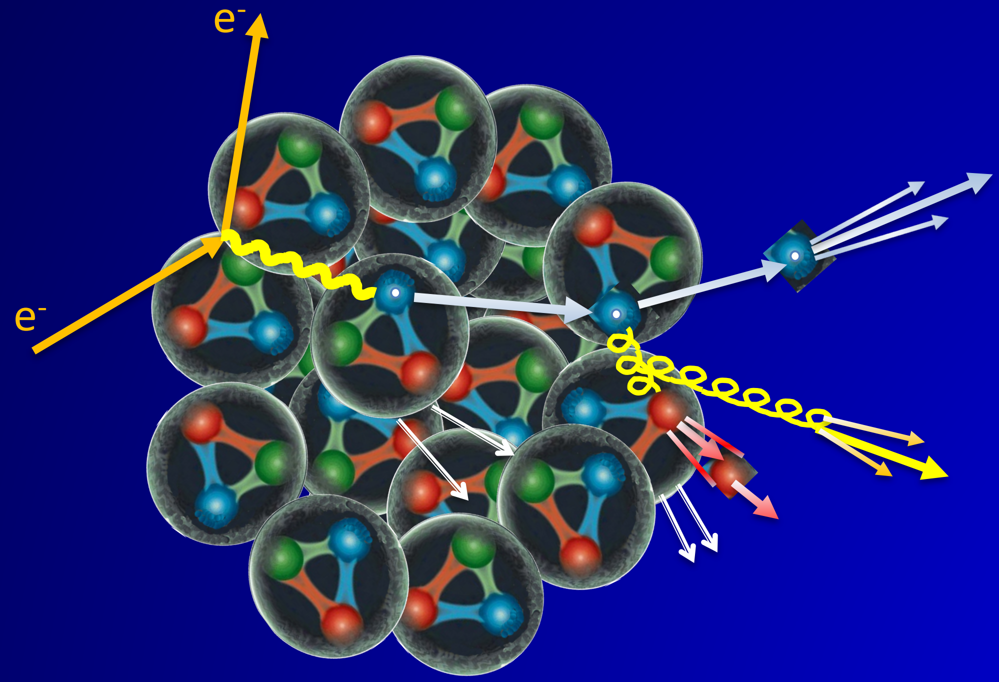
EIC Jets and Heavy Flavor Physics WG meeting 10.8.2020

Nuclear modification of jets, dijets and flavor dependence at the EIC

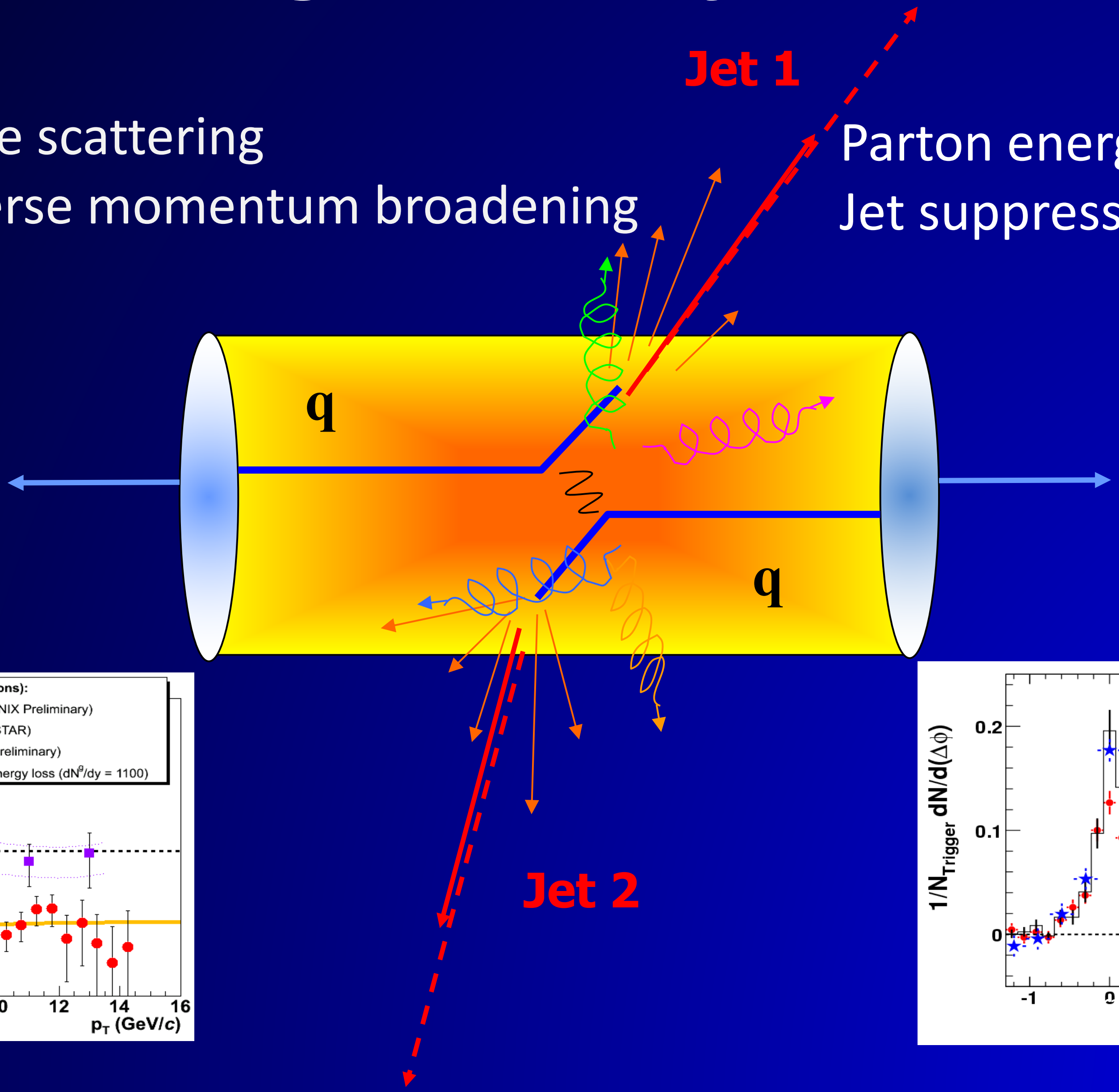


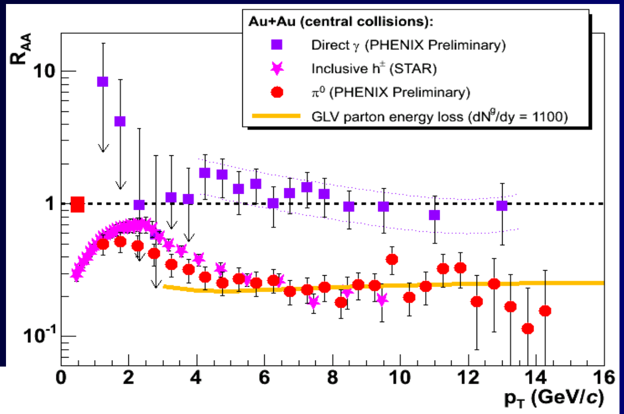
Xin-Nian Wang
Central China Normal University
Lawrence Berkeley National Laboratory

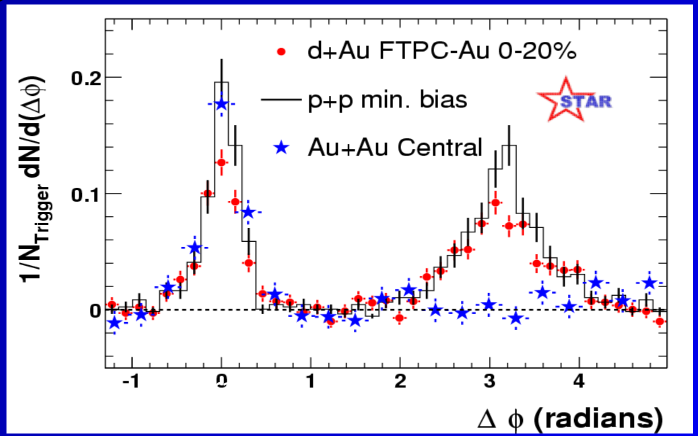
Jet quenching in heavy-ion collisions

Multiple scattering
Transverse momentum broadening

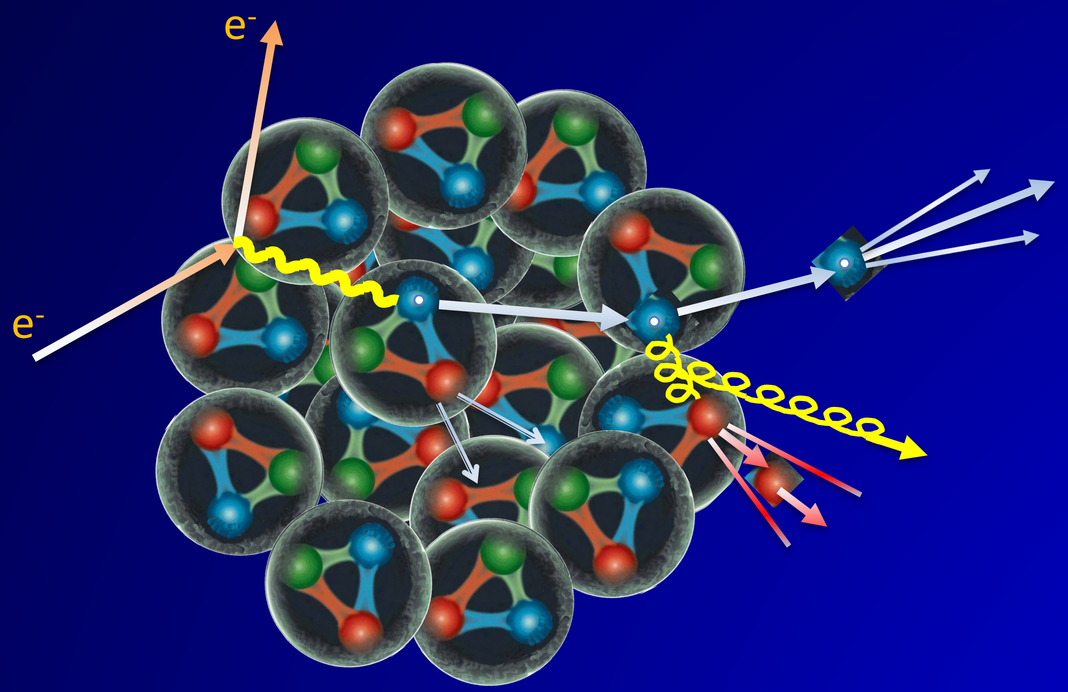
Parton energy loss
Jet suppression







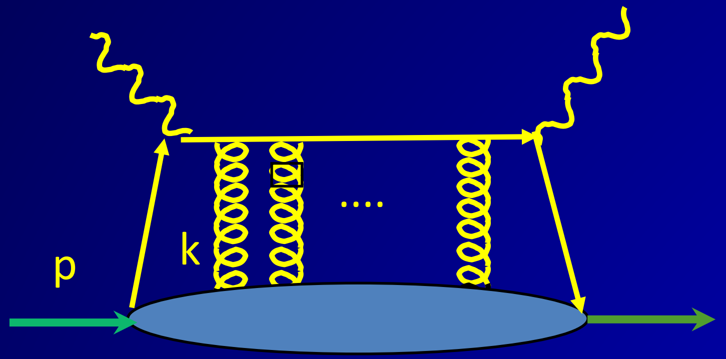
Jet production in DIS off nuclei



Multiple scattering, p_T broadening, parton energy loss, hadronization, hadronic interaction in nuclei

Parton scattering in nuclear medium

$$f_A^q(x,\vec{k}_\perp) = \int \frac{dy^-}{4\pi}\frac{d^2y_\perp}{(2\pi)^2} e^{ixp^+y^- - i\vec{k}_\perp\cdot\vec{y}_\perp}\langle A|\bar{\psi}(0)\gamma^+\mathcal{L}(0,y)\psi(y)|A\rangle$$



Liang, XNW & Zhou (0801.0434)

$$\Delta = \int dy\hat{q}(y)$$

$$f_A^q(x,\vec{k}_\perp) \approx \frac{A}{\pi\Delta}\int d^2q_\perp \exp\left[-\frac{(\vec{k}_\perp - \vec{q}_\perp)^2}{\Delta}\right] f_N^q(x,\vec{q}_\perp)$$

p_T broadening and Jet transport coefficient:

$$\hat{q}(y) = \frac{4\pi^2\alpha_s C_R}{N_c^2-1}\rho(y)xG(x)|_{x\approx 0}$$

BDMPS'96

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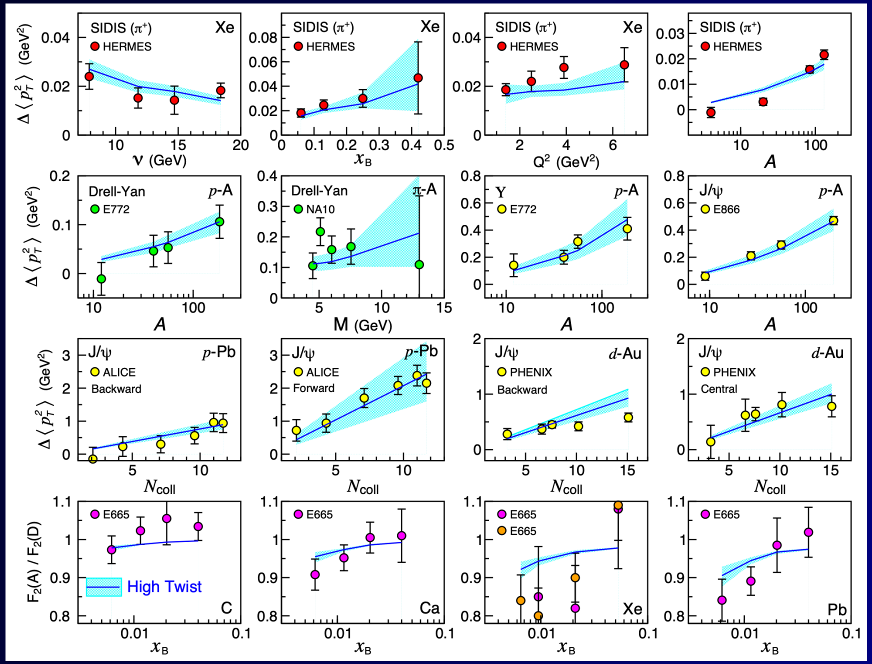
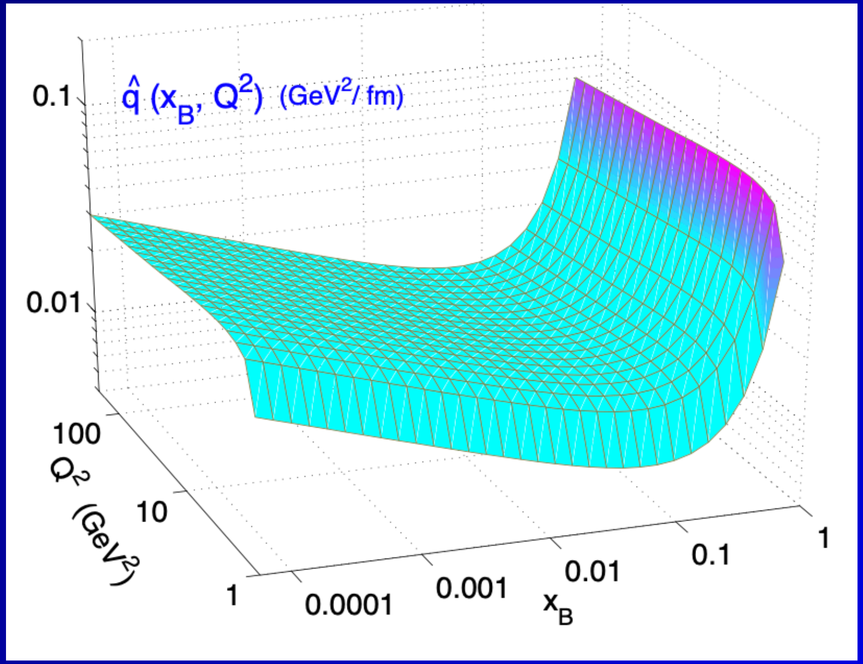
Jet transport coefficient in nuclei

A global extraction of the jet transport coefficient in nuclei

$$\hat{q}_0 \approx 0.02\ \ \mathrm{GeV}^2/\mathrm{fm}$$





Data on: DIS, SIDIS(π), Drell-Yan, J/ψ (pA), Υ (pA)

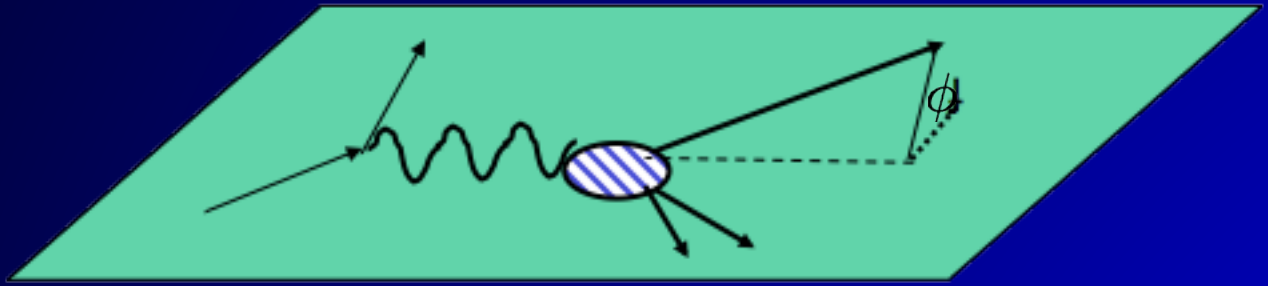
Ru, Kang, Wang, Xing & Zhang (1907.11808)

Azimuthal Asymmetry

Gao, Liang & XNW（2010）

$$\langle \cos\phi \rangle_{eA} = \frac{2(2-y)\sqrt{1-y}}{1+(1-y)^2}\frac{k_T}{Q}\frac{x_B f^q_{A\perp}(x_B,k_T)}{f^q_A(x_B,k_T)}$$

$$k_T \ll Q$$

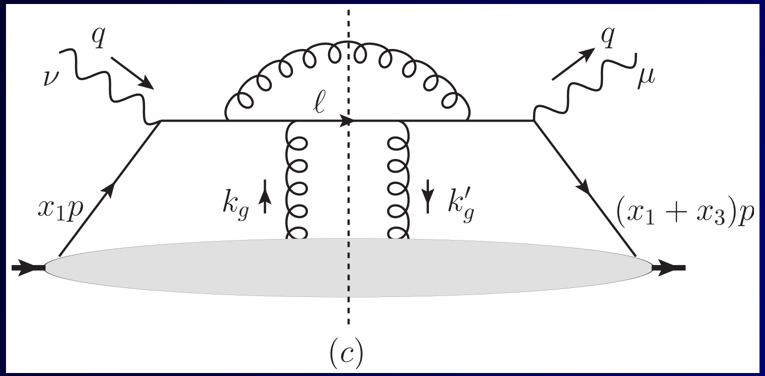


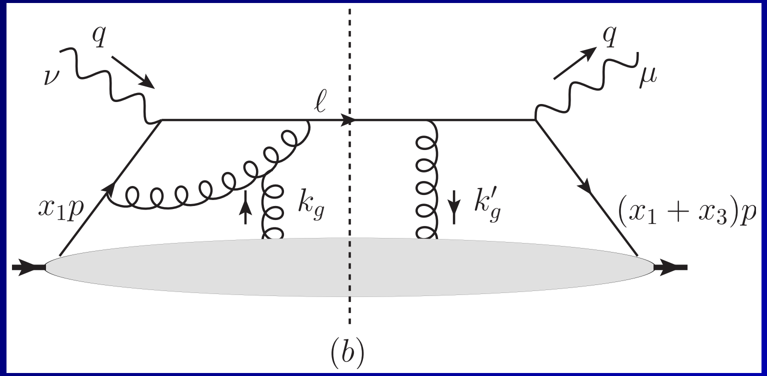
Twist-3 quark matrix elements

$$f^q_{A\perp}(x,k_T) = p^+ \int \frac{dy^-}{4\pi}\frac{d^2y_\perp}{(2\pi)^2} e^{ixp^+y^- - i\vec{k}_\perp\cdot\vec{y}_\perp} \langle A|\bar{\psi}(0)\frac{\gamma\cdot k_T}{k_T^2}\mathcal{L}(0,y)\psi(y)|A\rangle$$

$$\frac{\langle \cos\phi \rangle_{eA}}{\langle \cos\phi \rangle_{eN}} \approx \sqrt{\frac{\langle k_T^2\rangle_N}{\langle k_T^2\rangle_N + \Delta}}$$

Medium-induced radiative correction to qhat





- Cancellation of soft-collinear divergence
- Factorization of the collinear divergence

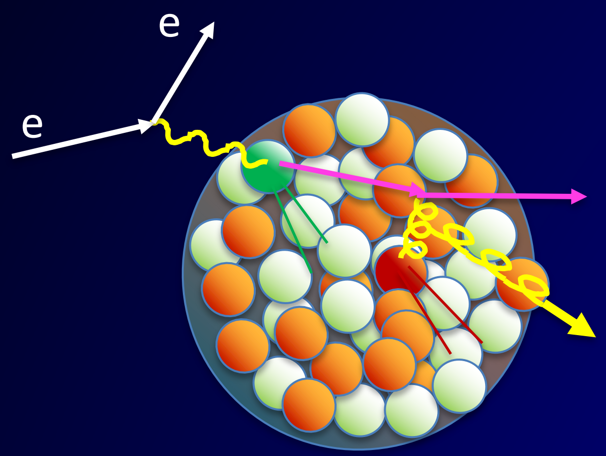
Kang, Wang, Xing & Wang, PRL 112, 102001(2014)

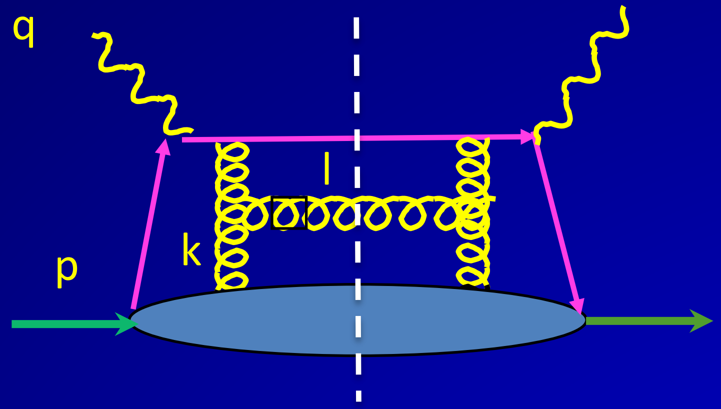
$$\frac{d\langle k_\perp^2 \sigma\rangle_{\rm NLO}}{dz_h} = \sigma_0 D_h(z,\mu_f^2) \otimes H_{\rm NLO}(x, x_B, Q^2, \mu_f^2) \otimes T_{qg}(x, x_1, x_2, \mu_f^2)$$

$$\frac{\partial}{\partial \ln \mu_f^2} T_{qg}(x_B, 0, 0, \mu_f^2) = \frac{\alpha_s}{2\pi} \int_{x_B}^{1} \frac{dx}{x} \left[\mathcal{P}_{qg\to qg} \otimes T_{qg} + P_{qg}(\hat{x}) T_{gg}(x, 0, 0, \mu_f^2) \right]$$

$$T_{qg}(x_B, 0, 0, \mu_f^2) \Longrightarrow \hat{q} \Longrightarrow \hat{q}(E, Q^2)$$

Parton energy loss in nuclear medium





$$\frac{dN_g}{dl_\perp^2\,dz} = \int_{y^-}^{\infty} dy_1^- \left[\rho_A(y_1^-, \vec{y}_\perp)\frac{2\pi\alpha_s}{N_c}\pi\int\frac{dk_\perp^2}{(2\pi)^2}\frac{\phi_g(0,\vec{k}_\perp)}{k_\perp^2}\right]\pi\frac{\alpha_s}{2\pi}P_{qg}(z)\frac{C_A}{l_\perp^2}\mathcal{N}_g(\vec{l}_\perp,\vec{k}_\perp)$$

Nucleon TMD gluon distr.

Zhang, Qin and XNW (1905.12699)

$$\mathcal{N}_g^{static+soft} = \int\frac{d\varphi}{2\pi}\frac{2\vec{k}_\perp\cdot\vec{l}_\perp}{(\vec{l}_\perp-\vec{k}_\perp)^2}\left(1-\cos\left[\frac{(\vec{l}_\perp-\vec{k}_\perp)^2}{2q^-z(1-z)}y_1^-\right]\right)$$

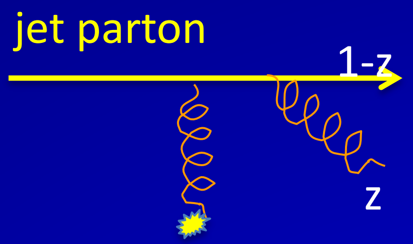
→ GLV

τ_f Formation time of the gluon emission y_1^-/τ_f

Jet tomography via leading hadrons

Guo & XNW (hep-ph/0005044)

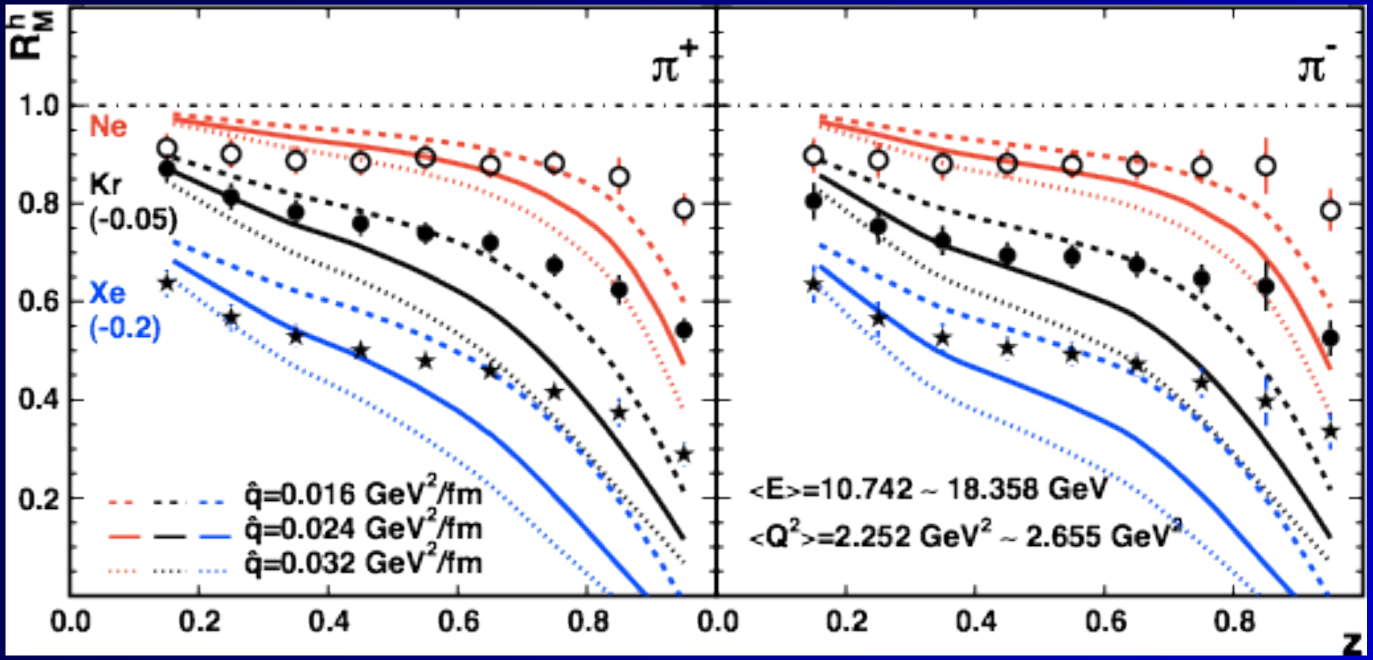
Medium induced splitting function (fractional energy loss distribution)



$$\Delta\widetilde{P}_{a\to ag}(z) \approx \frac{2C_A\alpha_s}{\pi}\int dx\hat{q}(x)\int\frac{d\ell_\perp^2}{\ell_\perp^4}P(z)\sin^2\frac{\ell_\perp^2(x-x_0)}{4z(1-z)E}$$

Modified frag function & hadron spectra: $\widetilde{D}_{c/h}(z_h) \approx [P_{a\to ag}(z) + \Delta\widetilde{P}_{a\to ag}(z)] \otimes D_{a/h}(z_h)$

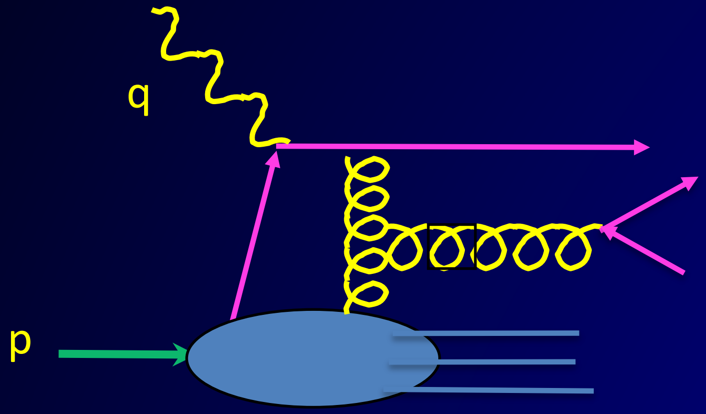
$$R = \frac{N_h^{eA}}{N_h^{eD}}$$



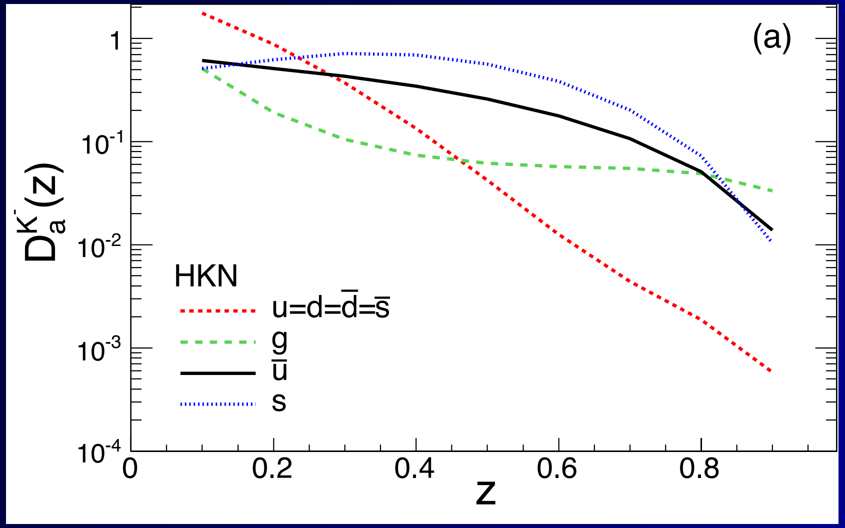
$\hat{q}_0 \approx 0.02 \ \ \mathrm{GeV}^2/\mathrm{fm}$

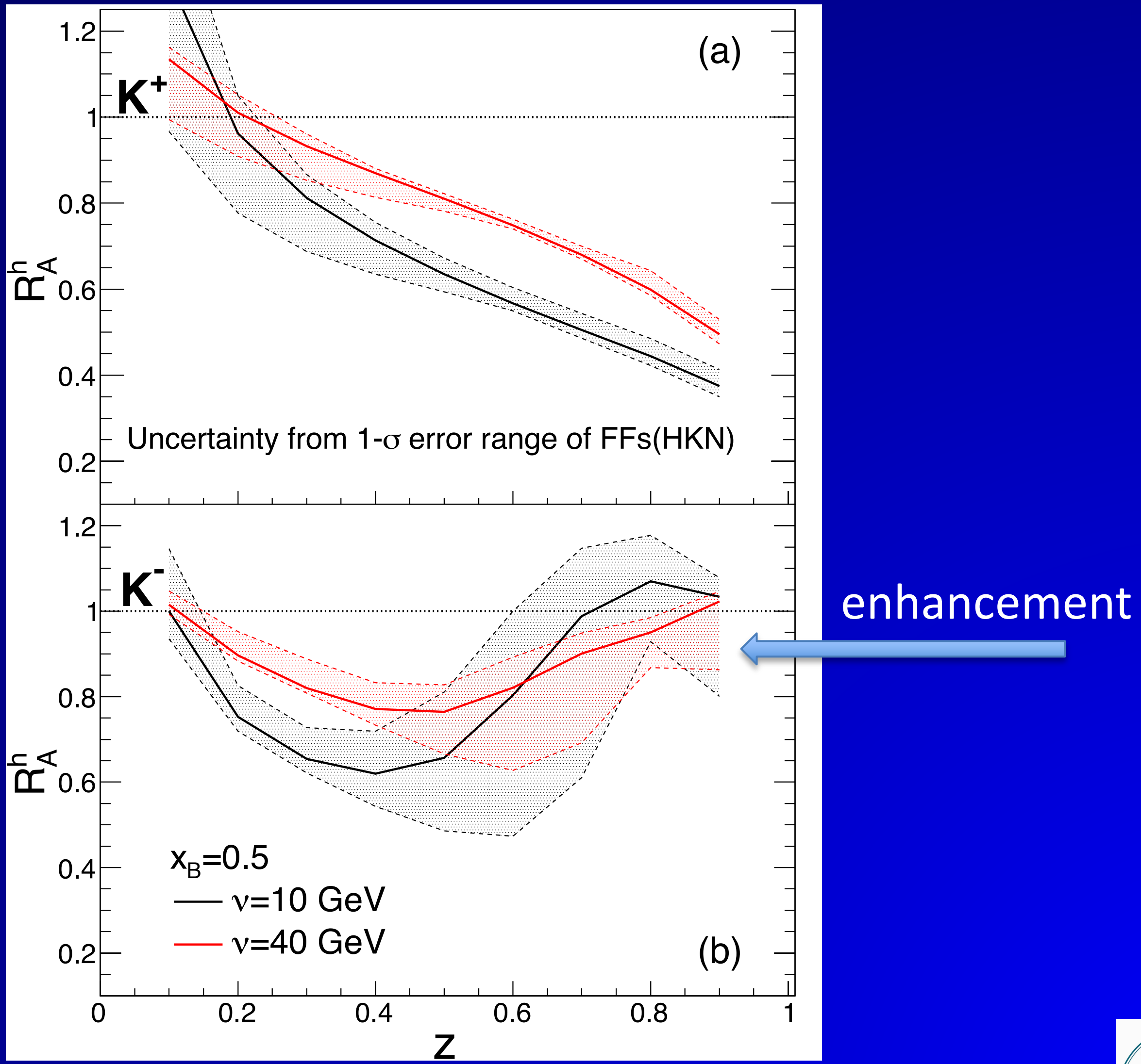
Deng & XNW (0910.3403), Chang, Deng & XNW (1401.5109)

Flavor conversion in eA SIDIS

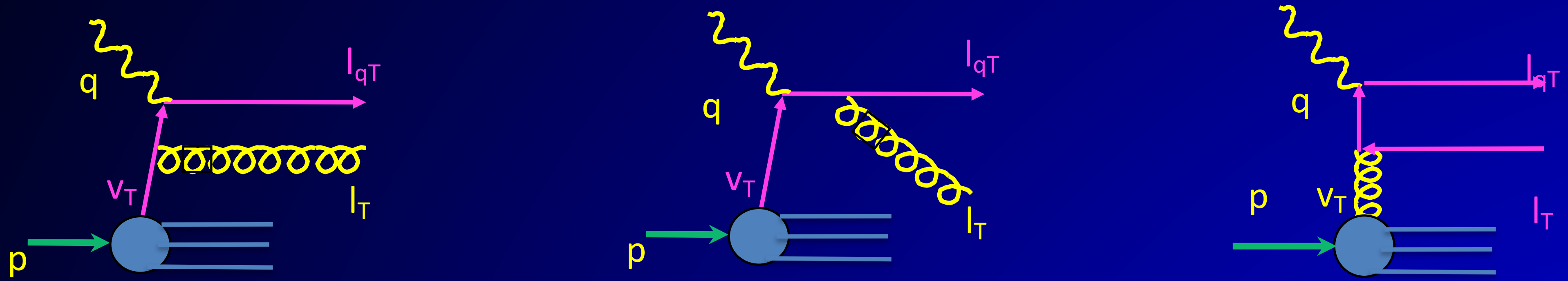


Chang, Deng & XNW, PRC 92 (2015) 5, 055207





Dijets production in DIS



TMD quark distribution: $f_q^A(x_B, \vec{v}_\perp)$

$$v_\perp = |\vec{l}_\perp + \vec{l}_{q\perp}|$$

$$\sqrt{l_\perp^2 + l_{q\perp}^2 + 2 l_\perp l_{q\perp} \cos\Delta\phi}$$

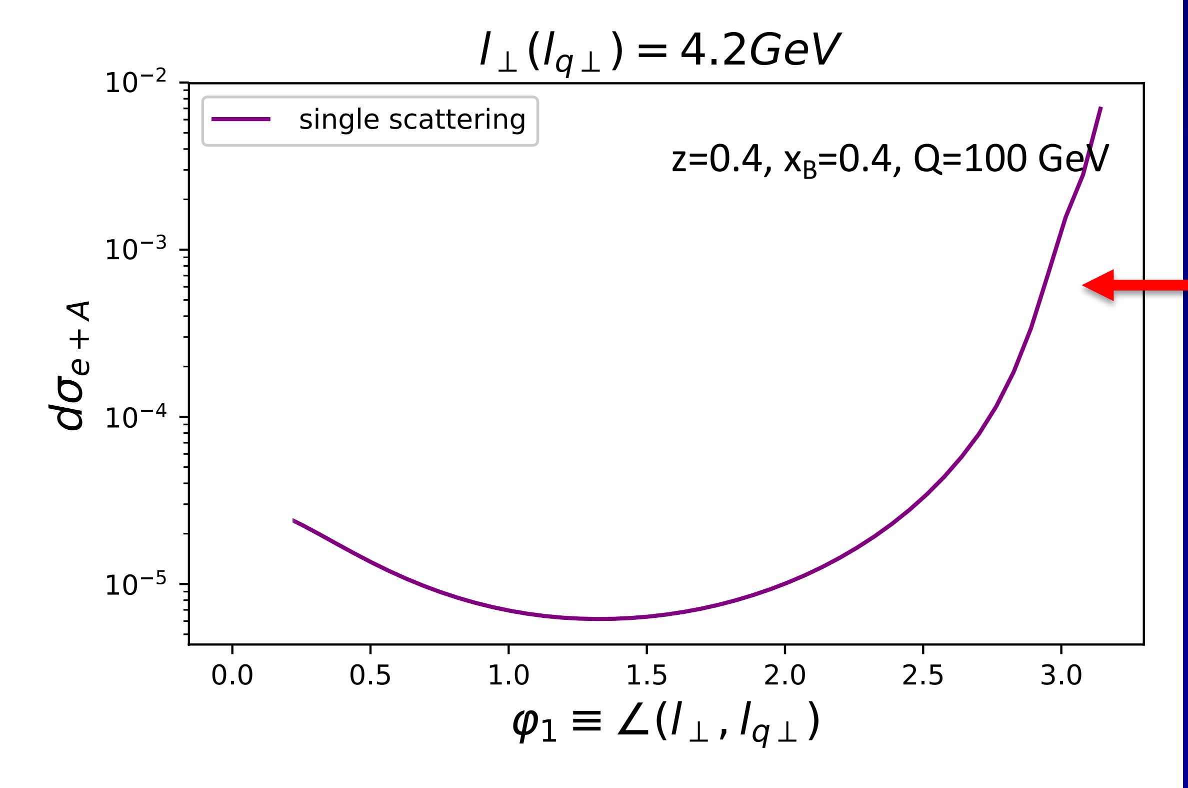
LO leading order contribution at large x_B

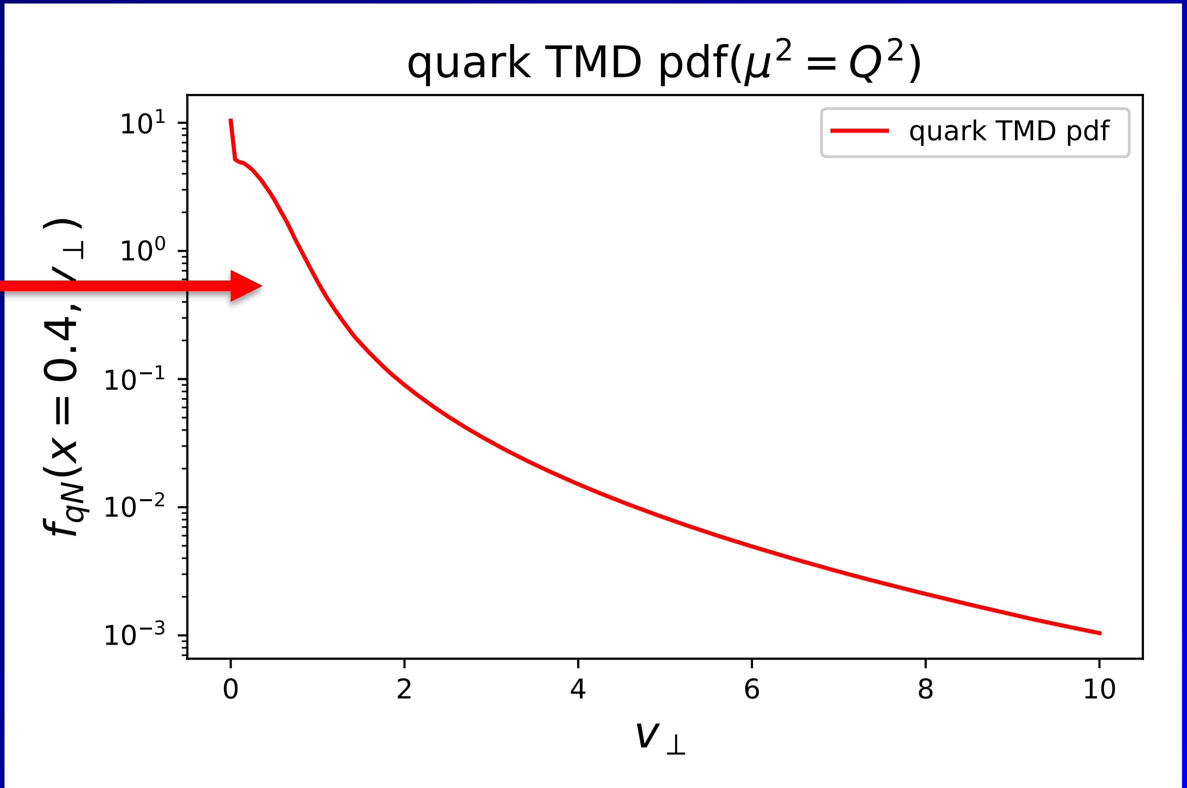
$$\frac{d\hat{\sigma}_S}{dx_B dQ^2 dz d^2 l_\perp d^2 l_{q\perp}} = \sigma_0 \frac{\alpha_s}{2\pi} \frac{1+z^2}{1-z} f_q^A(x_B, \vec{v}_\perp) \frac{C_F}{[\vec{l}_\perp - (1-z)(\vec{l}_\perp + \vec{l}_{q\perp})]^2}$$

Angular correlation of dijets with fixed l_T and l_{qT}

LO dijet angular correlation

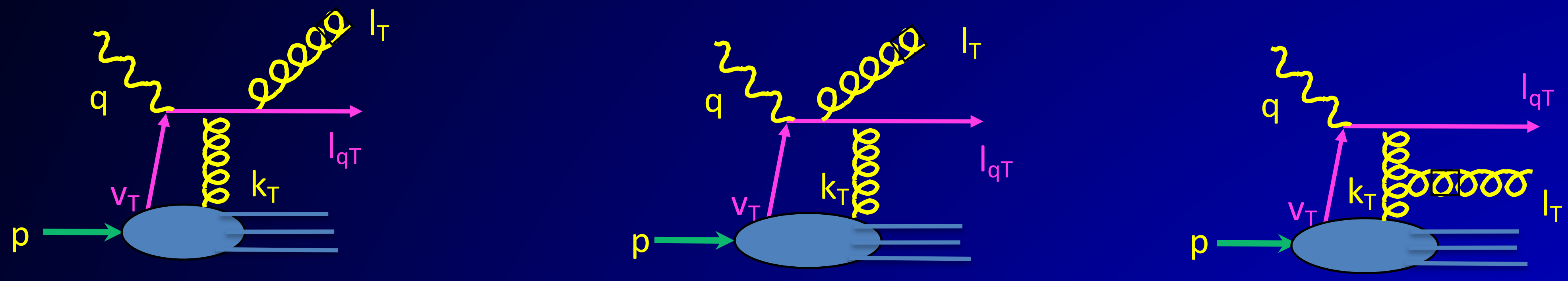
$$\frac{d\hat{\sigma}_S}{dx_B dQ^2 dz d^2 l_\perp d^2 l_{q\perp}} = \sigma_0 \frac{\alpha_s}{2\pi} \frac{1+z^2}{1-z} f_q^A(x_B, \vec{v}_\perp) \frac{C_F}{[\vec{l}_\perp - (1-z)(\vec{l}_\perp + \vec{l}_{q\perp})]^2}$$





F Hautmann, et al., Euro Phys J C, 74(12), 3220

Dijets from double scattering in EIC



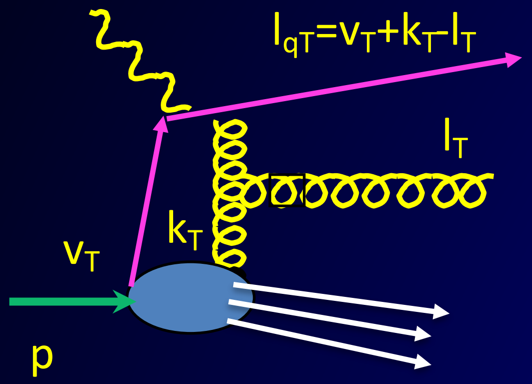
$$\frac{d\hat{\sigma}_D}{dx_B dQ^2 dz d^2 l_\perp d^2 l_{q\perp}} = \sigma_0 \frac{1+z^2}{1-z} \frac{\alpha_s^2}{N_c} \int dy_1^- \rho(y_1^-, \vec{y}_{N\perp})\, d^2\vec{v}_\perp \frac{d^2\vec{k}_\perp}{(2\pi)^2} f_q^A(x_B, \vec{v}_\perp) \frac{\phi(0,\vec{k}_\perp)}{k_\perp^2}$$

$$\otimes \delta^2(\vec{l}_\perp + \vec{l}_{q\perp} - \vec{k}_\perp - \vec{v}_\perp) \Big\{ C_F \mathcal{N}_{\rm coh}(\vec{l}_\perp, \vec{l}_{q\perp}, \vec{k}_\perp, \vec{v}_\perp)$$

$$+ \frac{1}{N_c} \mathcal{N}_{\rm qLPM}(\vec{l}_\perp, \vec{l}_{q\perp}, \vec{k}_\perp, \vec{v}_\perp) \left(1 - \cos\frac{[\vec{l}_\perp - (1-z)\vec{v}_\perp]^2}{2p^+ q^- z(1-z)} p^+ y_1^-\right)$$

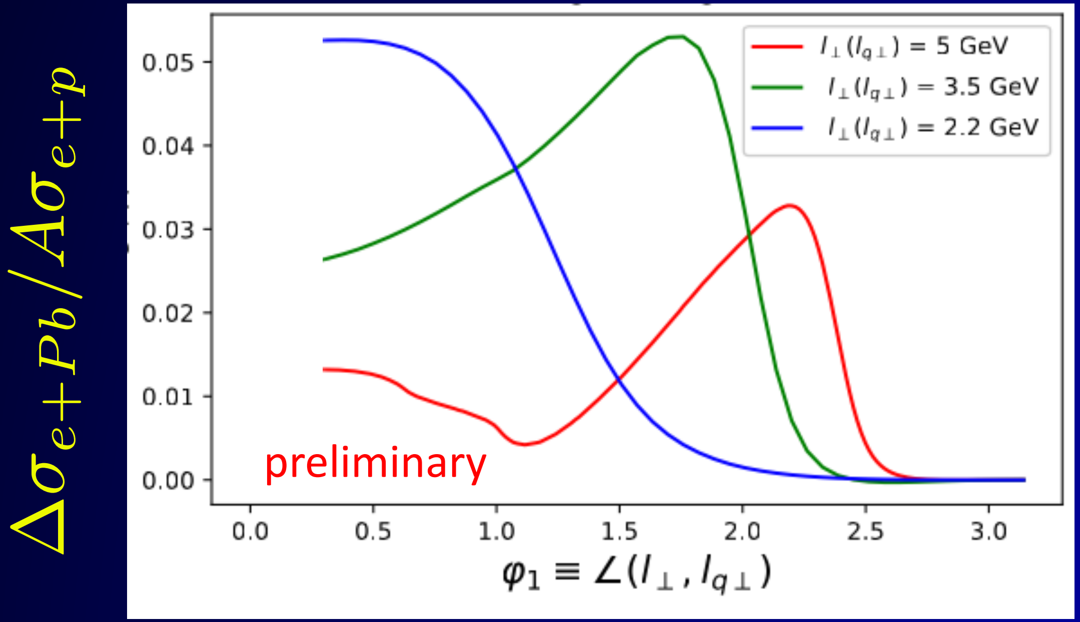
$$+ C_A \mathcal{N}_{\rm gLPM}(\vec{l}_\perp, \vec{l}_{q\perp}, \vec{k}_\perp, \vec{v}_\perp) \left(1 - \cos\frac{[\vec{l}_\perp - (1-z)\vec{v}_\perp - k_\perp]^2}{2p^+ q^- z(1-z)} p^+ y_1^-\right) \Big\}$$

Nuclear modification of dijets & TMD pdf at EIC



$$\frac{d\hat{\sigma}_D}{dx_B dQ^2 dz d^2 l_\perp d^2 l_{q\perp}} = \sigma_0 \frac{1+z^2}{1-z} \frac{\alpha_s^2}{N_c} \int dy_1^- \rho(y_1^-, \vec{y}_{N\perp})$$

$$\otimes \int d^2\vec{v}_\perp \int \frac{d^2\vec{k}_\perp}{(2\pi)^2} f_q^A(x_B, \vec{v}_\perp) \frac{\phi(0,\vec{k}_\perp)}{k_\perp^2} \mathcal{N}_g(\vec{l}_\perp, \vec{l}_{q\perp}, \vec{k}_\perp, \vec{v}_\perp)$$



$$\vec{l}_\perp + \vec{l}_{q\perp} = \vec{k}_\perp + \vec{v}_\perp$$

$$\frac{\Delta\sigma_{e+A}}{A\sigma_{e+p}} \propto A^{2/3}$$

Quadratic nuclear-size dependence due to LPM interference

Yuanyuan Zhang & XNW in preparation

Summary

- Jet transport coefficient is related to gluon distribution density in nuclear medium
- pT broadening and jet suppression can be used to extract jet transport coefficient
- qhat=0.02 GeV^2/fm in large nuclei
- Jet medium interaction leads to flavor conversion in SIDIS
- Modification of dijets at EIC can provide information about TMD parton distributions in nuclei