Cold Nuclear Matter effect on jet production at electron-ion colliders

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Base on the works in collaboration with I.Vitev
arXiv:2010.05912

EIC opportunities for Snowmass
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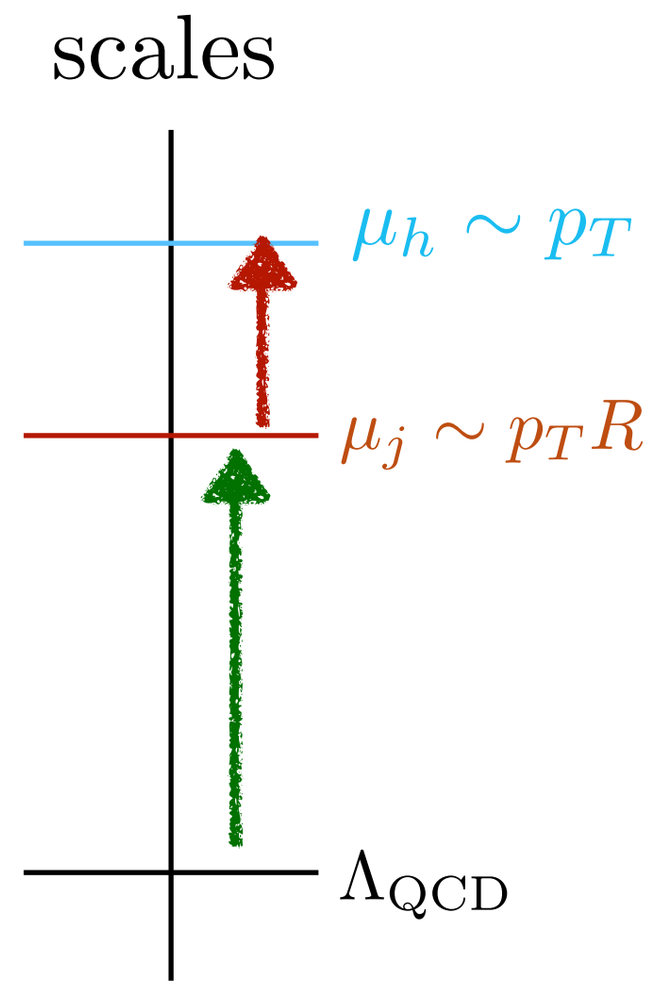
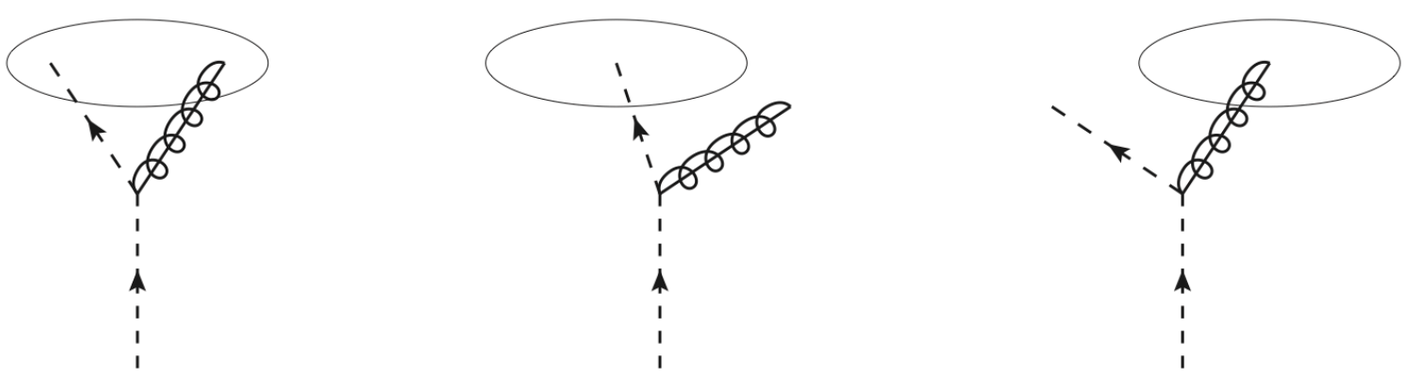
Semi-inclusive Jet Function

The inclusive jet cross section can be expressed in a factorized form with the help of semi-inclusive jet functions

$$E_J \frac{d^3\sigma^{lN\to jX}}{d^3P_J} = \frac{1}{S}\sum_{i,f}\int_0^1 \frac{dx}{x}\int_0^1 \frac{dz}{z^2} f_{i/N}(x,\mu) \times \hat{\sigma}^{i\to f}(s,t,u,\mu) J_f(z, p_T R, \mu)$$

Hard part: arXiv:1505.06415
Jet Function: arXiv:1606.06732



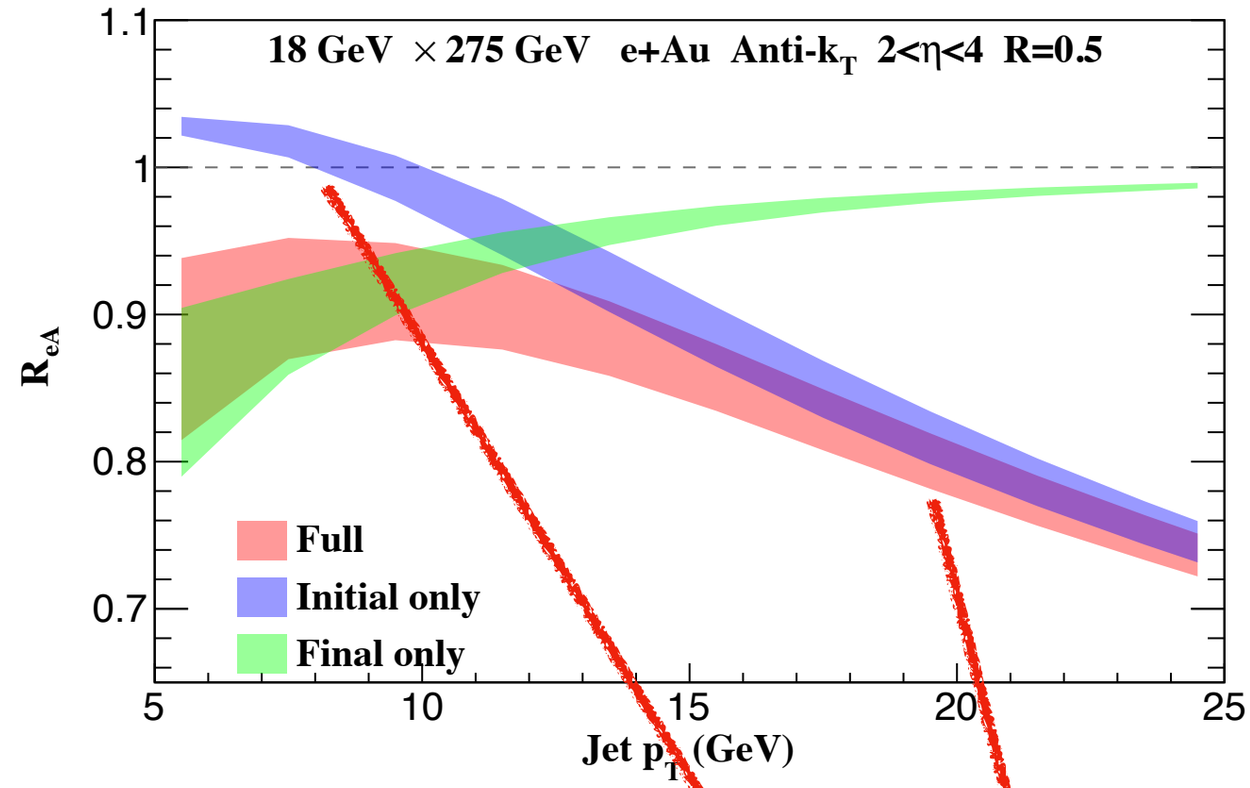


Contribution to the semi-inclusive quark jet function

Inclusive jet cross section

Fixed $\langle k_\perp^2 \rangle / \lambda_g = 0.12\ \mathrm{GeV}^2/\mathrm{fm}$

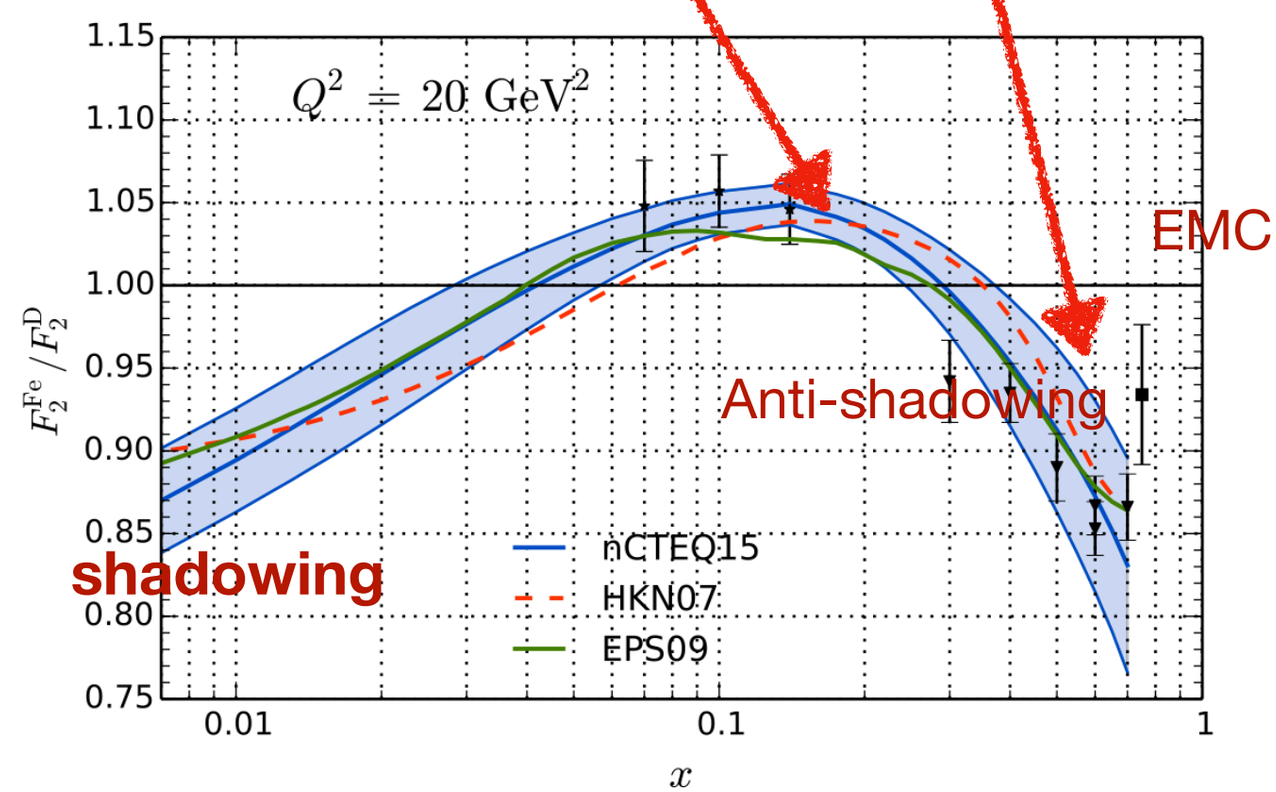
The forward proton/nucleus going rapidity region 2< η <4 produce the largest nuclear effects.



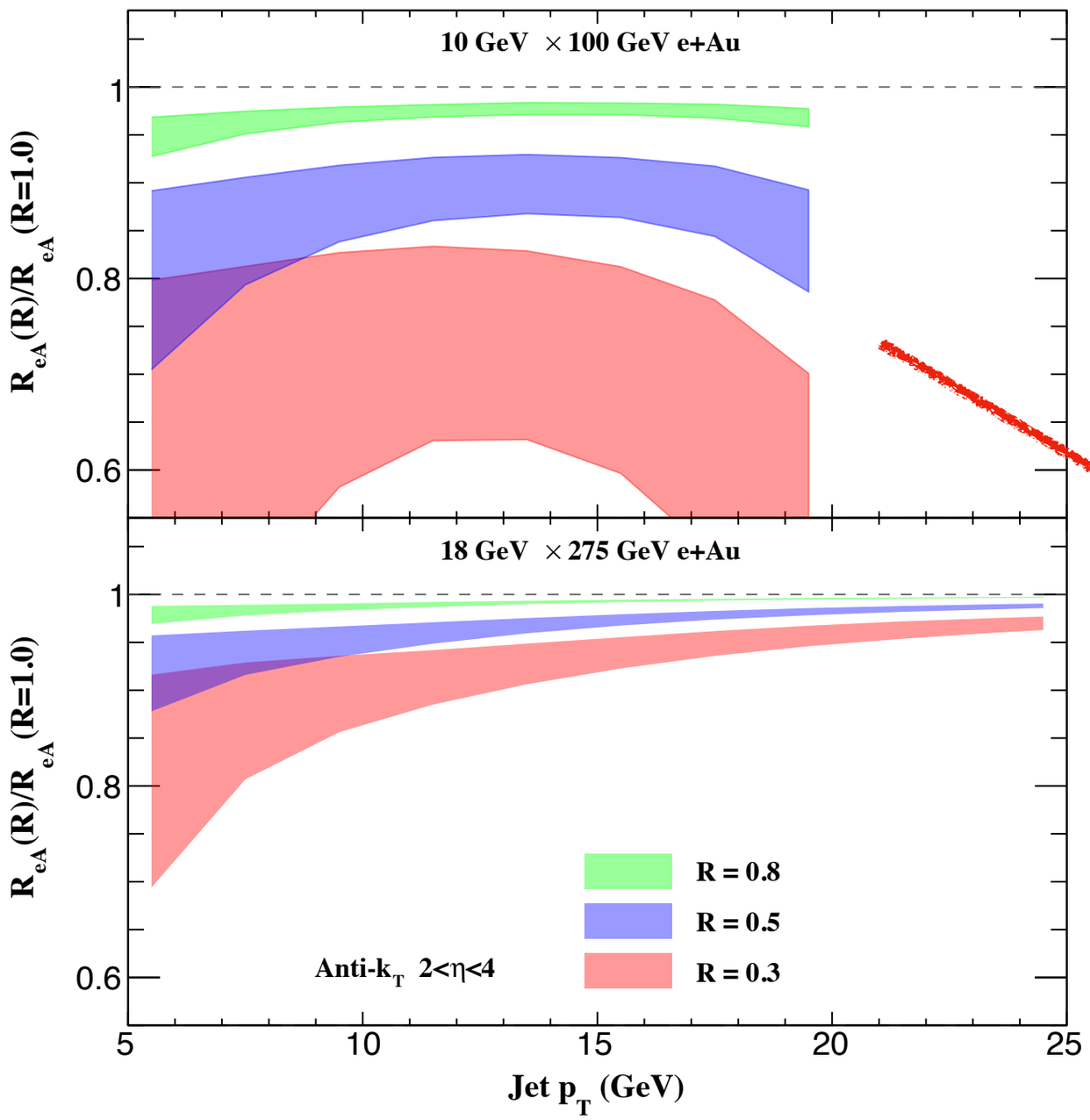
Modifications defined as

$$R_{\mathrm{eA}}(R) = \frac{1}{A} \frac{\int_{\eta 1}^{\eta 2} d\sigma/d\eta dp_T \big|_{e+A}}{\int_{\eta 1}^{\eta 2} d\sigma/d\eta dp_T \big|_{e+p}}$$

- Bands are scale uncertainties
- Bjorken x in the anti-shadowing and EMC region
- Final State effects decreasing with p_T increasing



Inclusive jet cross section



Essential to reduce the role of nPDFs and enhance the effects due to final-state interactions

$$\frac{R_{\mathrm{eA}}(R)}{R_{\mathrm{eA}}(R=1)}$$

enhanced by the steeper pT spectra near the phase space boundary

- Suppression is more significant for smaller jet radii
- scale uncertainties are larger for smaller p_T
- Final State effects decreasing with p_T increasing

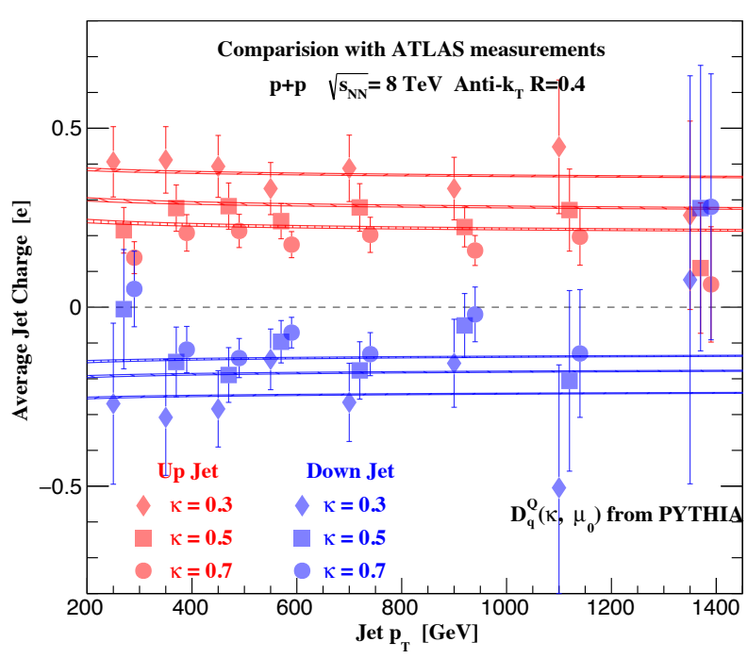
Jet charge in SCET

$$\langle Q_{\kappa,q}\rangle = \frac{\tilde{\mathcal{J}}_{qq}(E,R,\kappa,\mu)}{J_q(E,R,\mu)} \exp\left[\int_{1\mathrm{GeV}}^{\mu} \frac{d\mu'}{\mu'}\frac{\alpha_s(\mu')}{\pi}\tilde{P}_{qq}(\kappa)\right]\tilde{D}_q^Q(\kappa)$$

- The perturbative part contains the ? dependence on the jet algorithm

$$\widetilde{\mathcal{J}}_{ij}(E,R,\kappa,\mu) = \int_0^1 \mathrm{d}z z^\kappa \mathcal{J}_{ij}(E,R,z,\mu)$$

Matching the jet function to fragmentation function



- The non-perturbative part can be related to fragmentation functions

from weighted-definition of jet charge

$$\widetilde{D}_q^h(\kappa,\mu) = \int_0^1 \mathrm{d}z z^\kappa D_q^h(z,\mu)$$

sum over all the hadrons in the jet

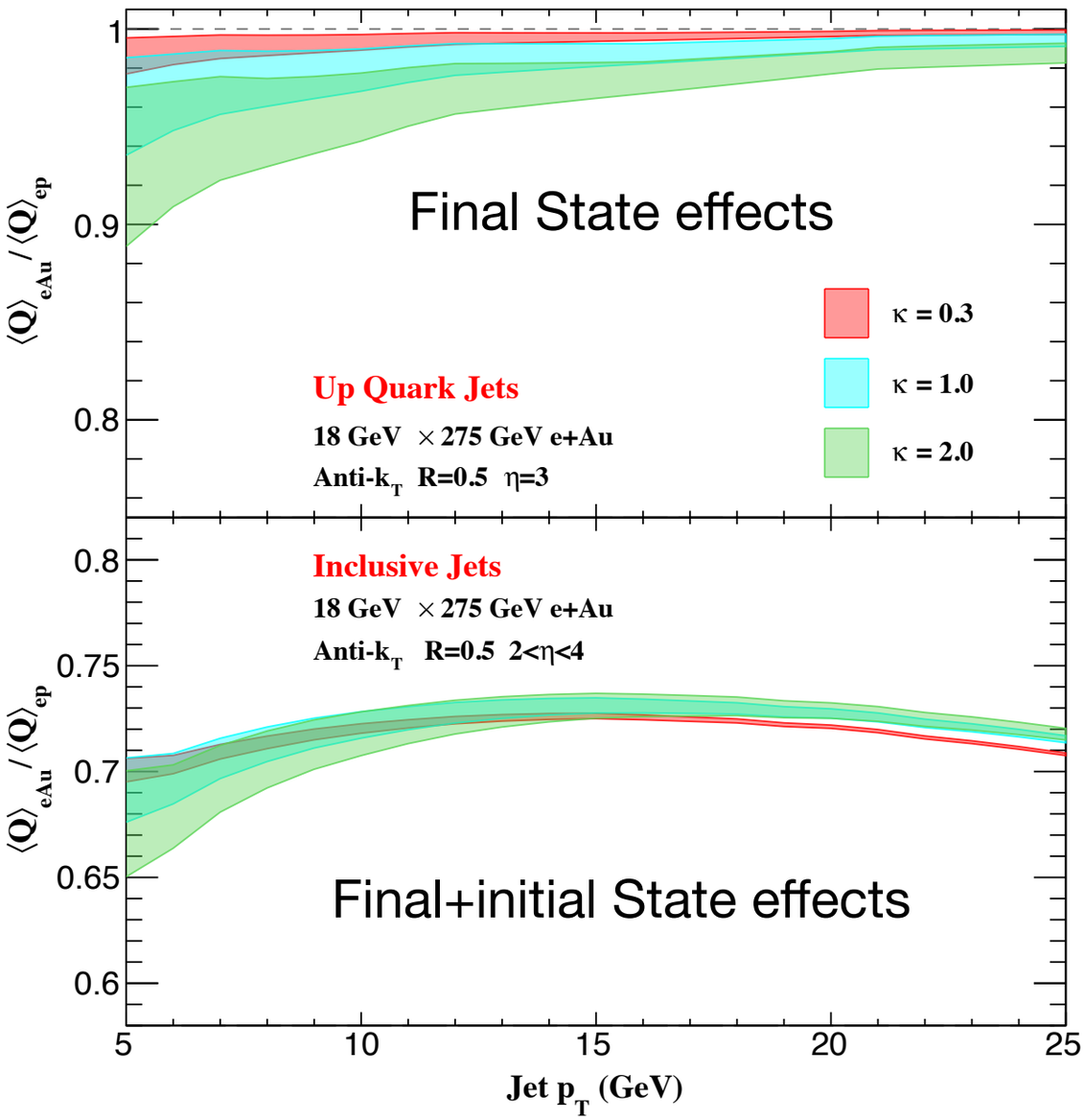
$$\tilde{D}_q^Q(\kappa,\mu) = \sum_h Q_h \widetilde{D}_q^h(\kappa,\mu)$$

the evolution equation

$$\mu\frac{d}{d\mu}\tilde{D}_q^Q(\kappa,\mu) = \frac{\alpha_s(\mu)}{\pi}\tilde{P}_{qq}(\kappa)\tilde{D}_q^Q(\kappa,\mu)$$

Krohn, Schwartz, Waalewijn, arXiv:1209.2421
Waalewijn arXiv:1209.3019

Jet Charge



In general, final state effects are small

Larger correction for larger κ because medium induced radiation tends to be soft

At LO, approximately

$$\langle Q_\kappa \rangle = (f_u - f_{\bar{u}}) \langle Q_\kappa^u \rangle + (f_d - f_{\bar{d}}) \langle Q_\kappa^d \rangle$$

positive charge negative charge

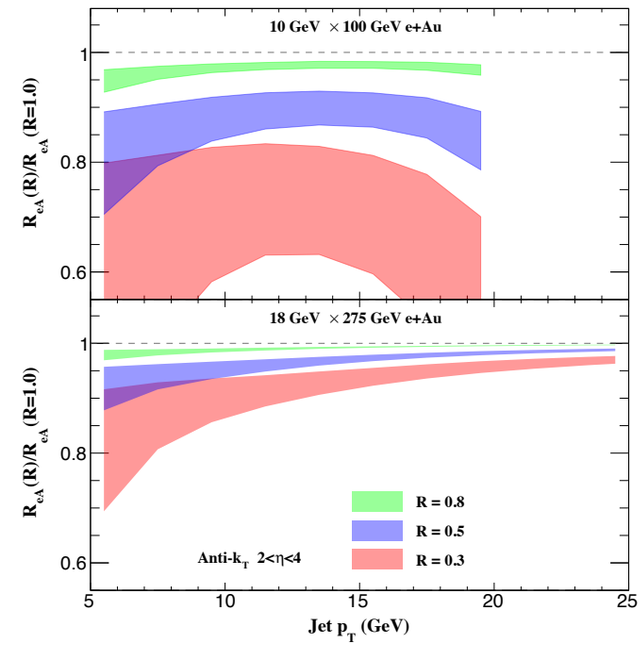
Cancellation between u and d jet

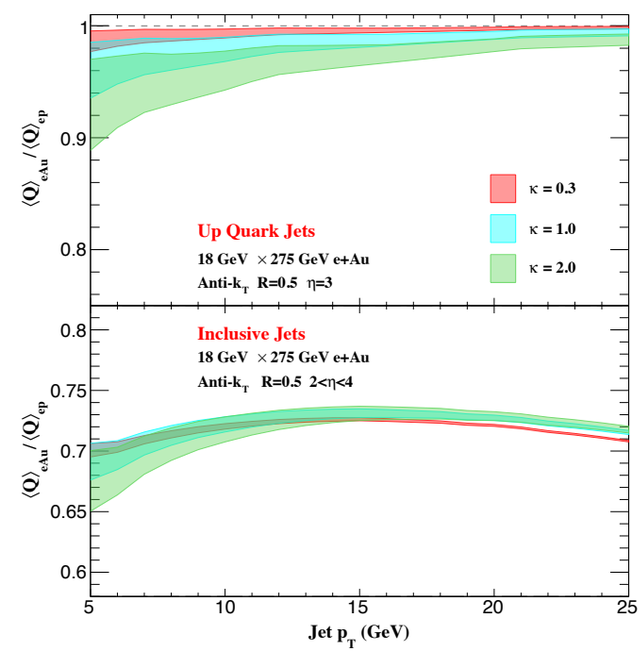
Initial state effects is large

Precision measurement of the charge will be an excellent way to constrain isospin effects and the up/down quark PDFs in the nucleus.

Conclusion

- we investigated the nuclear matter effect for jet production at EIC
- we presented theoretical predictions for the inclusive jet cross section and average jet charge at EIC
- we discussed how to disentangle the initial state effect and final state effect at EIC





Understand the nuclear matter effects

Extract the flavor information and constrain the nuclear PDFs.