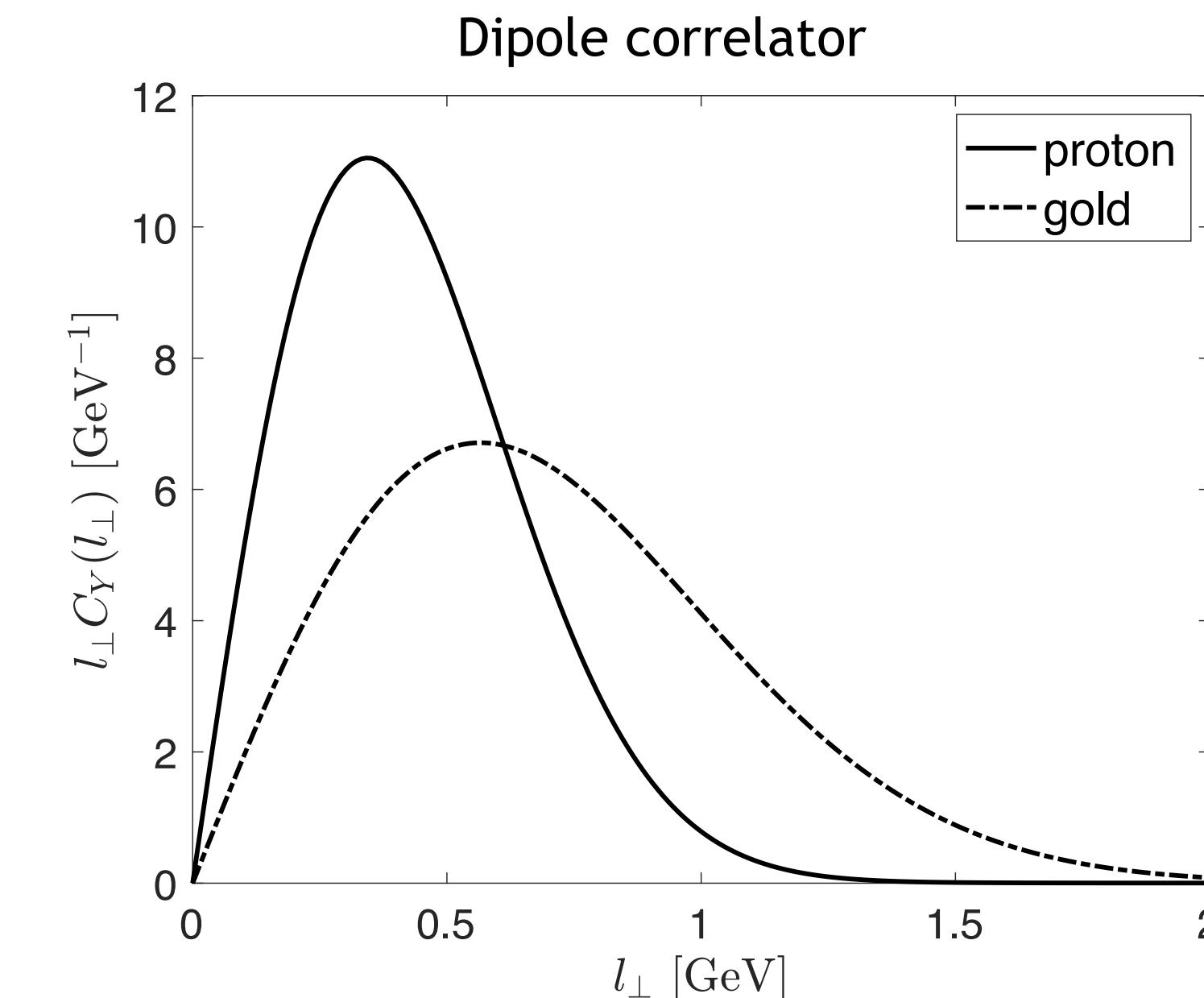
Correlators and small-x evolution:

Small-x evolution of dipole:
running coupling Balitsky Kovchegov equation

Balitsky. Phys.Rev.D 75 014001 (2007)

Initial conditions:
modified McLerran Venugopalan (MVe)
+ optical Glauber

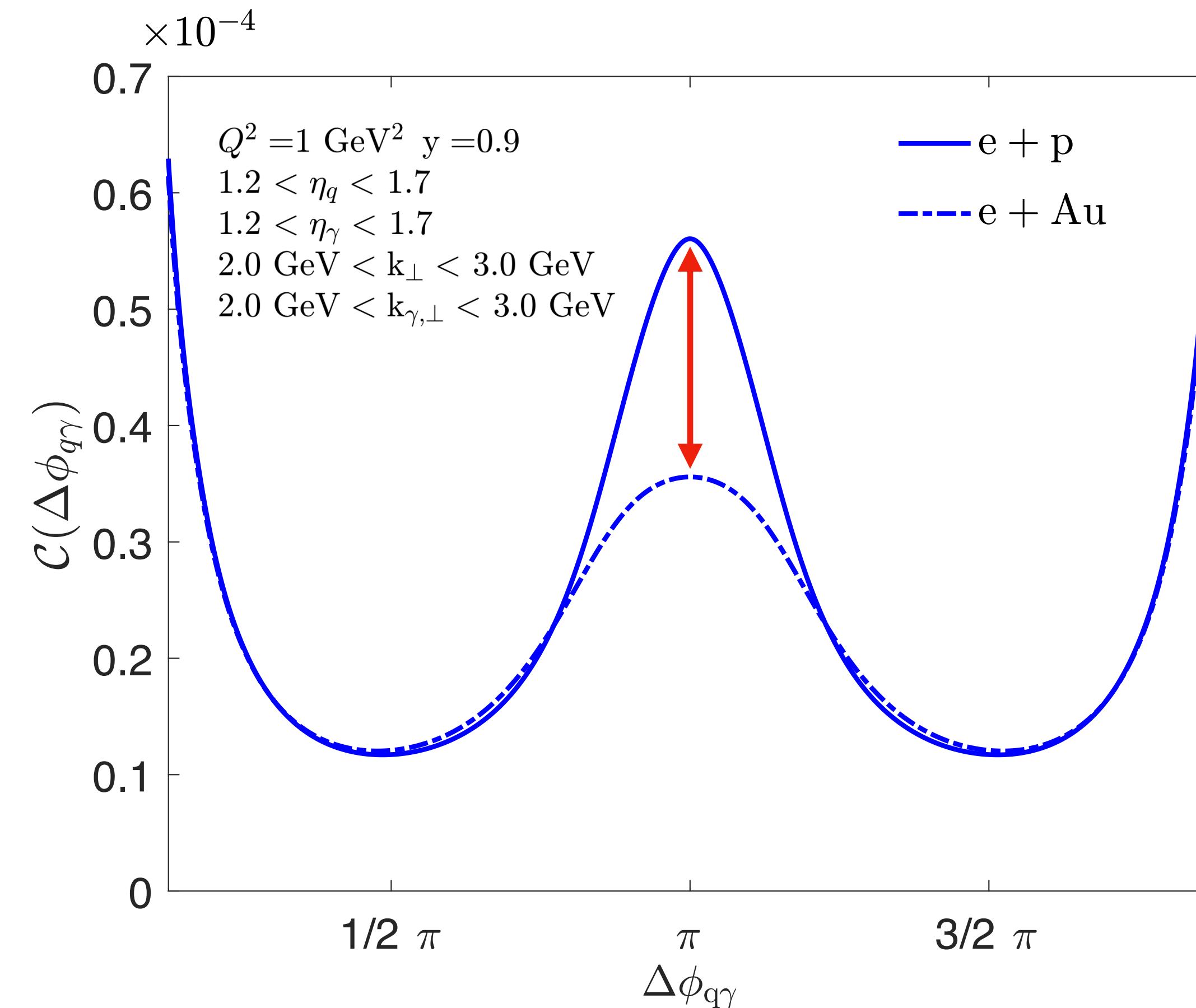
Lappi, Mäntysaari. Phys.Rev. D 88, 114020 (2013)



Azimuthal angle correlations: prompt photon+quark for kinematics of the EIC

Two features:

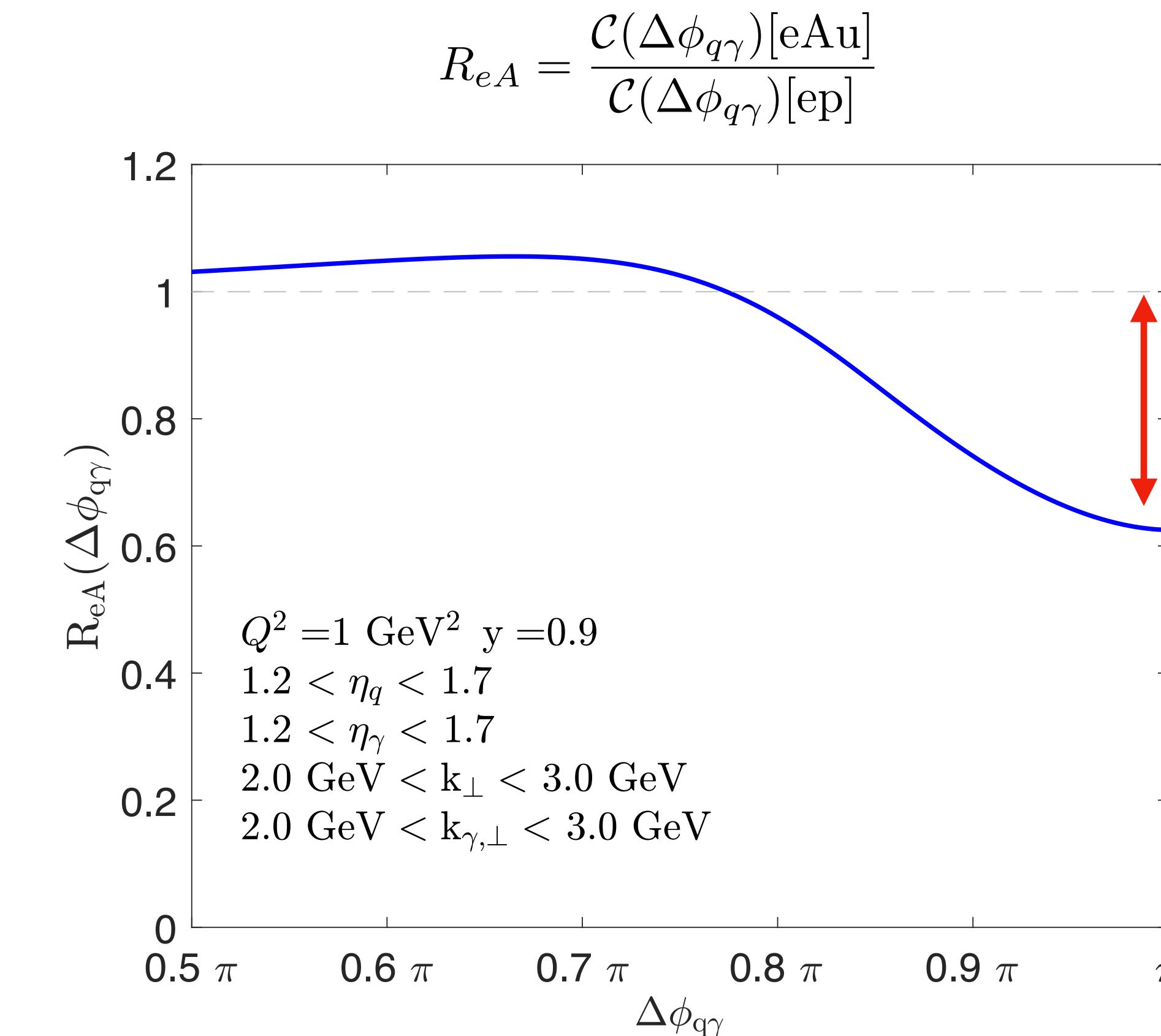
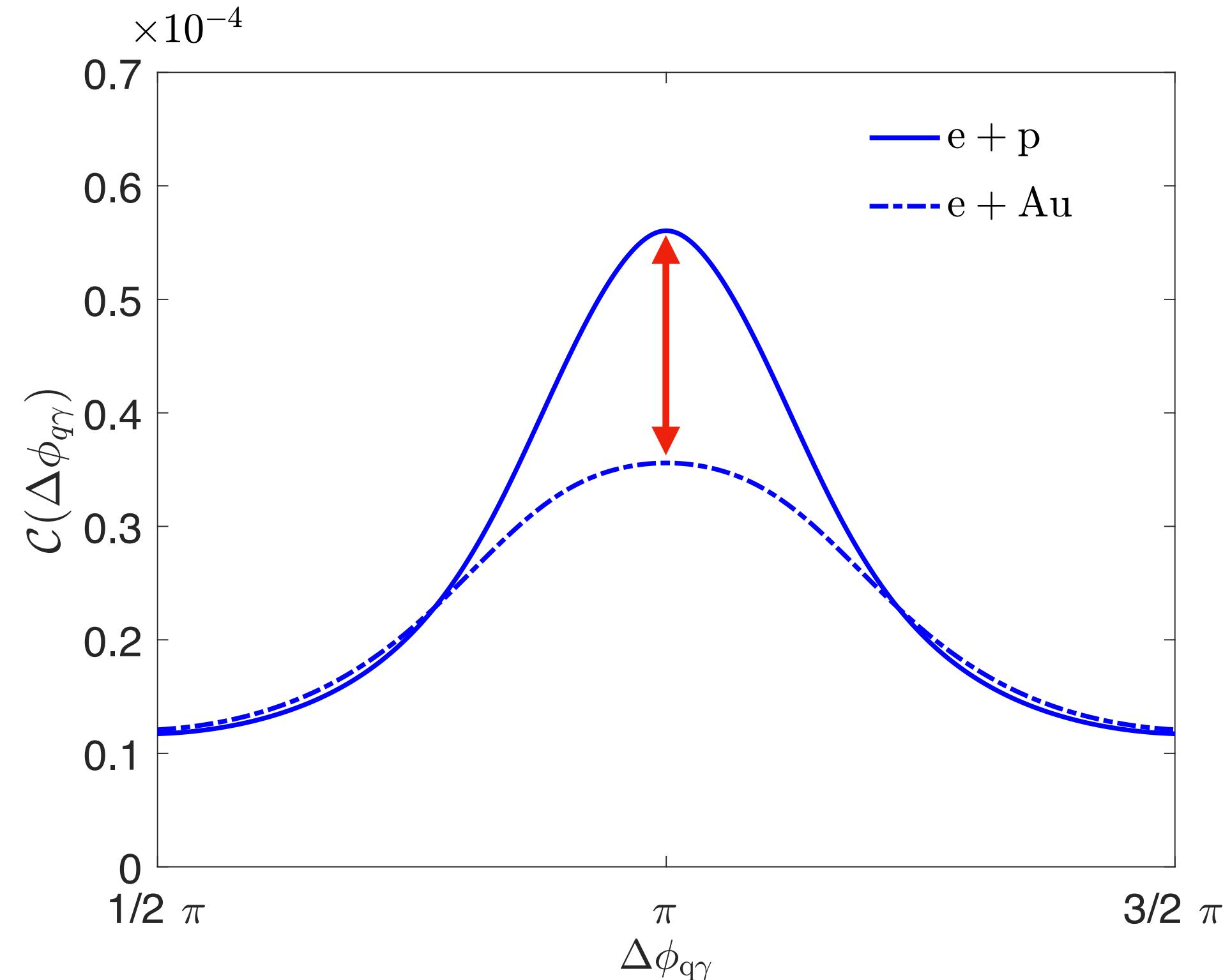
- Back-to-back (away side) peak, **suppressed** for e+A compared to e+p
- Near side peak due to photon emitted collinearly from quark, not significantly affected by nuclear species.



Kolb  , Roy, FS, Schenke, Venugopalan. 2008.04372

Azimuthal angle correlations: prompt photon+quark

Back-to-back (away side) peak suppression

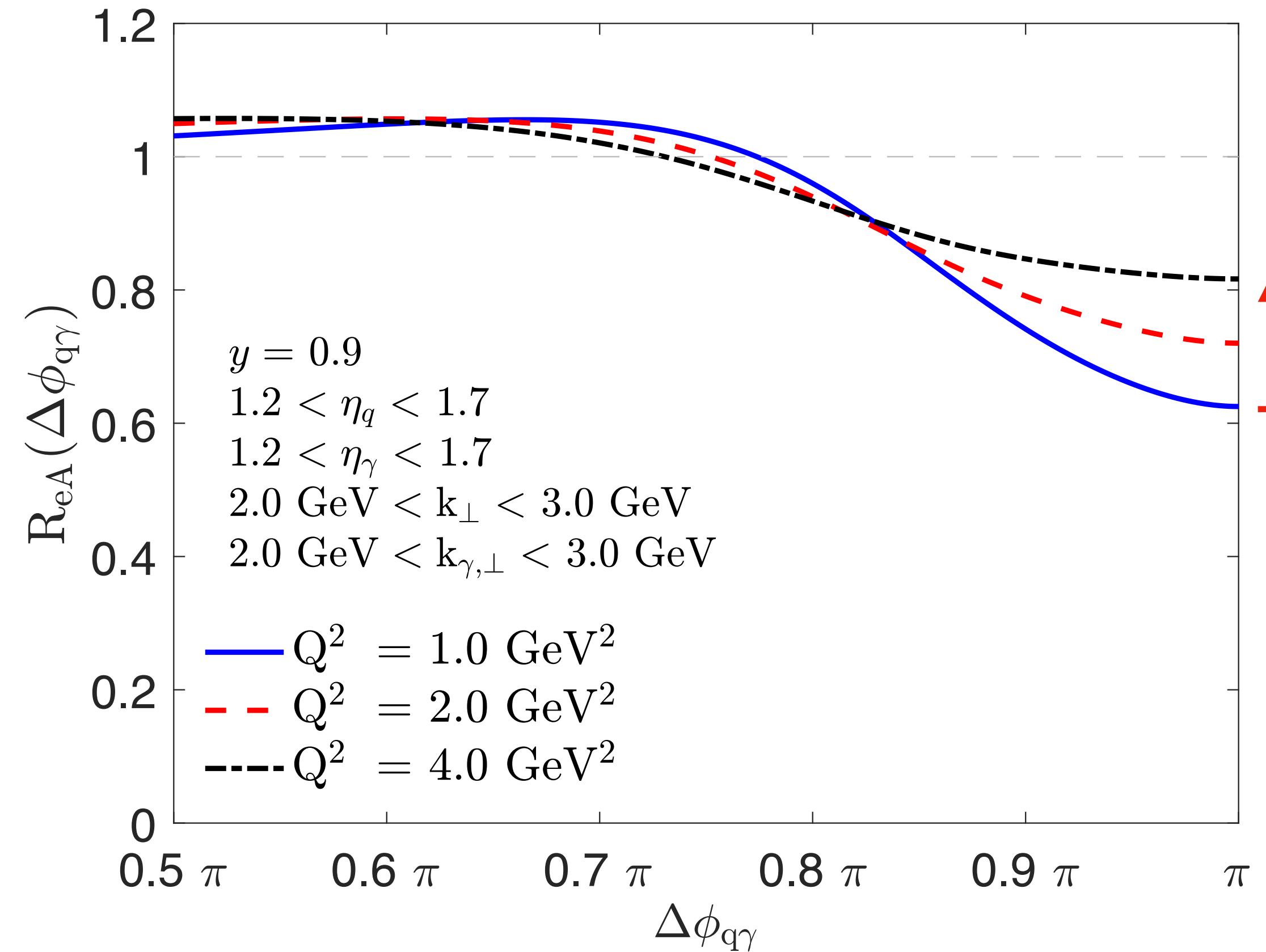


Suppression and broadening of back-to-back peak due to nuclear enhancement of $Q_{s,Au}^2 = 2.7 Q_{s,p}^2$ for min-bias.

Kolb , Roy, FS, Schenke, Venugopalan. 2008.04372

Azimuthal angle correlations: prompt photon+quark

Q^2 dependence: a tuning knob from dilute to dense



R_{eA} useful to characterize multiple scattering with dense gluon system

Suppression weakens as photon resolution Q^2 is increased

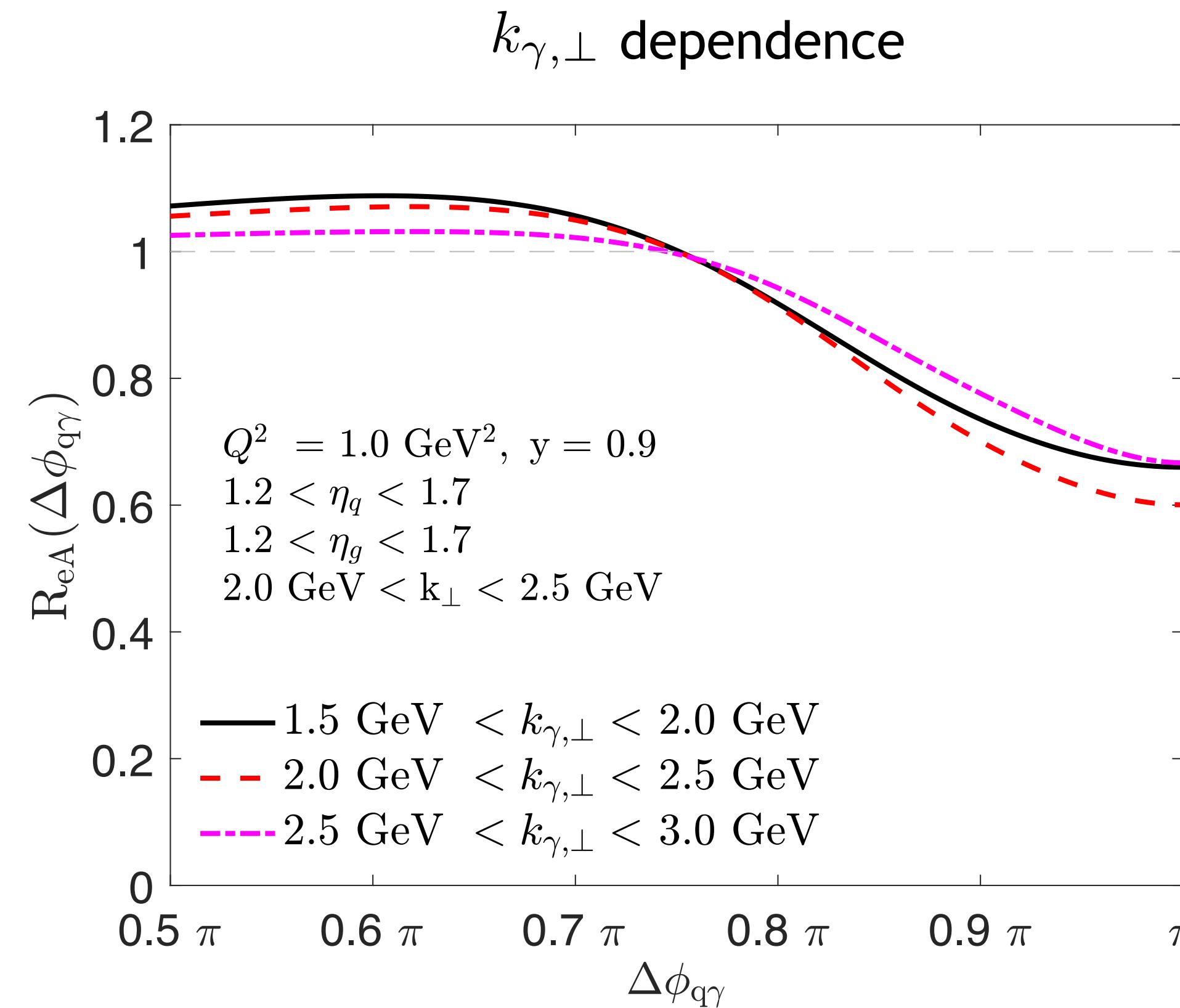
In the dilute limit ($Q^2 \gg Q_s^2$) the ratio $R_{eA} \rightarrow 1$

Virtuality of DIS provides an additional handle compared to p+A collisions

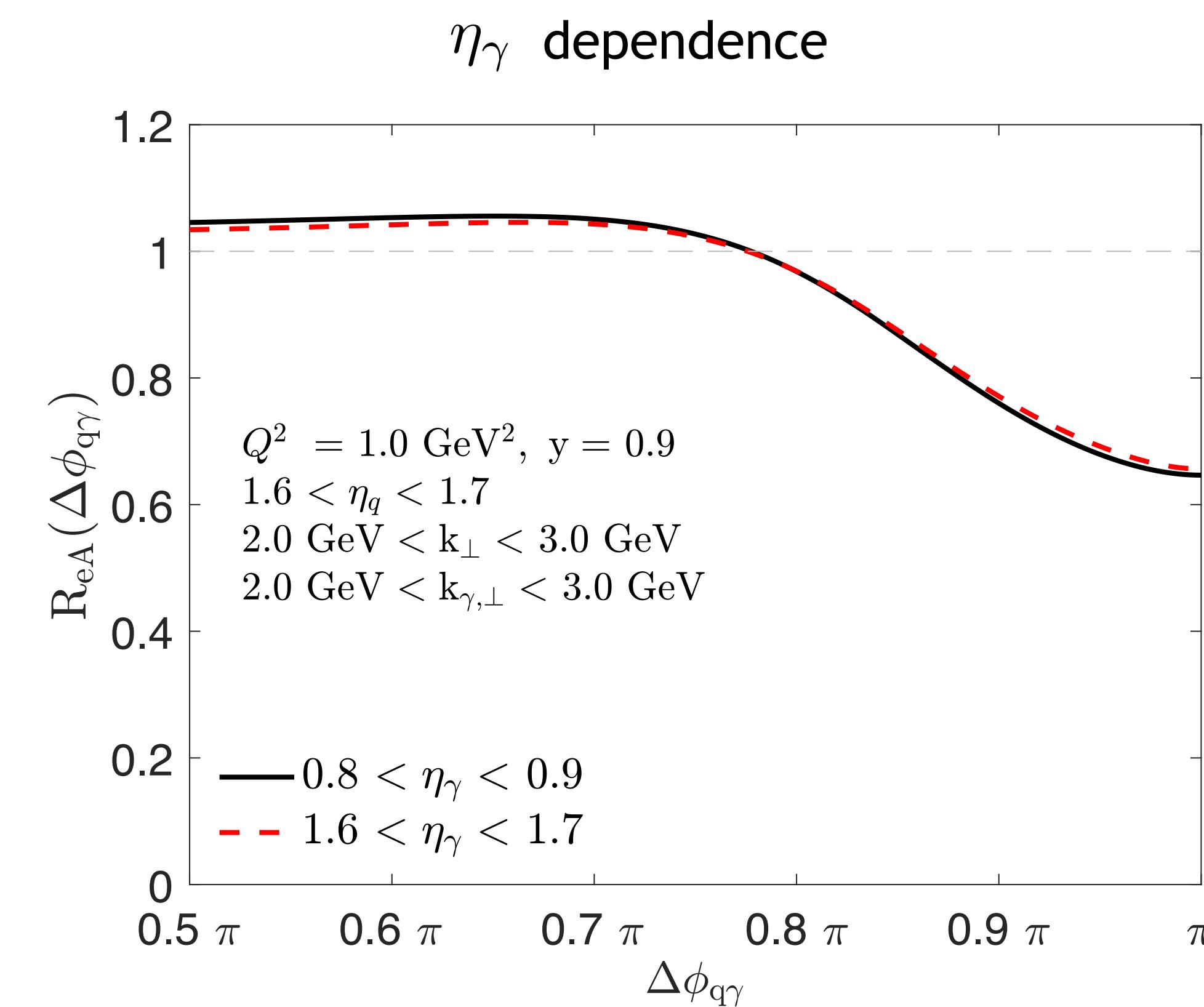
Kolb  , Roy, FS, Schenke, Venugopalan. 2008.04372

Azimuthal angle correlations: prompt photon+quark

Kinematics of the photon dependence



suppression maximal when $k_{\gamma,\perp} \sim k_\perp$



suppression weakly depends on rapidity
limited small-x evolution

Summary

- Computed inclusive prompt photon+quark differential cross-section within CGC
 - fragmentation:** sensitive to quadrupole correlator/ (unpol) Weizsacker Williams gluon TMD
 - direct:** sensitive to dipole correlator/ dipole gluon TMD
- Numerical study of azimuthal angle correlations at EIC
 - suppression and broadening of back-to-back peak**
 - study dependence on virtuality, and transverse momenta and rapidity of photon**

Outlook

- Extend our results to Next-to-Leading-Order (in CGC power counting)

Numerical evaluation of: NLO impact factor + NLO JIMWLK/BK

Roy, Venugopalan. Phys. Rev. D 101, 034028 (2020)

- Incorporate Sudakov resummation

Studied in dihadron production in eA

Mueller, Xiao, Yuan. Phys.Rev.D 88 11, 114010 (2013)

Zheng, Aschenauer, Lee, Xiao. Phys. Rev. D 89, 074037 (2014)

- Include fragmentation, parton shower and jet reconstruction

Need reconstruction of small k_\perp jets

Alternatively study prompt photon+hadron correlations

for p+A collisions:

Benić, Dumitru. Phys. Rev. D 97, 014012 (2018)

Jalilian-Marian, Rezaeian. Phys.Rev.D 86 034016 (2012)