QM QUARK MATTER KRAKÓW 2022

29TH INTERNATIONAL CONFERENCE ON ULTRARELATIVISTIC NUCLEUS - NUCLEUS COLLISIONS
APRIL 4-10, 2022
KRAKÓW, POLAND

Multiple Parton Scattering and Gluon Saturation in Dijet Production at EIC

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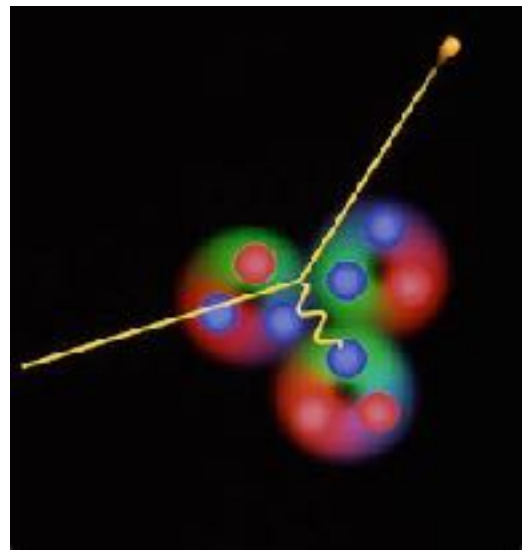
Collaborator : Xin-Nian Wang (LBL)

Probe $\hat{q}$ (jet quenching) in Cold Nuclei

Electron Ion Collision

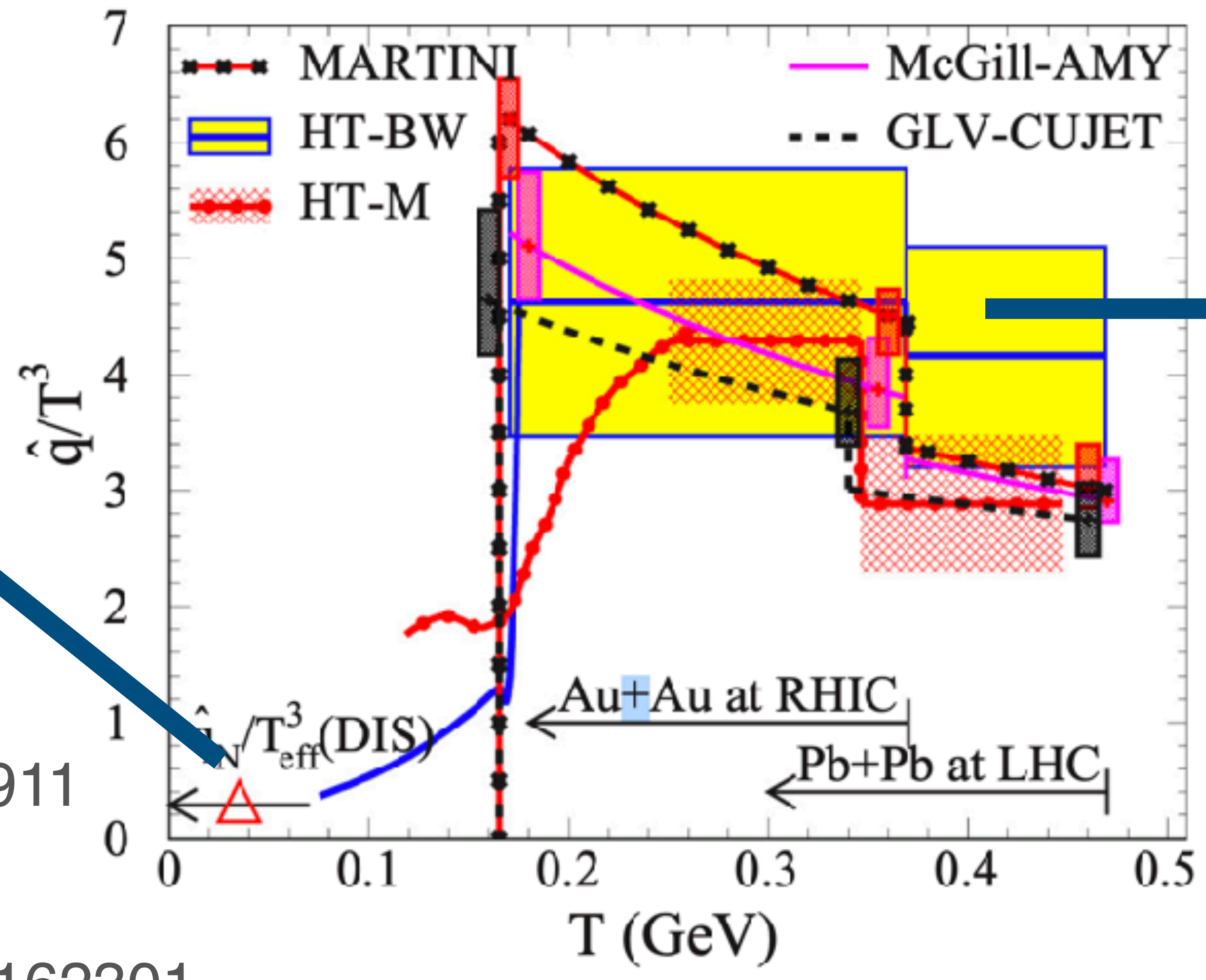


$\hat{q} \approx 0.015$ GeV$^2/fm$

NB Chang et al, PRC **89.3** (2014): 034911

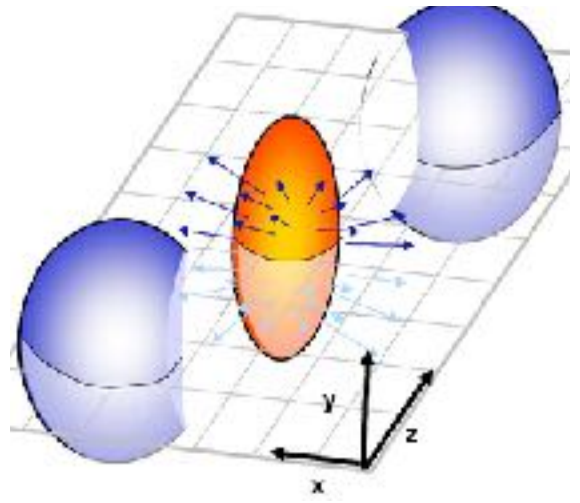
P. Ru et al, arXiv:2004.00027

E Wang, XN Wang, PRL **89.16** (2002): 162301



JET Collaboration, PRC **90**, 014909

Heavy Ion Collision



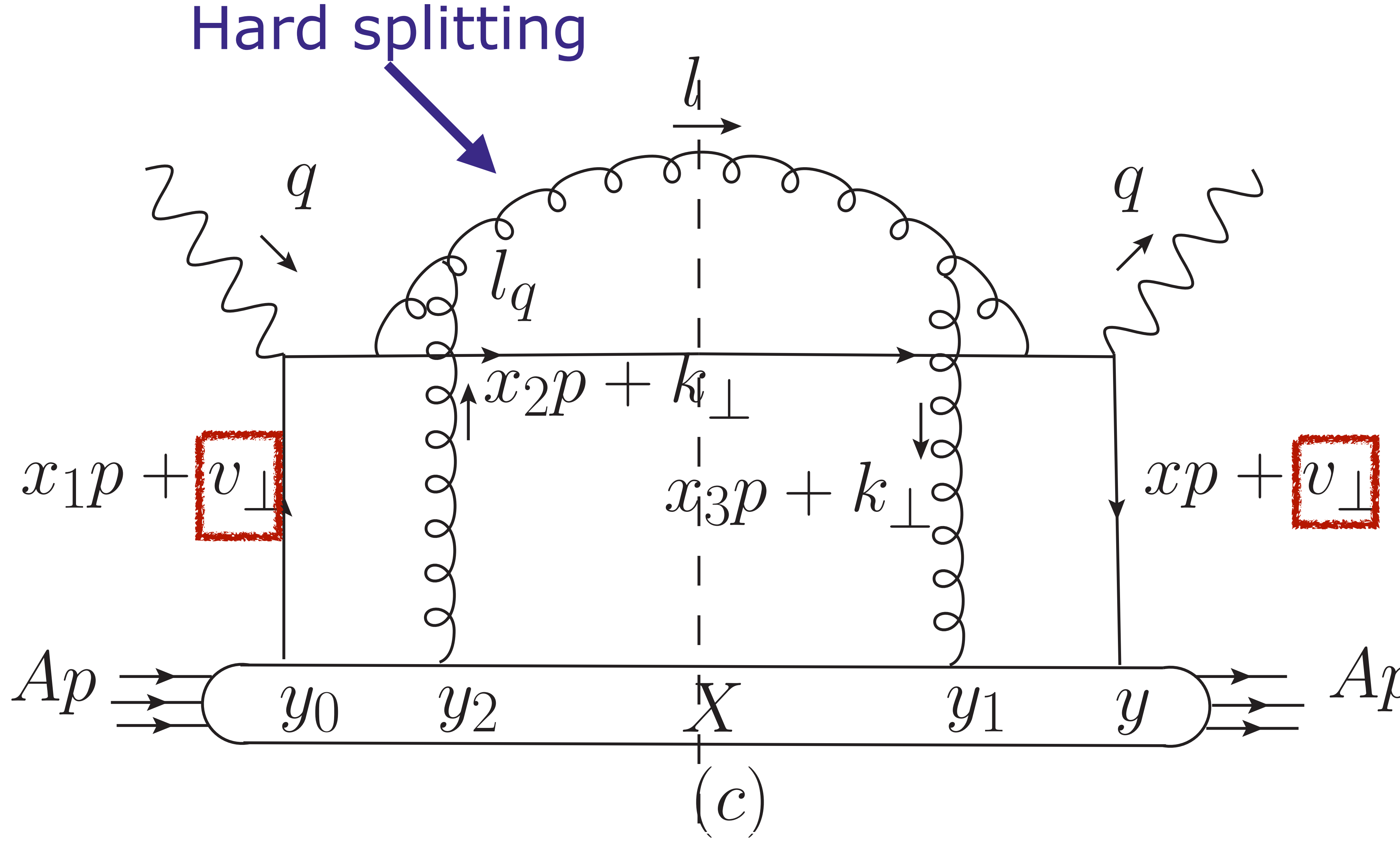
$\hat{q} \approx 1.2 \pm 0.3$ GeV$^2/fm$ RHIC

$\hat{q} \approx 1.9 \pm 0.7$ GeV$^2/fm$ LHC

JET Collaboration, PRC **90**, 014909

- $\hat{q}$ average pT transfer squared per unit length
- $\hat{q}$ related to gluon TMD PDF $\hat{q} = \int d^2k_\perp \hat{q}\left(k_\perp\right) = C\int d^2k_\perp \rho\phi\left(x_g, k_\perp\right)$

Use Dijet to probe gluon TMD PDF or $\hat{q}$



- Based on Generalized High Twist Approach

  Relax $l_\perp, l_{q\perp} \gg k_\perp$, no $k_\perp$ /twist expansion
- The second scattering probe gluon TMD pdf
- Include initial quark $v_\perp$ and pT broadening

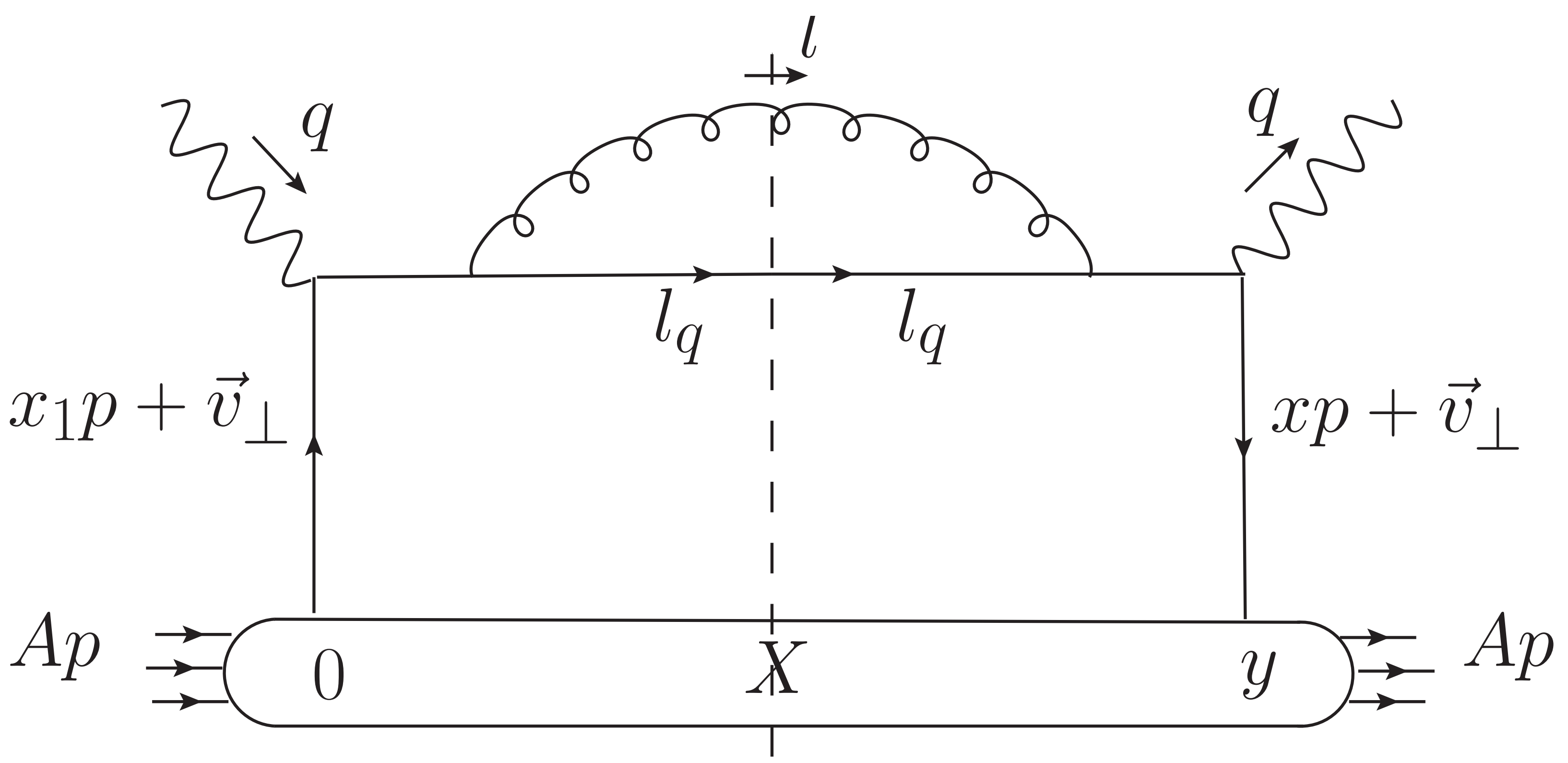
Include saturation in gluon TMD PDF , determine saturation scale self-consistently

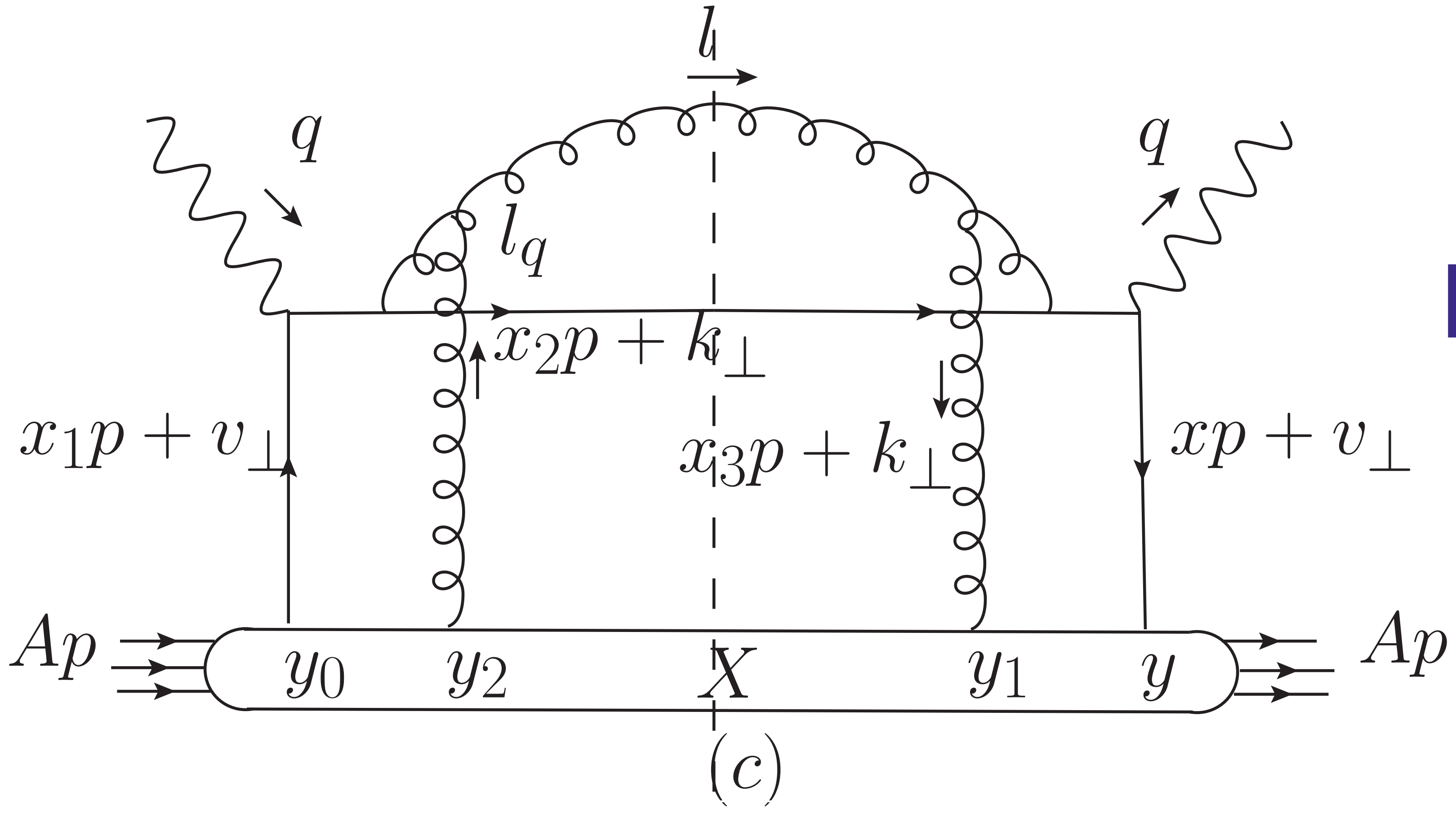
$$\phi_N(x_G, k_\perp, \mu^2) = \begin{cases} \phi_N^0 \text{ at } Q_s, & k_\perp < Q_s; \\ \phi_N^0(\mu^2 = k_\perp^2), & k_\perp > Q_s, \end{cases}$$

$$Q_s^2(x_B, Q^2, b_\perp) = C \int dy_0^- \rho(y_0^-, b_\perp) \int \frac{d^2k_\perp}{(2\pi)^2} \alpha_s(\mu) \phi_N(x_G, k_\perp, \mu^2)$$

TMDlib Package F Hautmann et al., EPJC 74 (2014), 3220

Dijet in e+A: Single scattering & Double scattering





LPM effect

$$\frac{d\hat{\sigma}^S_{eA}}{dx_B dQ^2 dz d^2l_\perp d^2l_{q\perp}} \propto q_A(x_B, \vec{v}_\perp)$$

$$q_A = \int dy_0^- d^2b_\perp \rho q_N$$

nuclear modification : initial quark pT broadening

$$\frac{d\hat{\sigma}^D_{eA}}{dx_B dQ^2 dz d^2l_\perp d^2l_{q\perp}} \propto q_N(x_B, \vec{v}_\perp, \vec{b}_\perp) \otimes \phi_N(x_G, \vec{k}_\perp)$$

$$\otimes [\mathcal{N}_g^{\text{nonLPM}} + \mathcal{N}_g^{\text{qLPM}} + \mathcal{N}_g^{\text{gLPM}}]$$

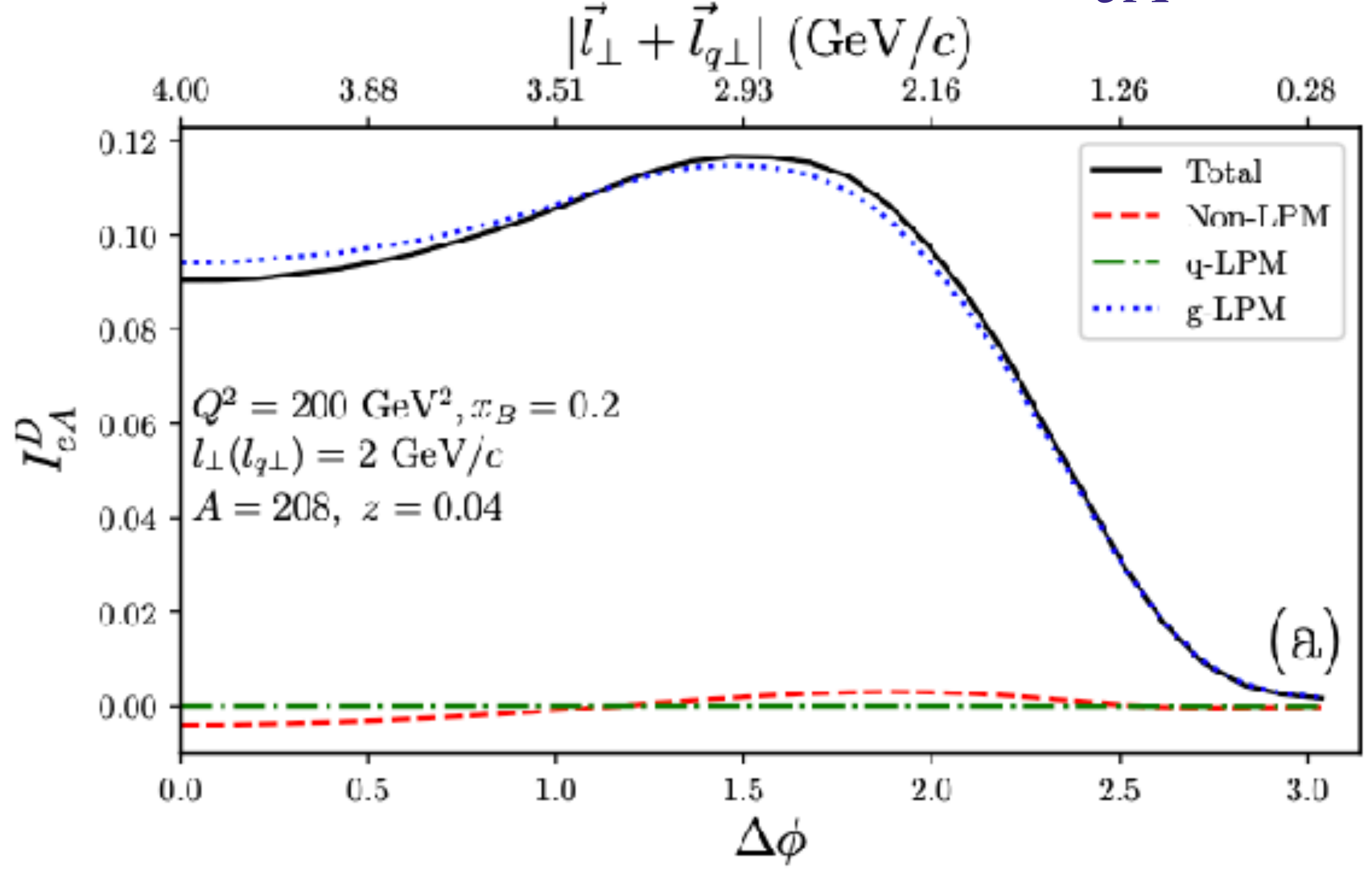
nuclear modification : initial quark pT broadening + second scattering

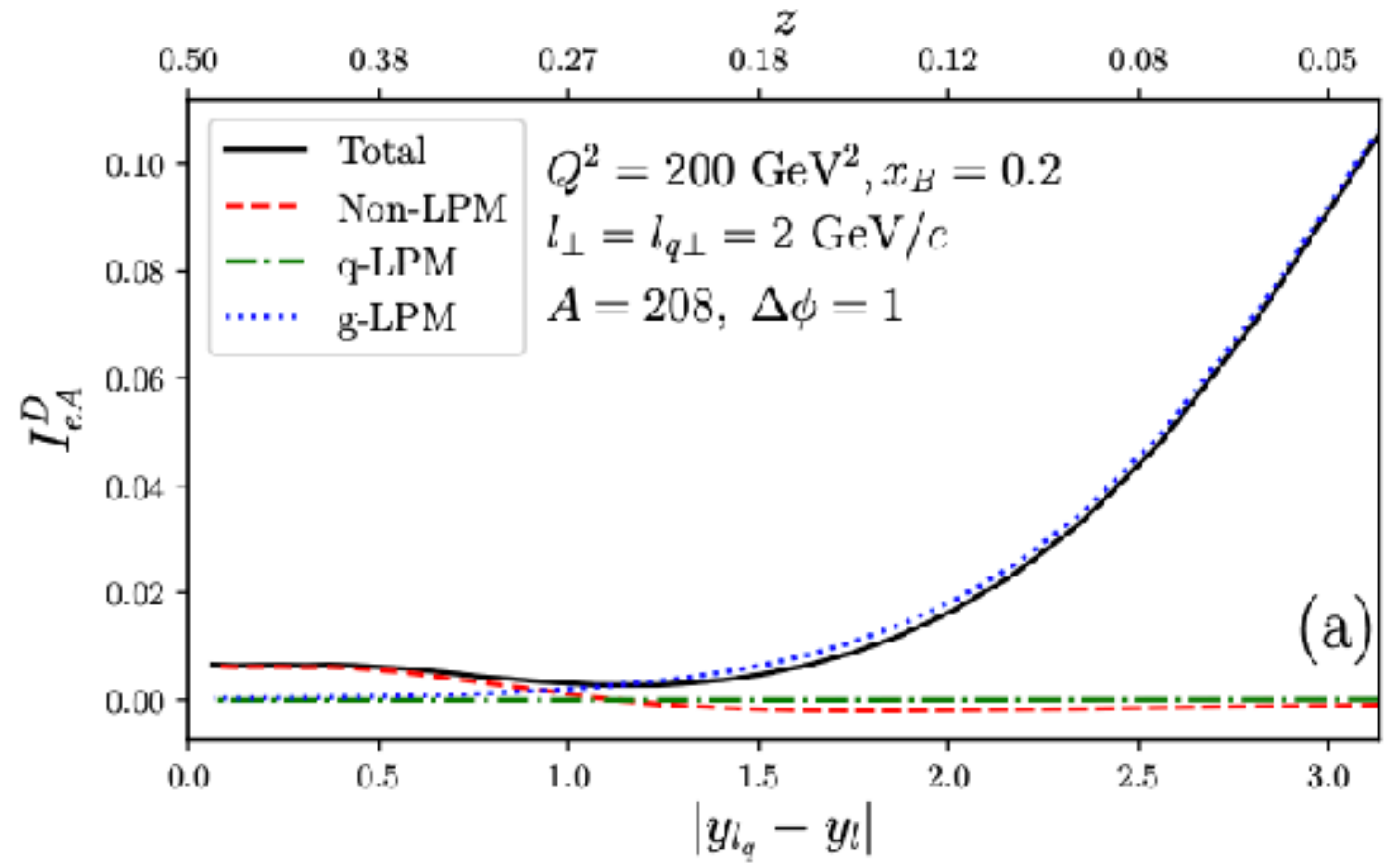
Liang, Z. T., Wang, X. N., & Zhou, J. (2008). *PRD*, *77*(12), 125010.

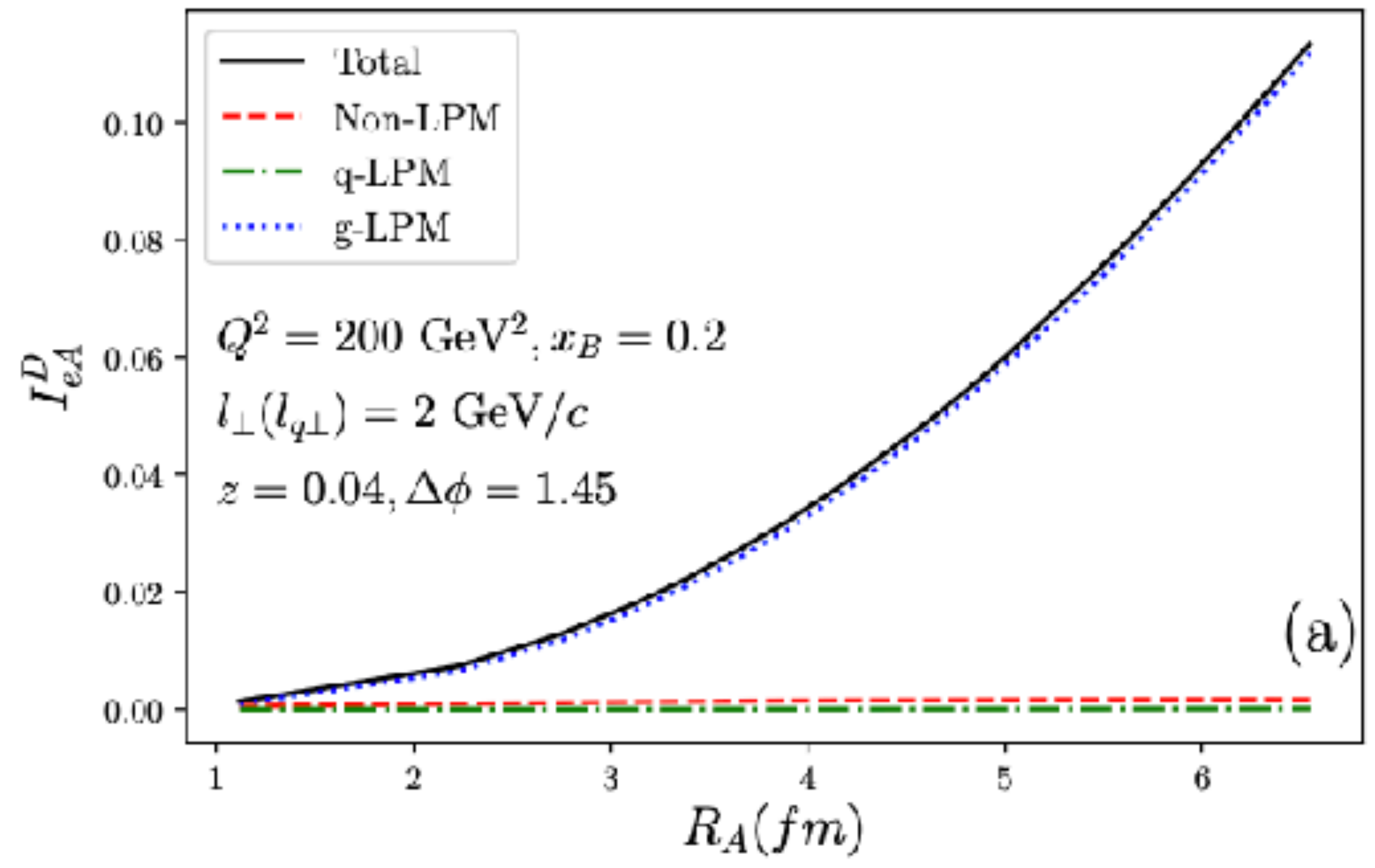
- Embed pT broadening (Gaussian, width $\Delta = \int dy_0^- \hat{q}_F$) in nucleon quark pdf $q_N(x, \vec{v}_\perp, \vec{b}_\perp)$
- Gluon TMD pdf related to $\hat{q}$: $\hat{q} = \int d^2k_\perp \hat{q}(k_\perp) = C \int d^2k_\perp \rho \phi\left(x_g, k_\perp\right)$

Nuclear Modification : $\Delta\phi$, $|y_{l_q} - y_l|$, R_A dependence

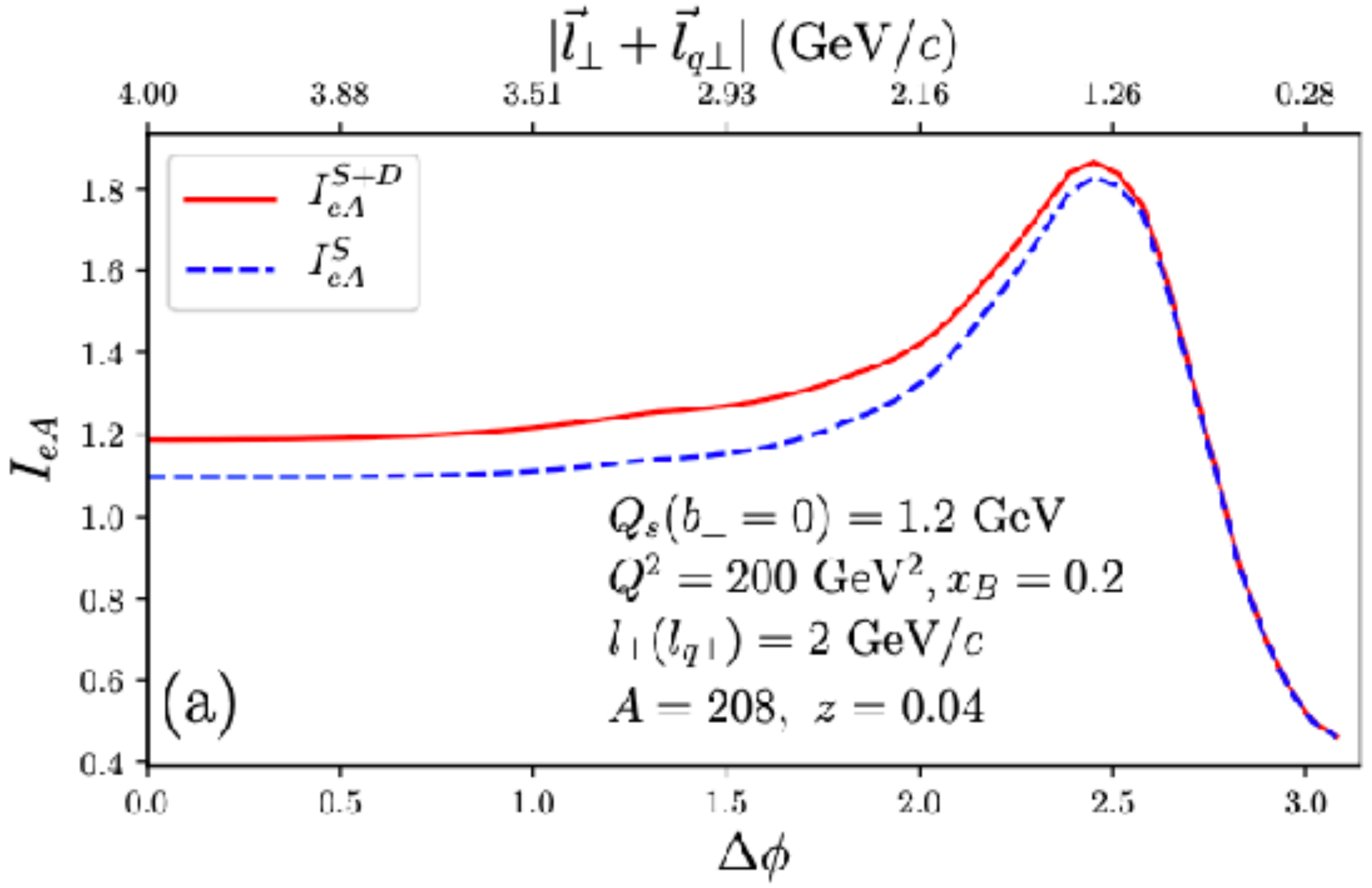
$$I_{eA}^{S(D)}(l_\perp, l_{q\perp}, \Delta\phi, z) = \frac{d\hat{\sigma}_{eA}^{S(D)}}{d\mathscr{P}} / A \frac{d\hat{\sigma}_{ep}}{d\mathscr{P}} \qquad d\mathscr{P} \equiv dx_B dQ^2 dz d^2 l_\perp d^2 l_{q\perp}$$

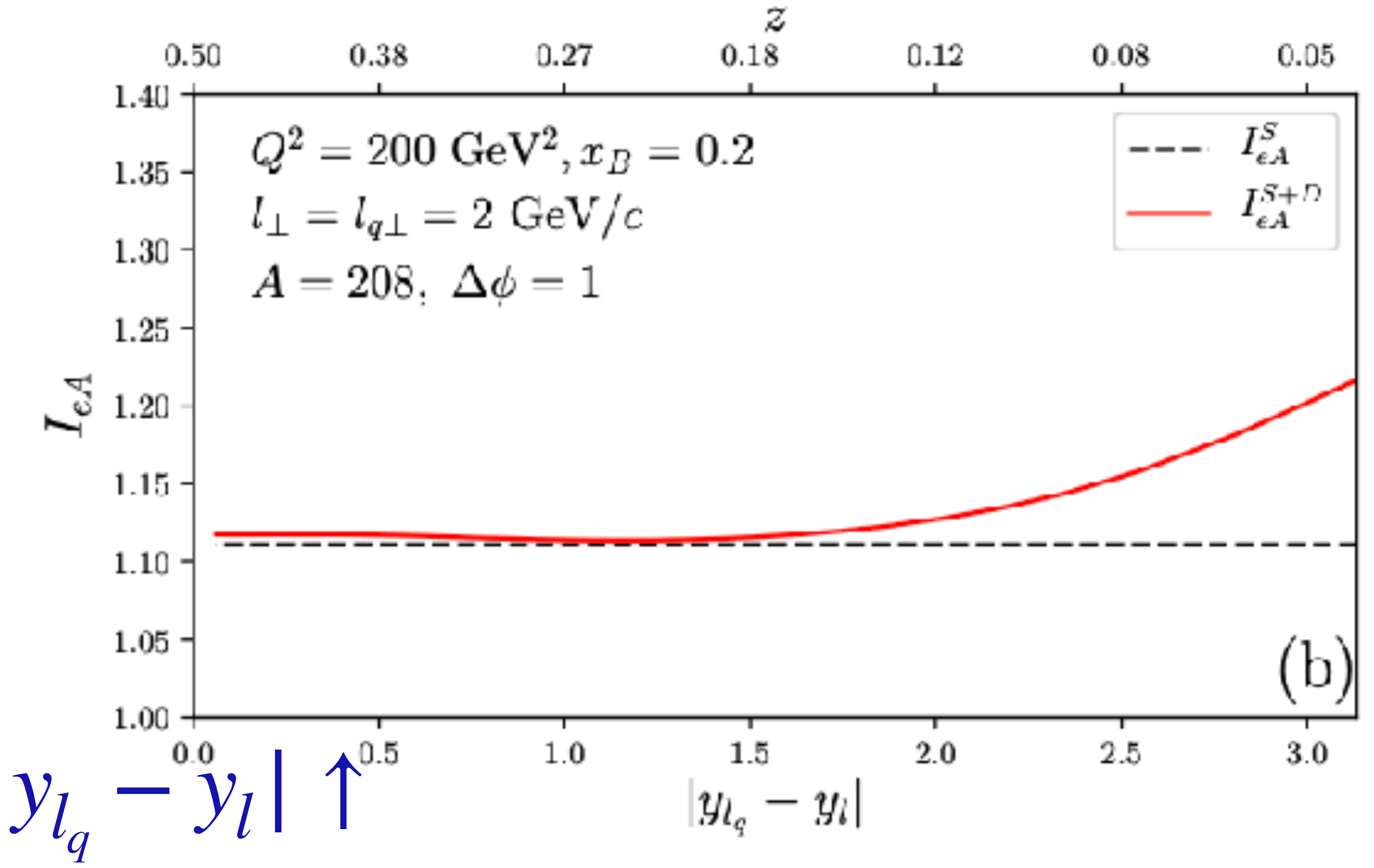


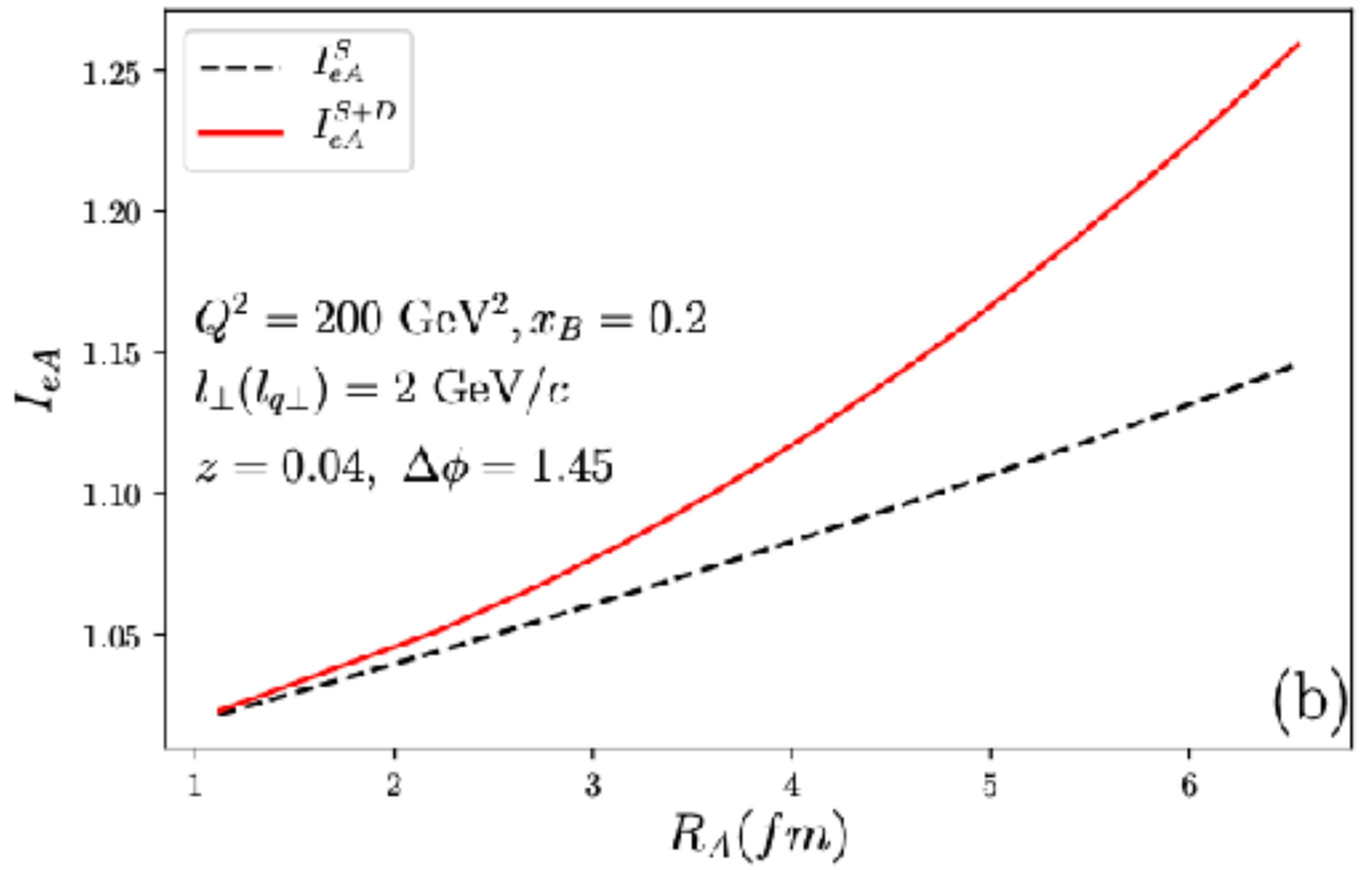




gLPM: dominant







$|y_{l_q} - y_l| \uparrow$

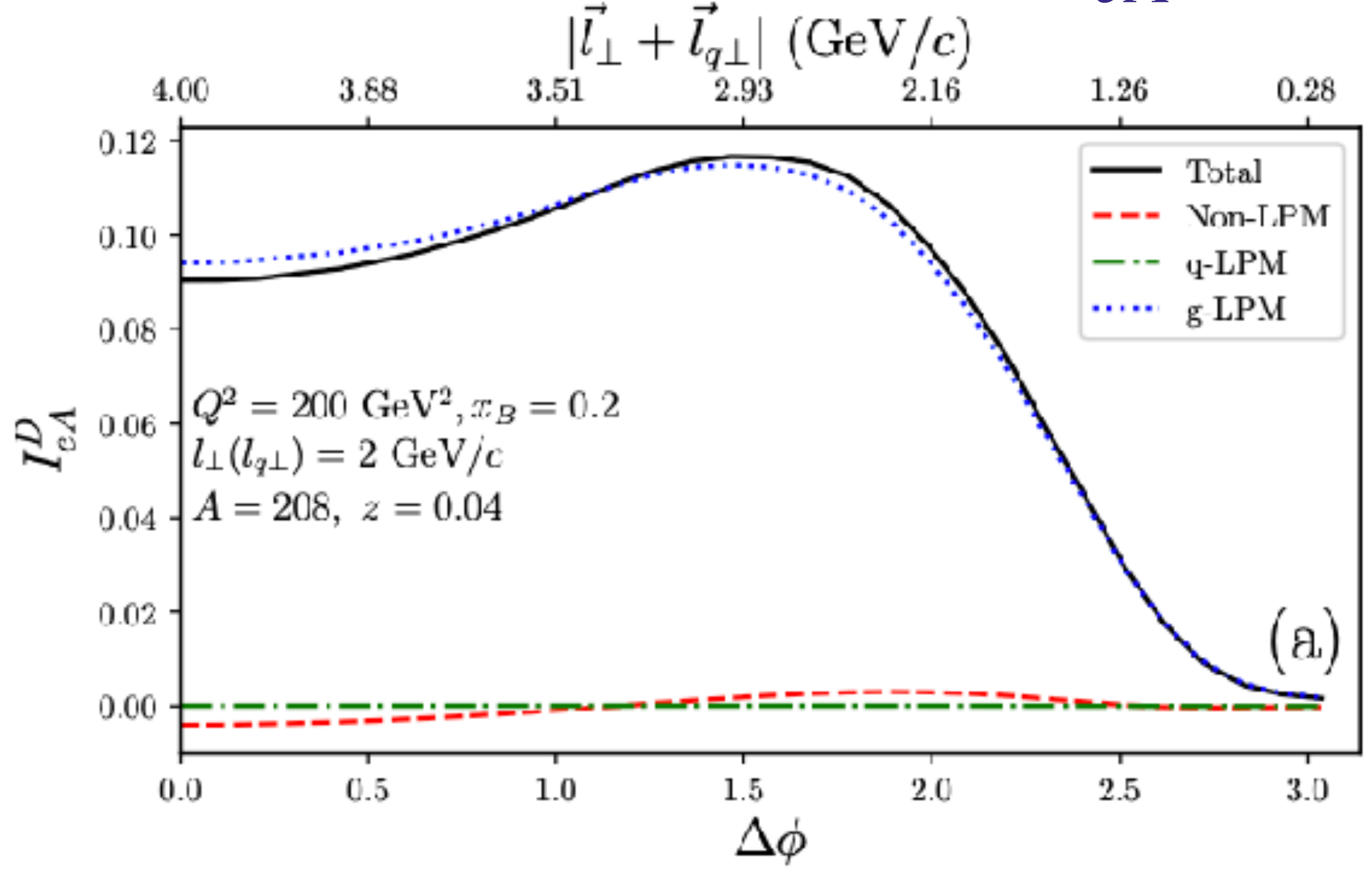
Single scattering dominant

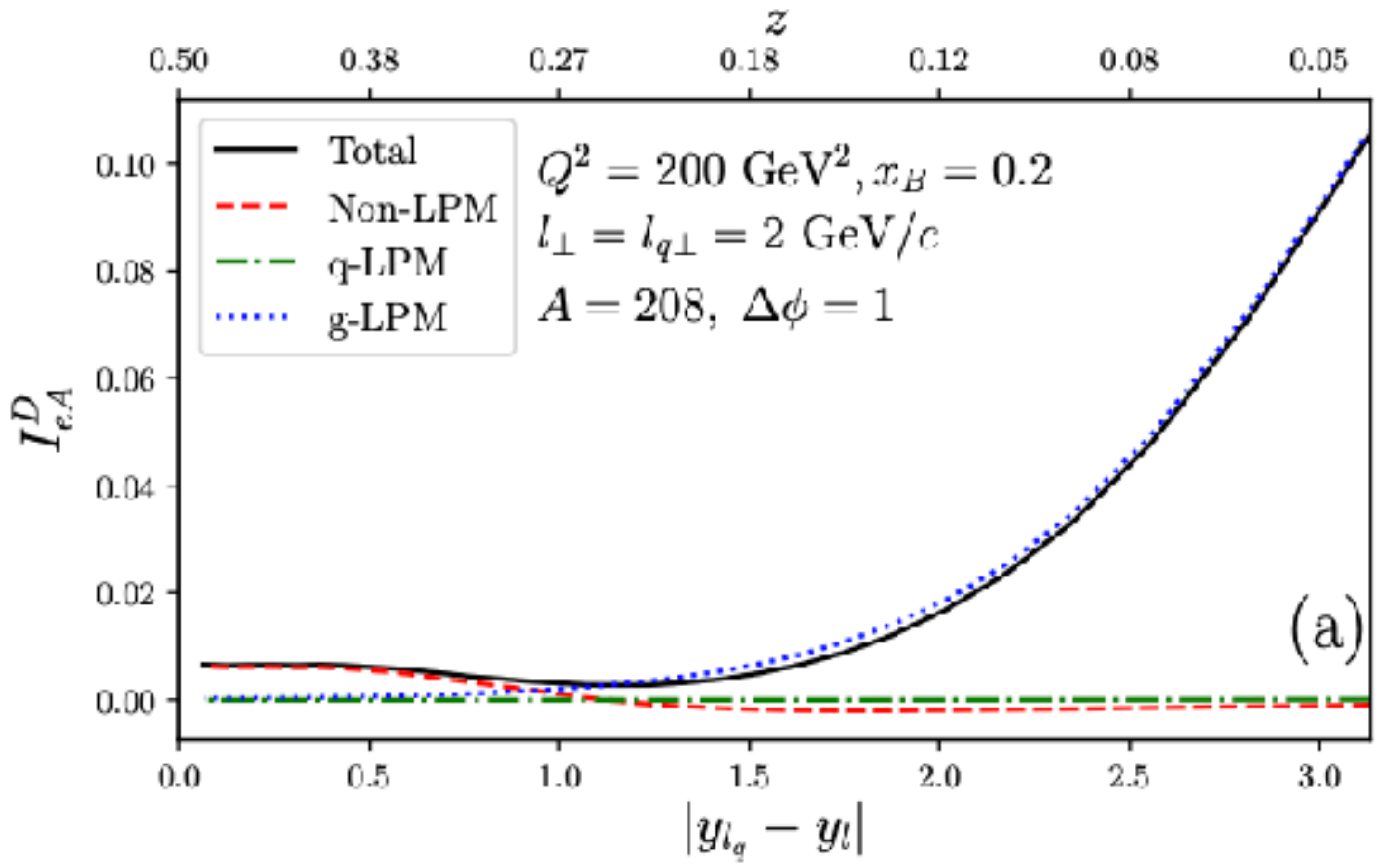
LPM disappear, incoherent contri ↑

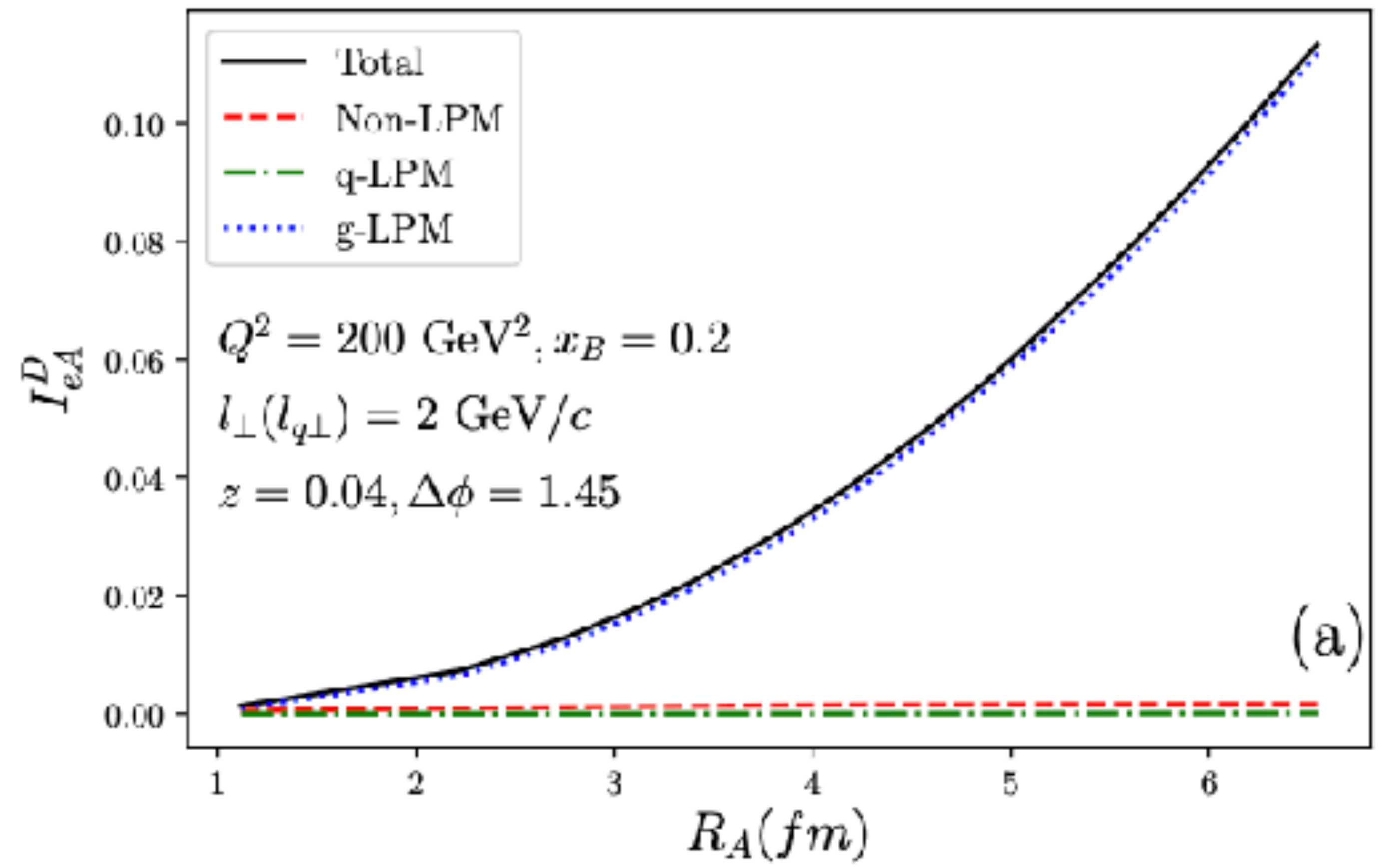
LPM→Non-linear R_A dependence

Nuclear Modification : $\Delta\phi$, $|y_{l_q} - y_l|$, R_A dependence

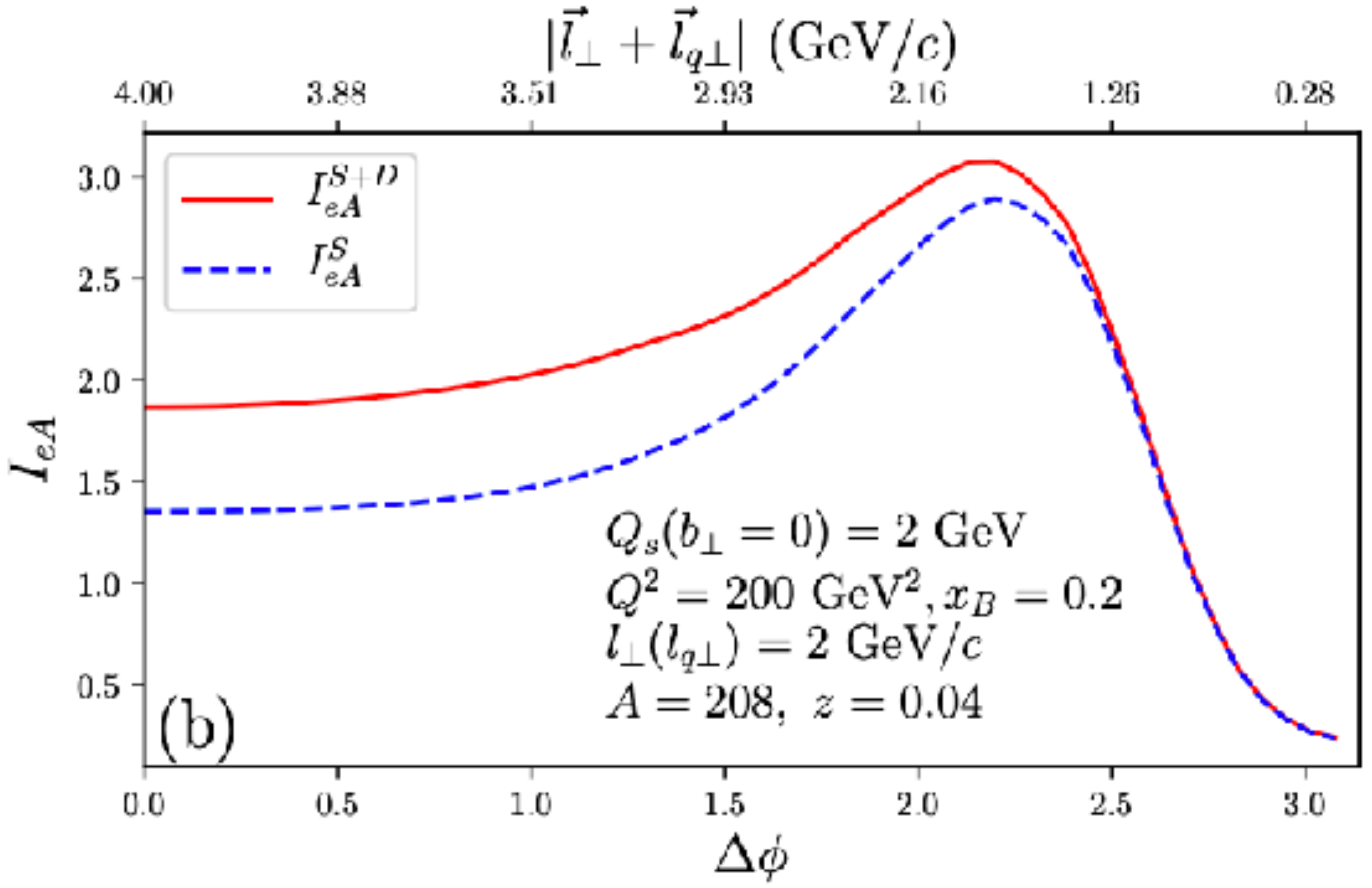
$$I_{eA}^{S(D)}(l_\perp, l_{q\perp}, \Delta\phi, z) = \frac{d\hat{\sigma}_{eA}^{S(D)}}{d\mathscr{P}} / A \frac{d\hat{\sigma}_{ep}}{d\mathscr{P}} \qquad d\mathscr{P} \equiv dx_B dQ^2 dz d^2 l_\perp d^2 l_{q\perp}$$

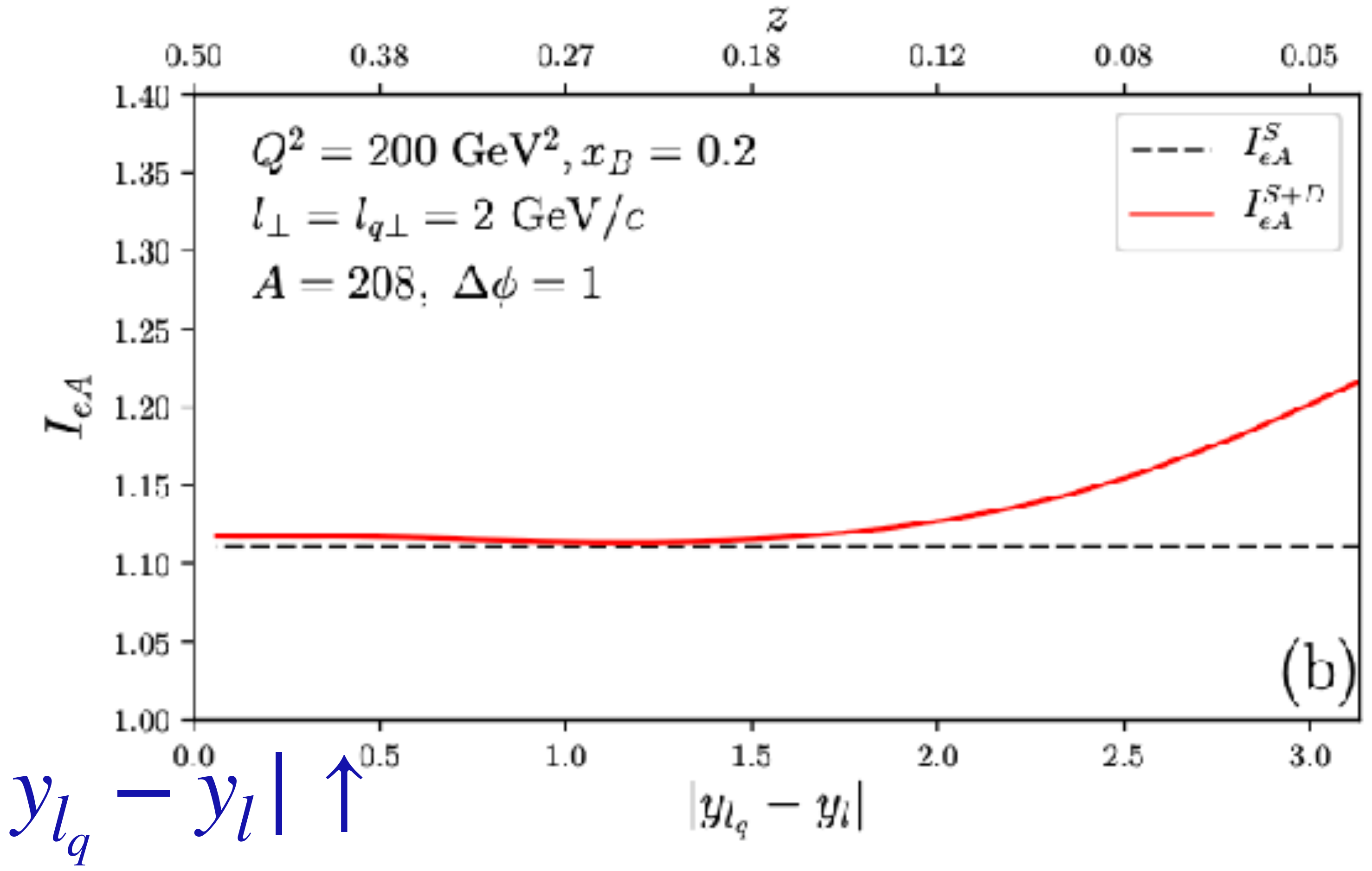


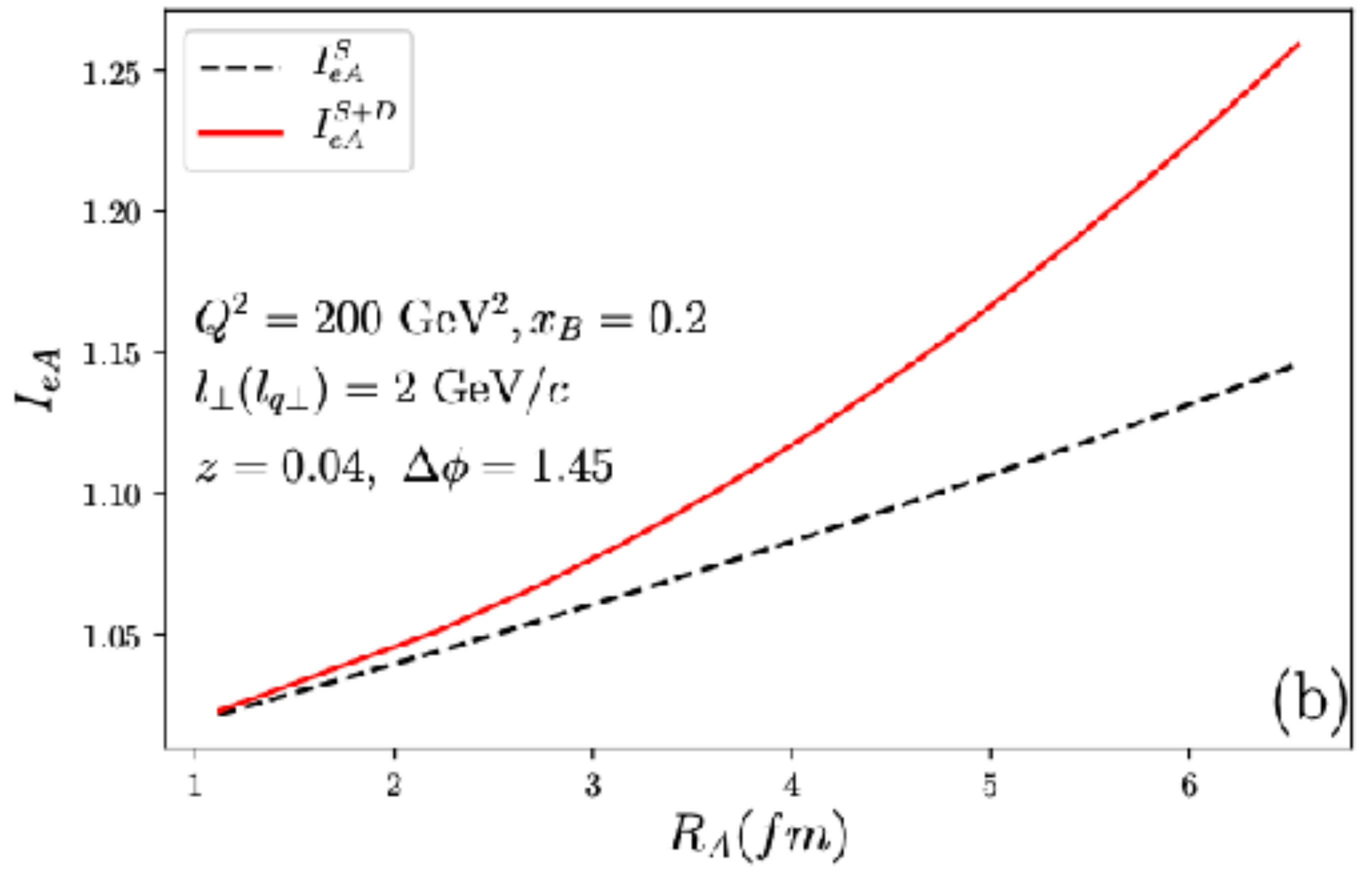




gLPM： dominant







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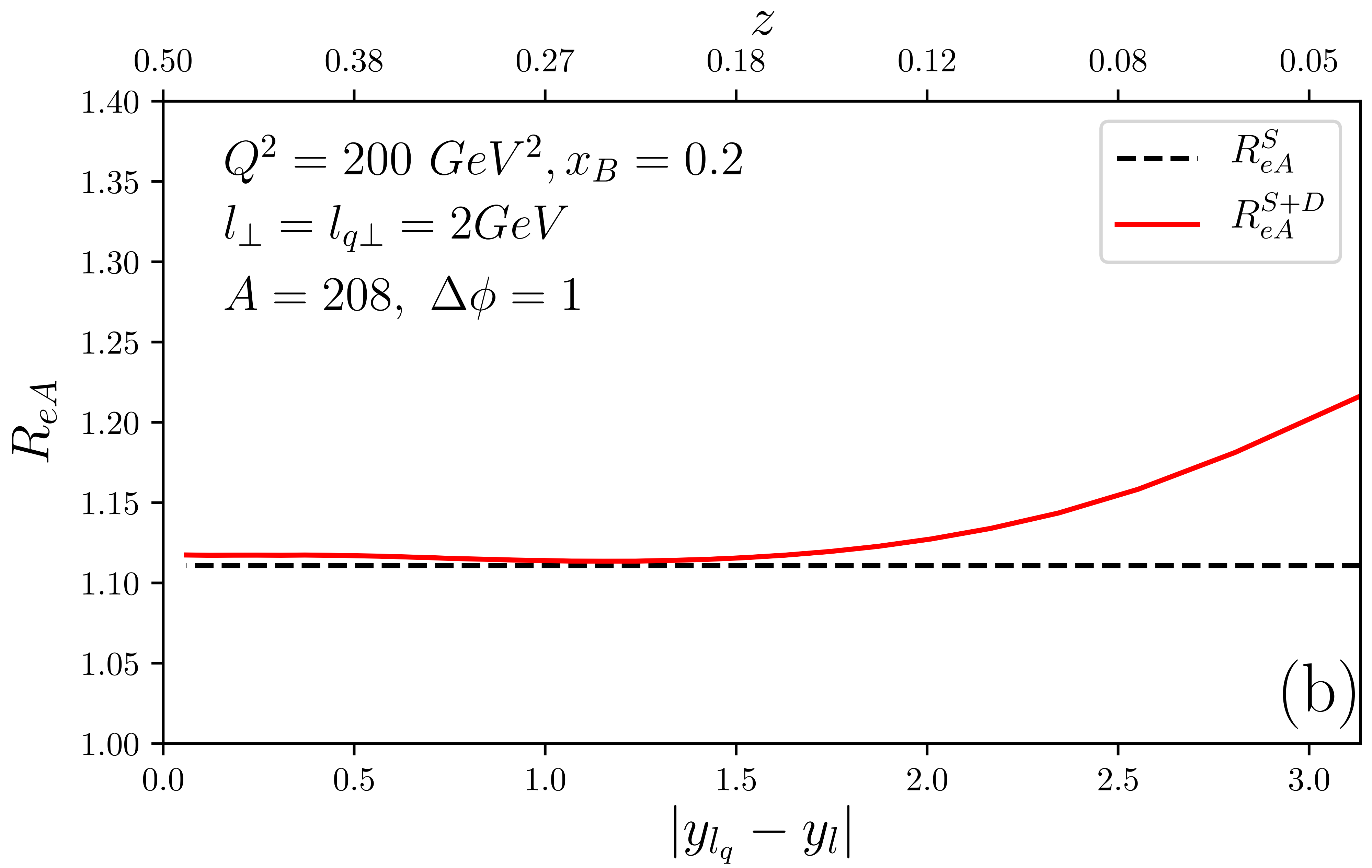
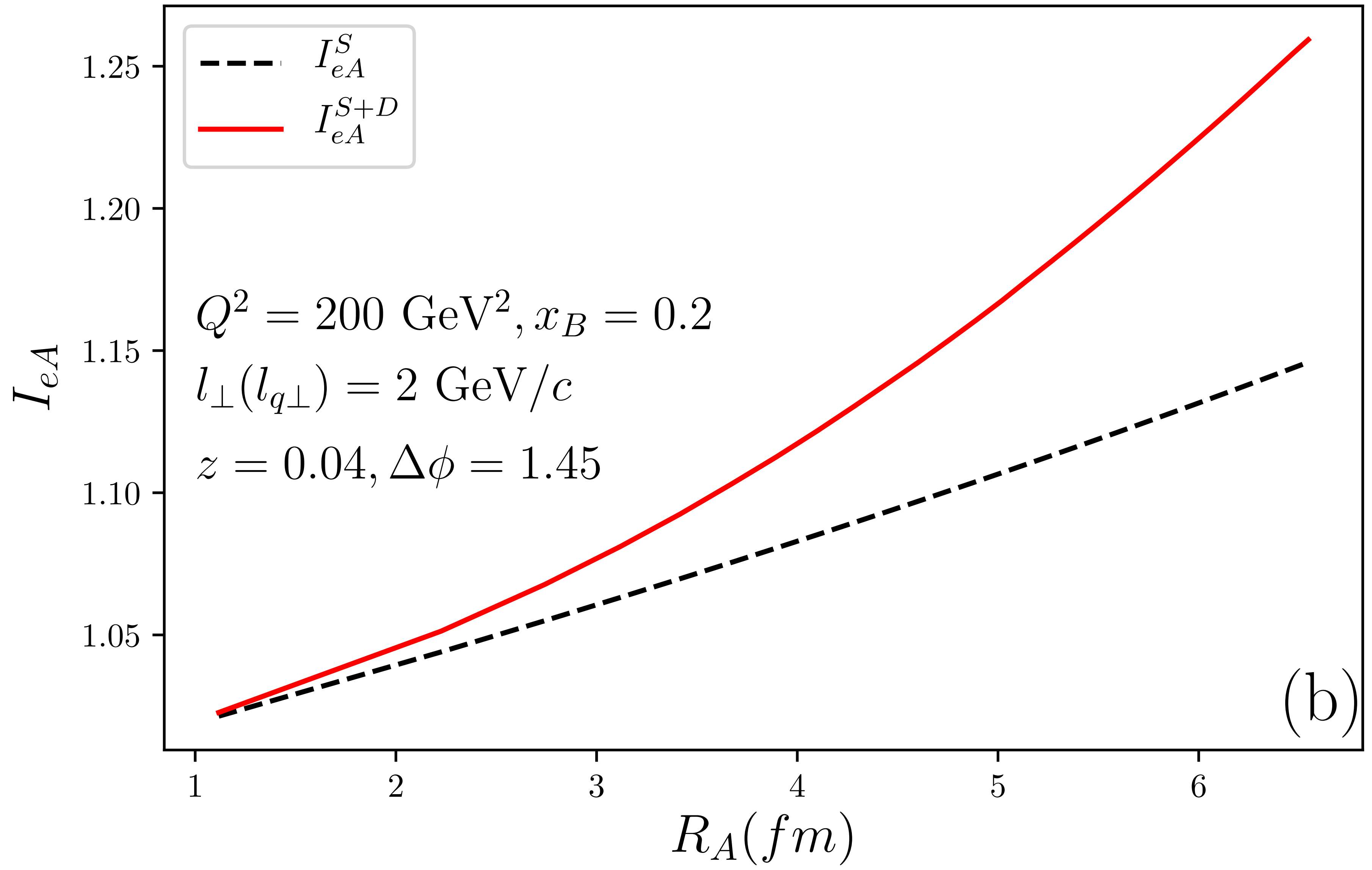
Summary





- Use dijet correlation in e+A to probe gluon TMD pdf $\phi(x_G, k_\perp)$ or TMD $\hat{q}(k_\perp)$
- Nuclear modification in single and double scattering depend on $\phi(x_G, k_\perp)$
- LPM effect and gluon saturation embedded in $\phi(x_G, k_\perp)$ bring unique features in $\Delta\phi, |y_{l_q} - y_l|, R_A$ dependence of nuclear modification ratio

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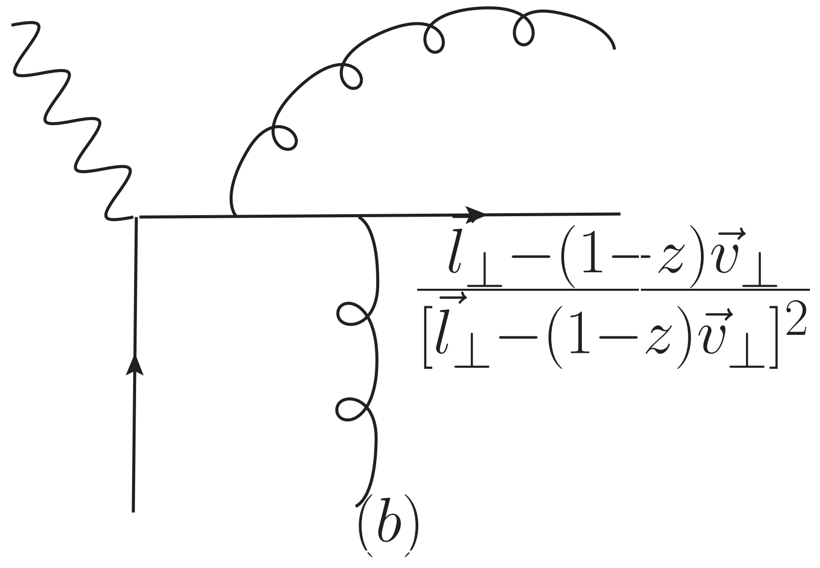
Thanks !

Backup: Different contribution in double scattering

Contribution divided by how gluon radiated, understand from central cut diagrams

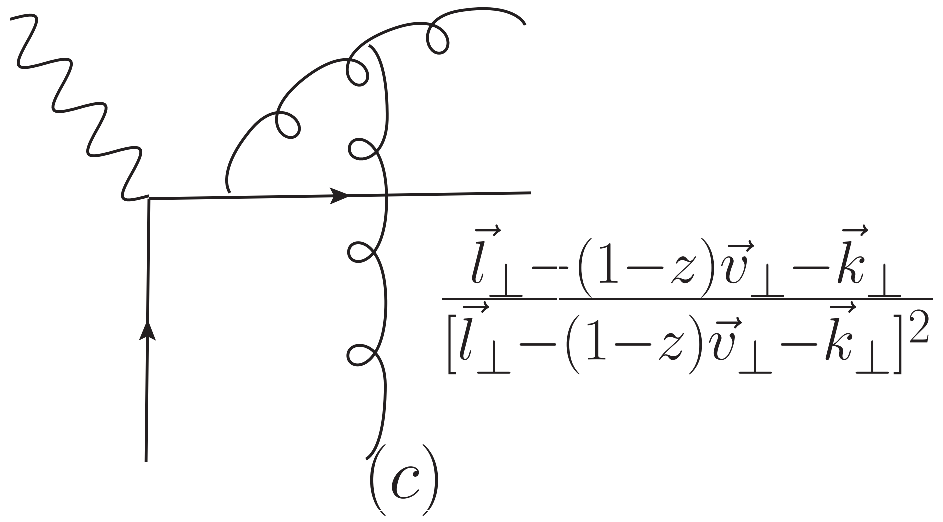
$$\mathcal{N}_g^{\text{qLPM}} = \frac{1}{N_c}(\cdots)\left[1-\cos\left(\frac{y_1^- - y_0^-}{\tau_{gf}}\right)\right]$$

$$\tau_{qf} = \frac{2q^- z(1-z)}{[\vec{l}_\perp - (1-z)\vec{v}_\perp]^2}$$



$$\mathcal{N}_g^{\text{gLPM}} = C_A(\cdots)\left[1-\cos\left(\frac{y_1^- - y_0^-}{\tau_{gf}}\right)\right]$$

$$\tau_{gf} = \frac{2q^- z(1-z)}{[\vec{l}_\perp - (1-z)\vec{v}_\perp - \vec{k}_\perp]^2}$$



$$\mathcal{N}_g^{\text{nonLPM}} = C_F(\cdots)$$

no LPM interference