Jet charge for spin asymmetries

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Jets for 3D imaging, 2020

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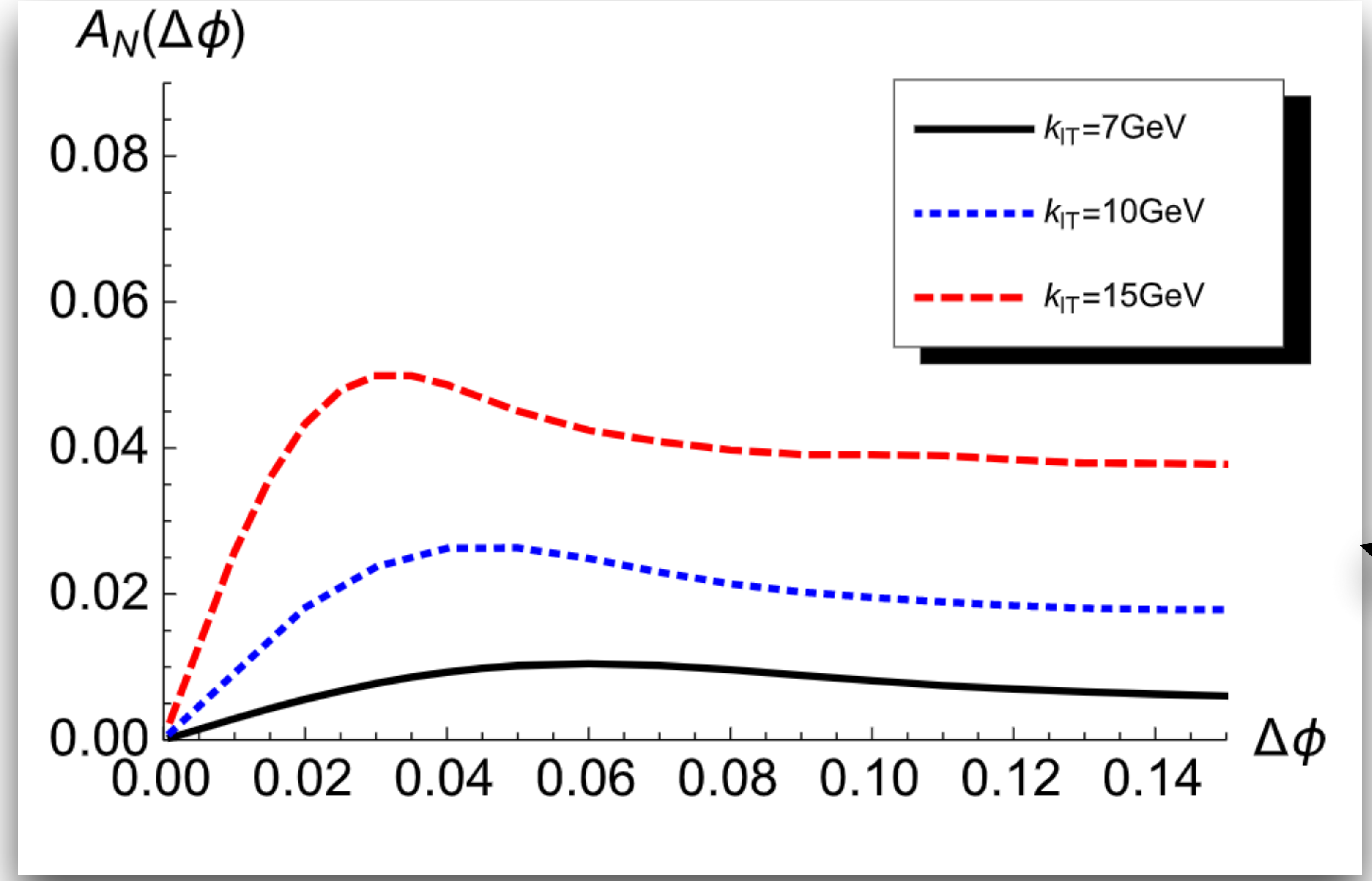
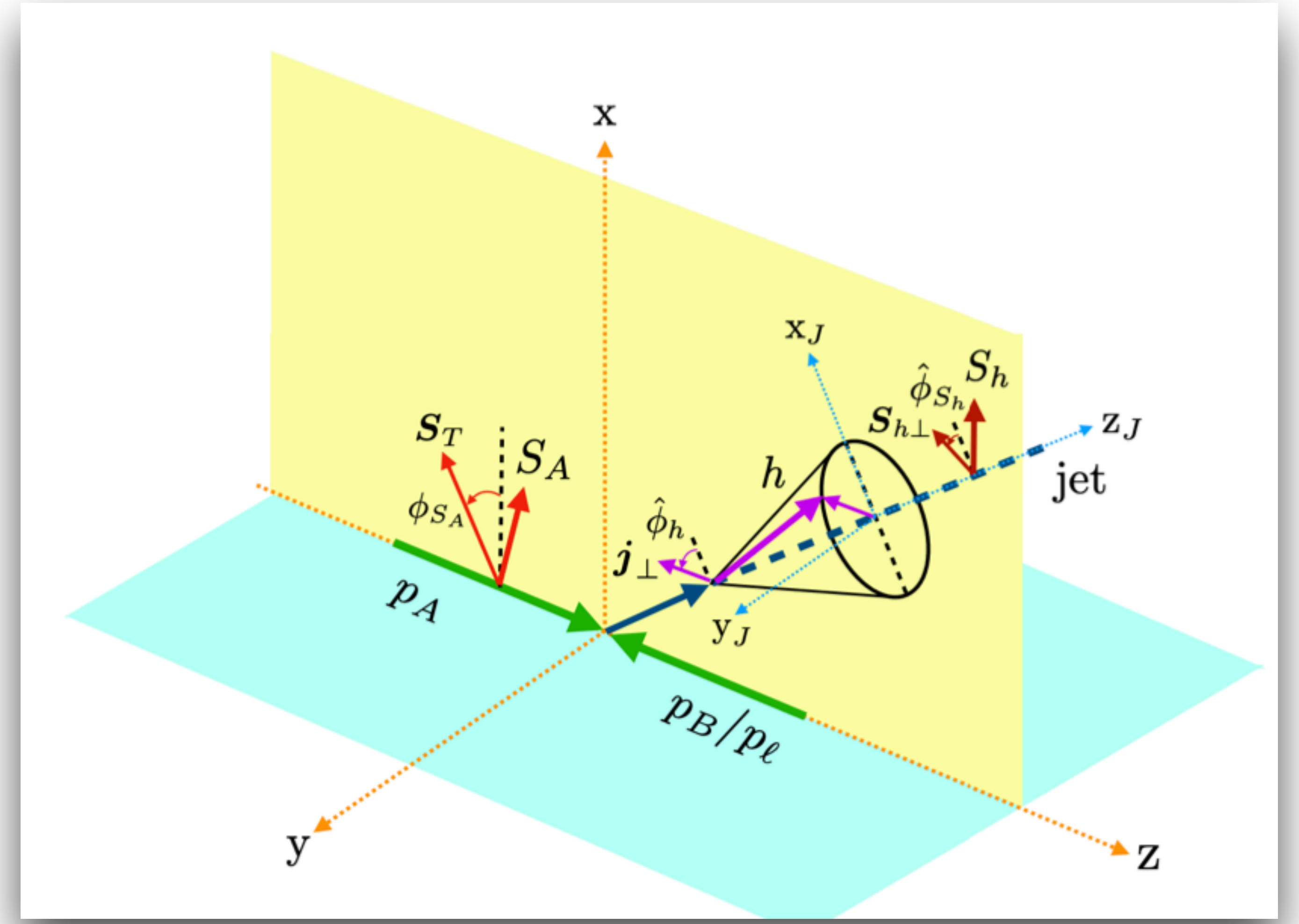
Jets @ EIC



XL, Ringer, Vogelsang, Yuan, 19

Proton polarization,
Sivers function

Proton polarization,
Collins function

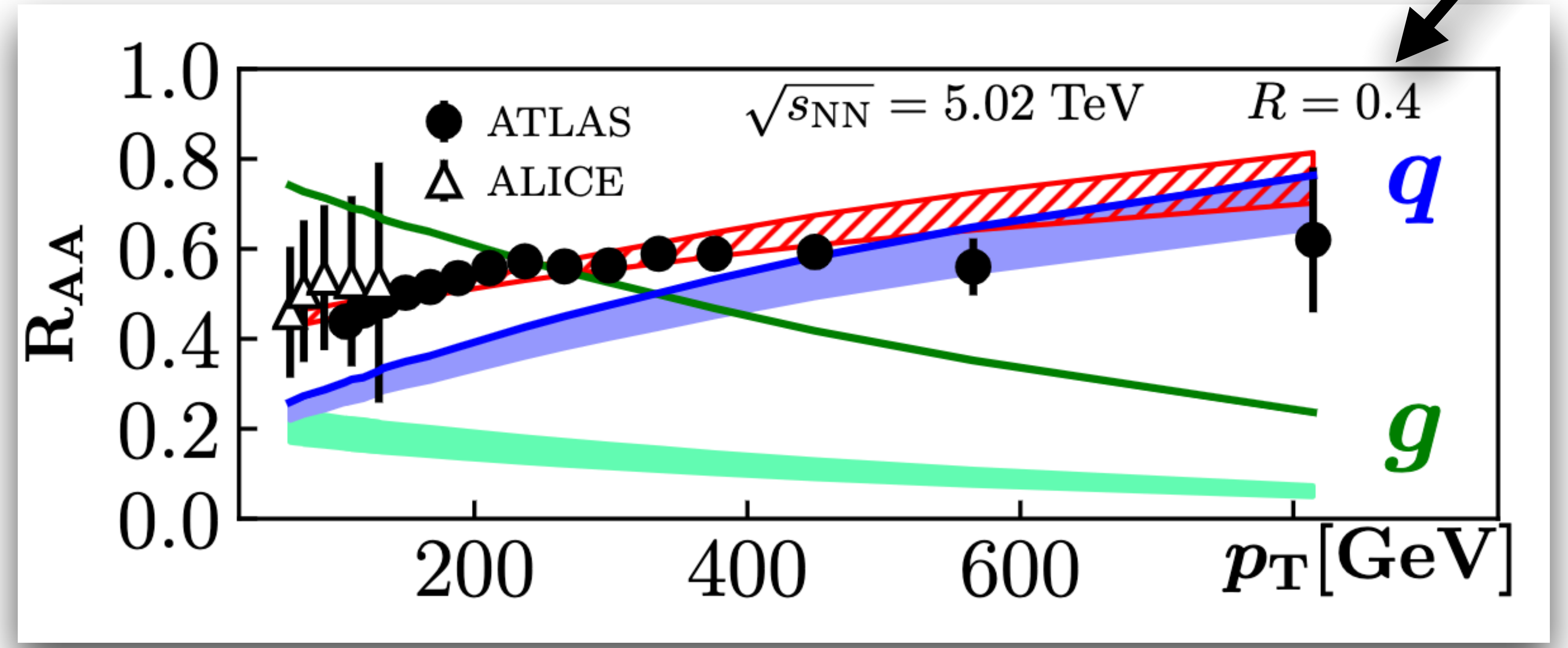


Kang, Lee, Zhao, 20

Jets/substructures

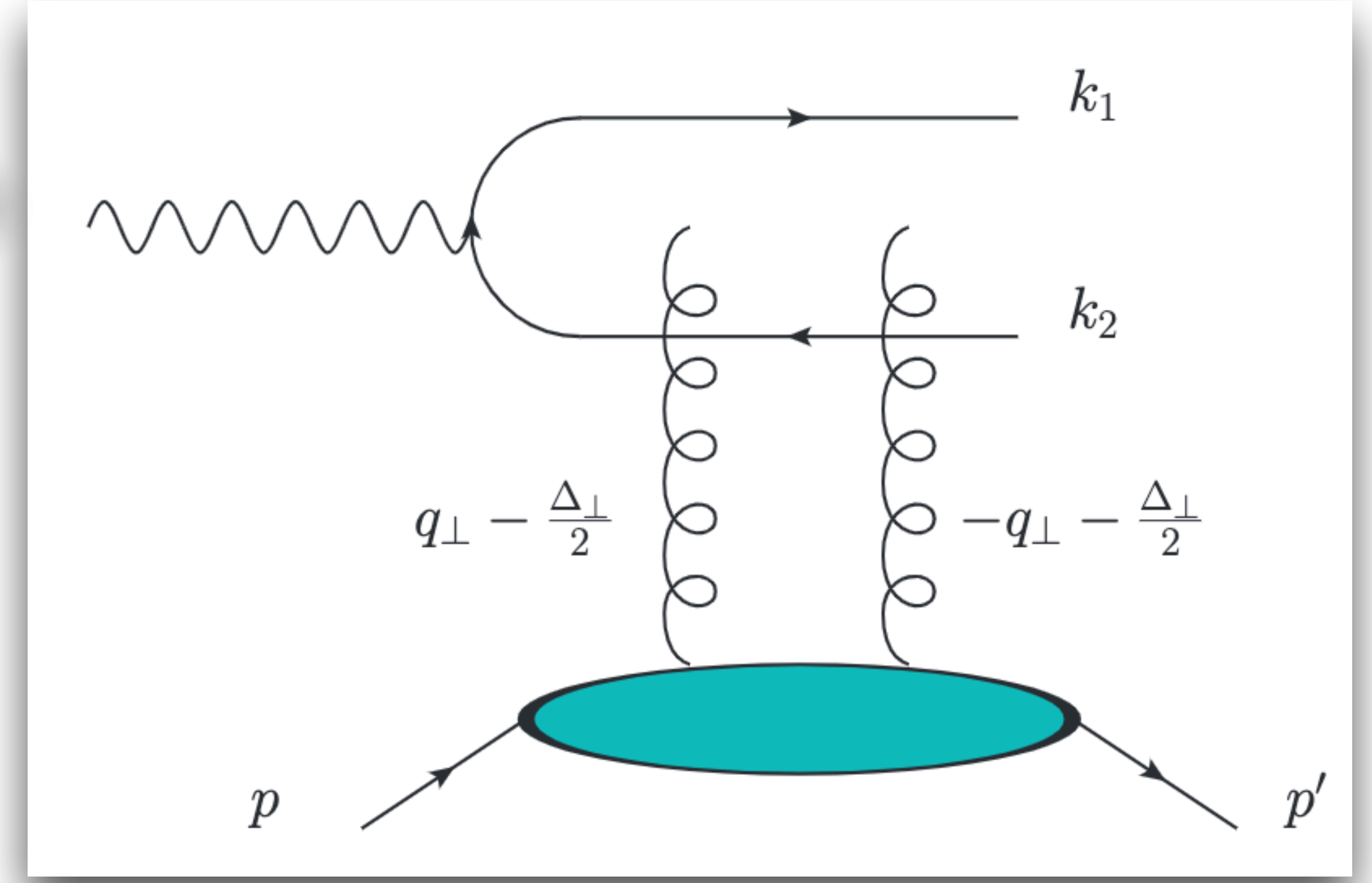
Heavy ion

Small-x, GPD



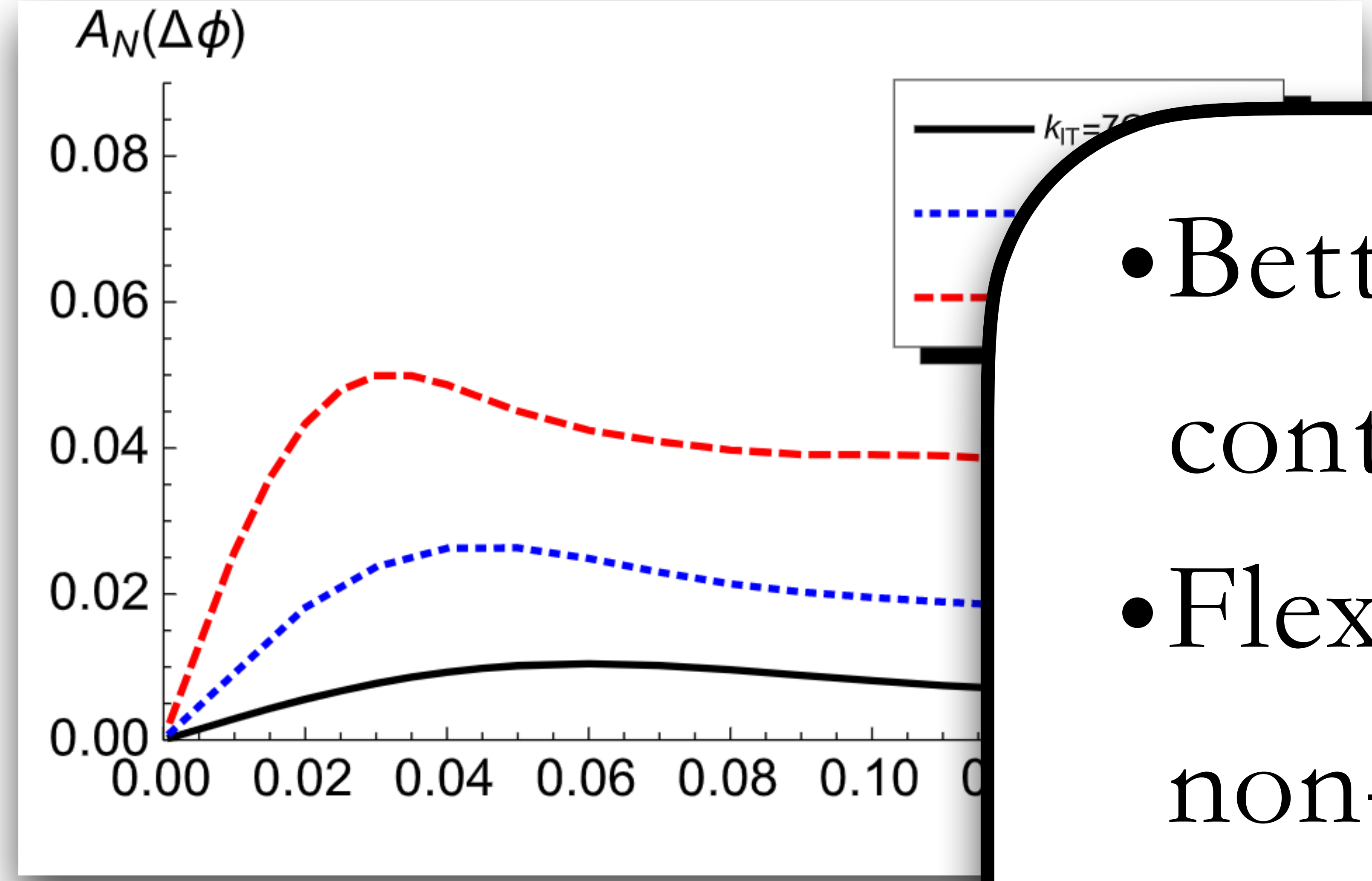
Qiu, et al, 19

Growing interests in jet probes of the internal structures

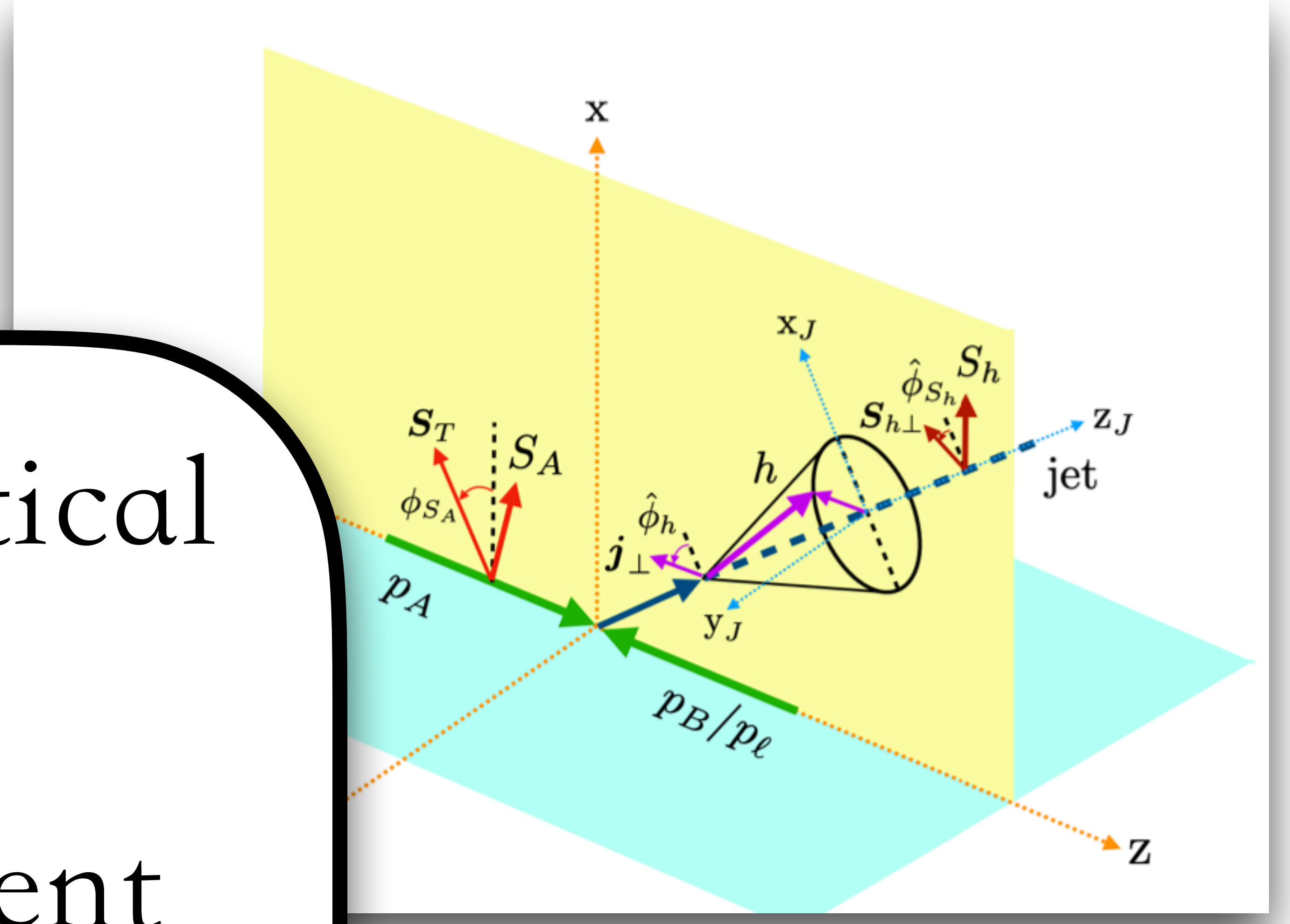


Hatta, Xiao, Yuan, 17

Jets @ EIC



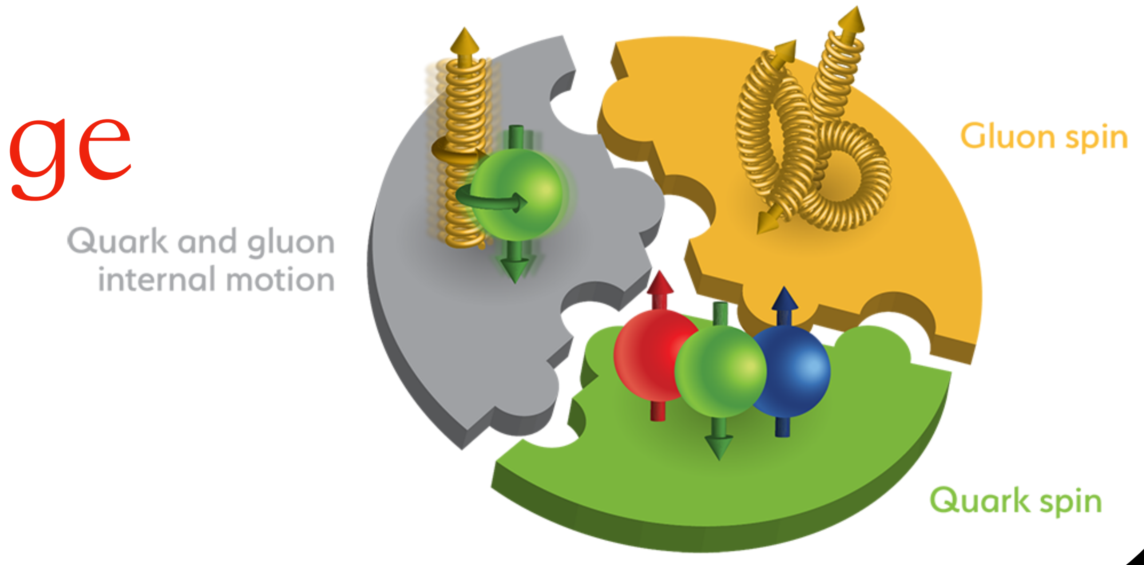
XL, Ringer, Vogelsa

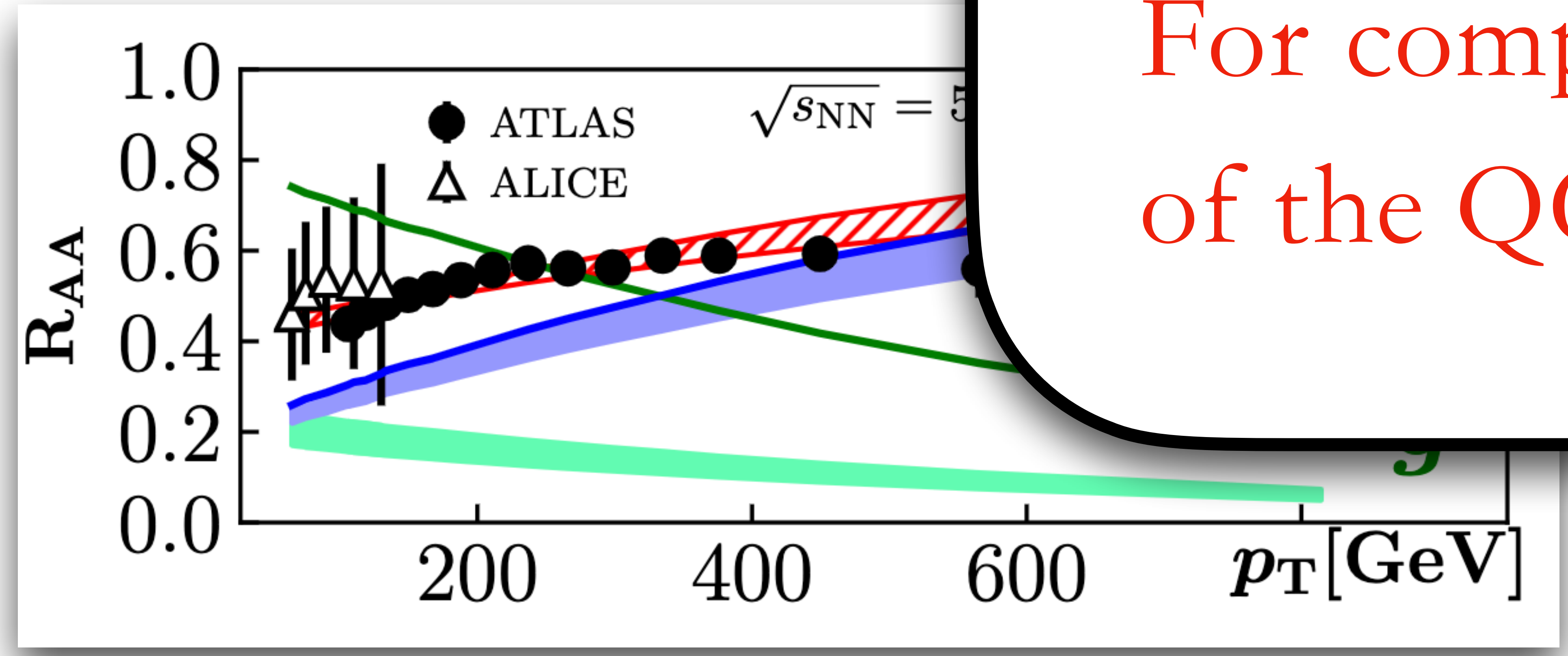


Kang, Lee, Zhao, 20

- Better parton proxies, better theoretical control
- Flexible, dis-entangle between different non-perturbative objects
- Flavor separation ?

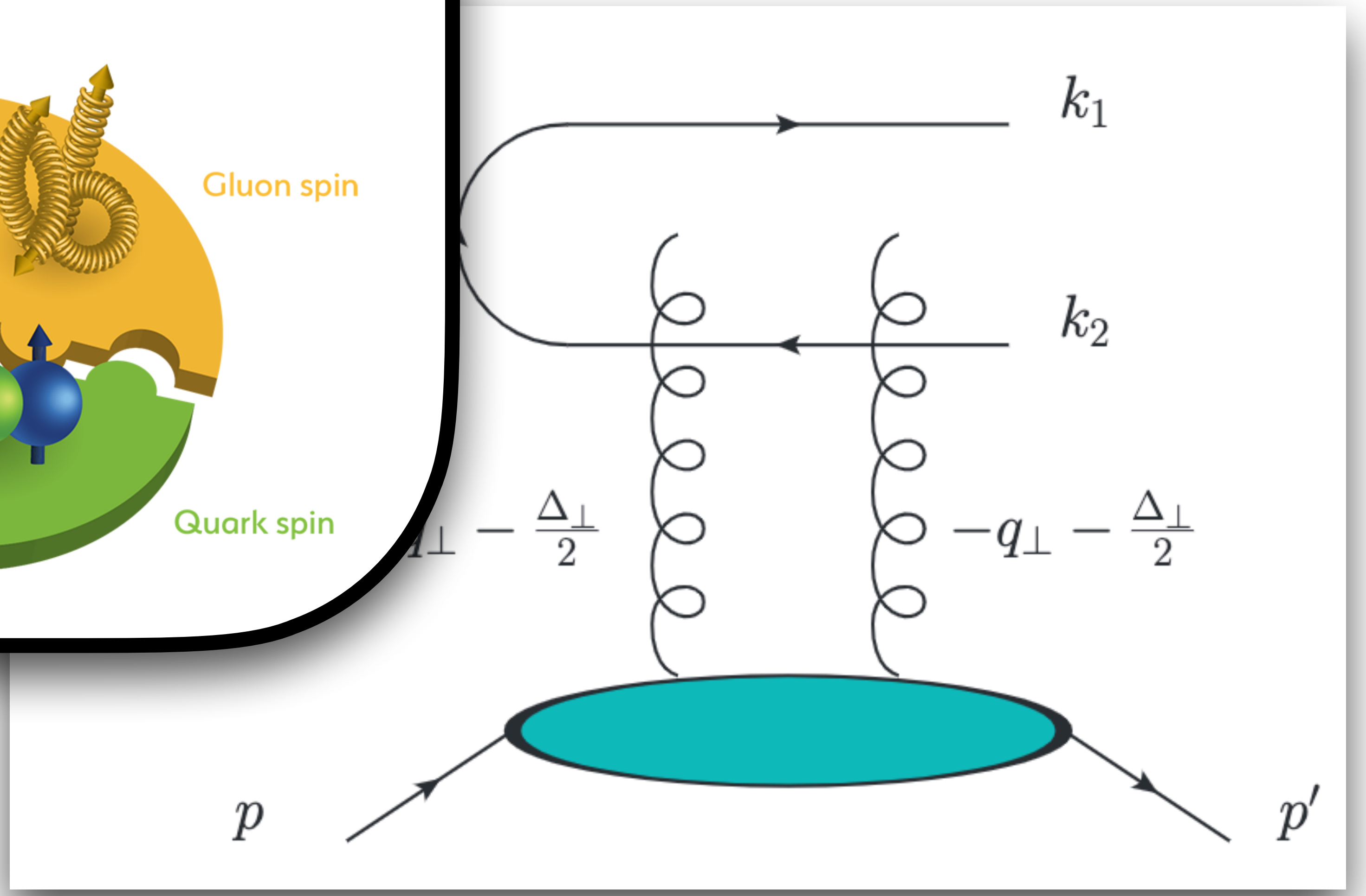
For complete knowledge of the QCD dynamics





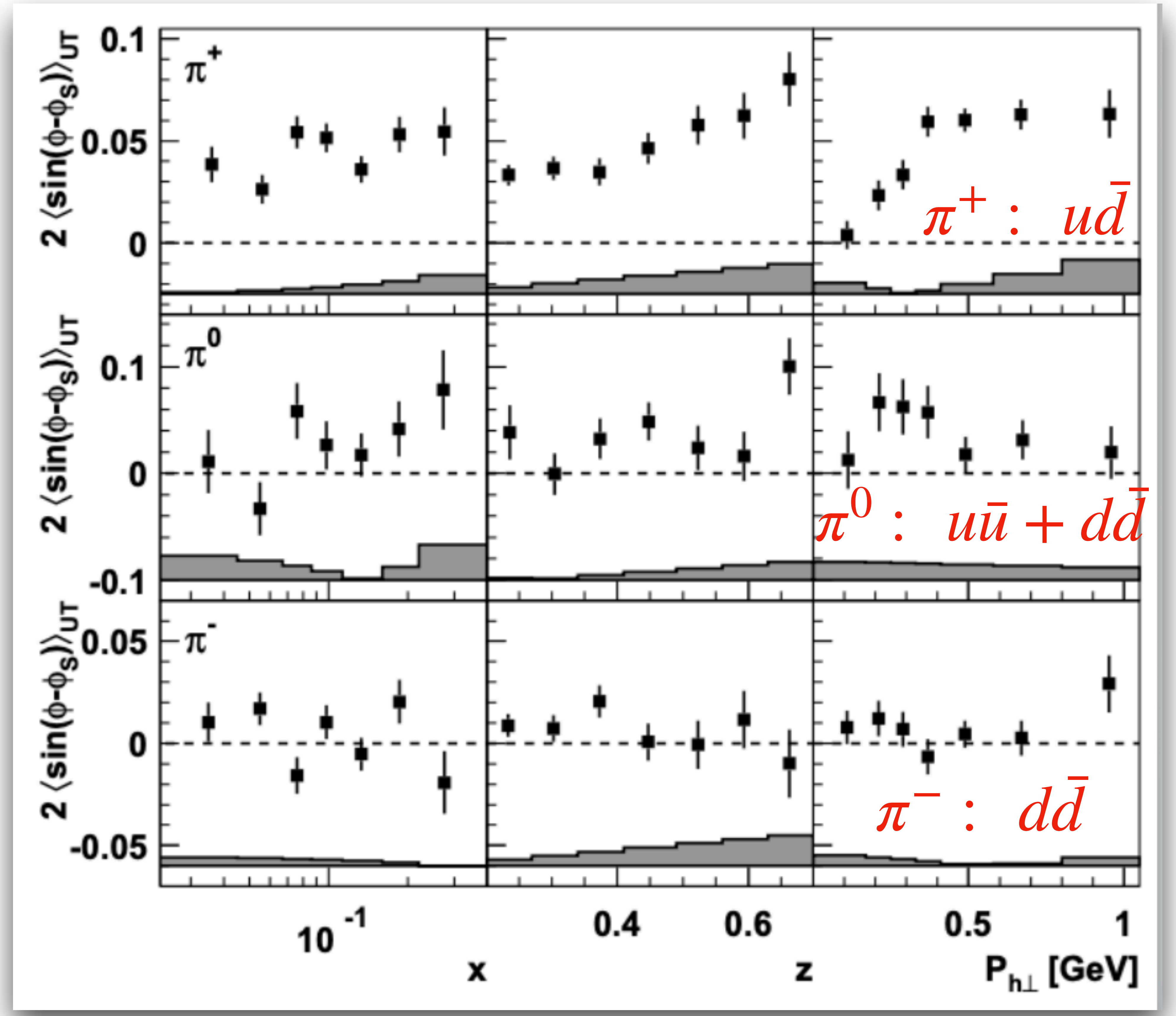
Qiu, et al, 19

internal structures



Hatta, Xiao, Yuan, 17

Jets @ EIC

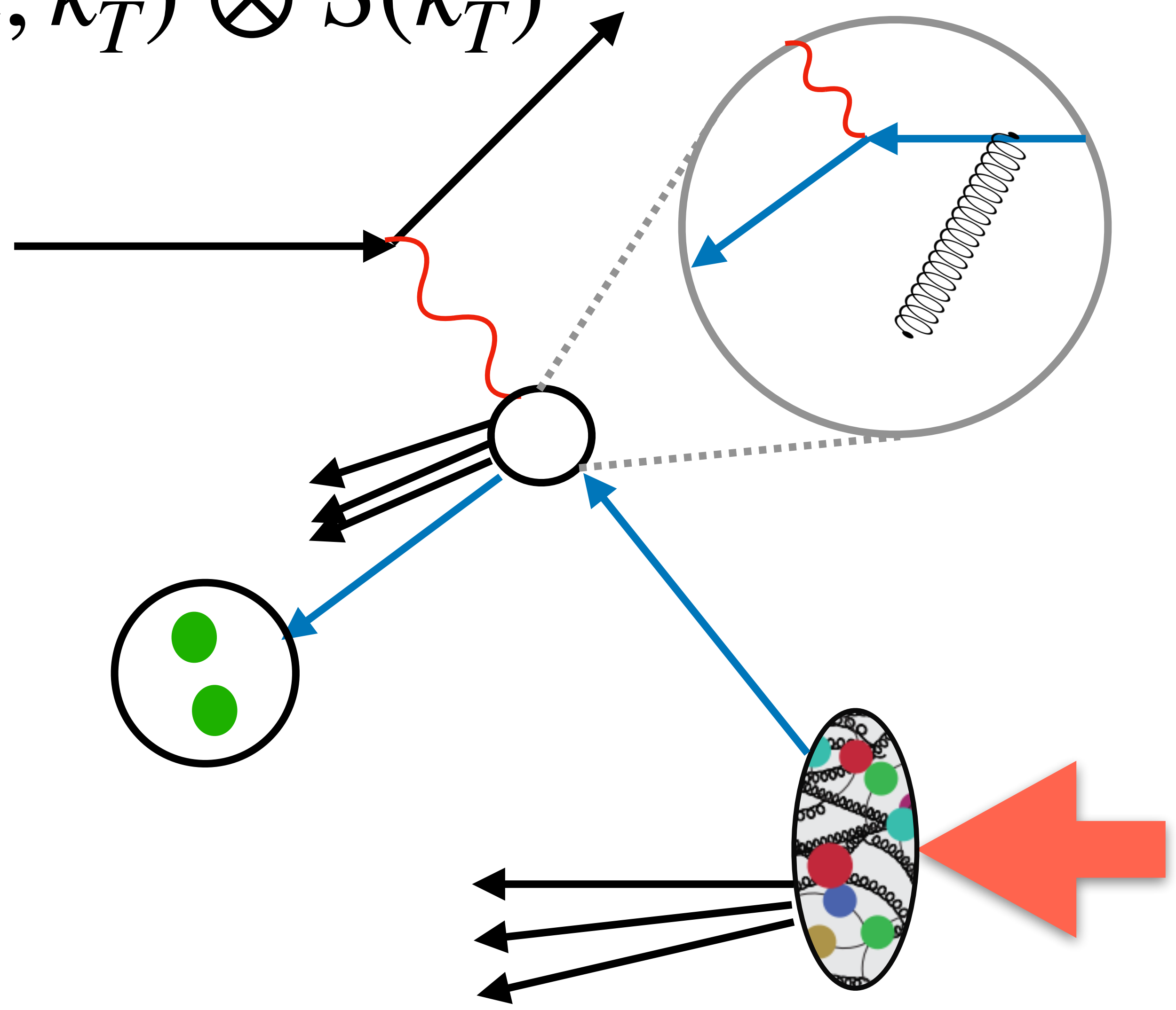


HERMES collaboration, 2009

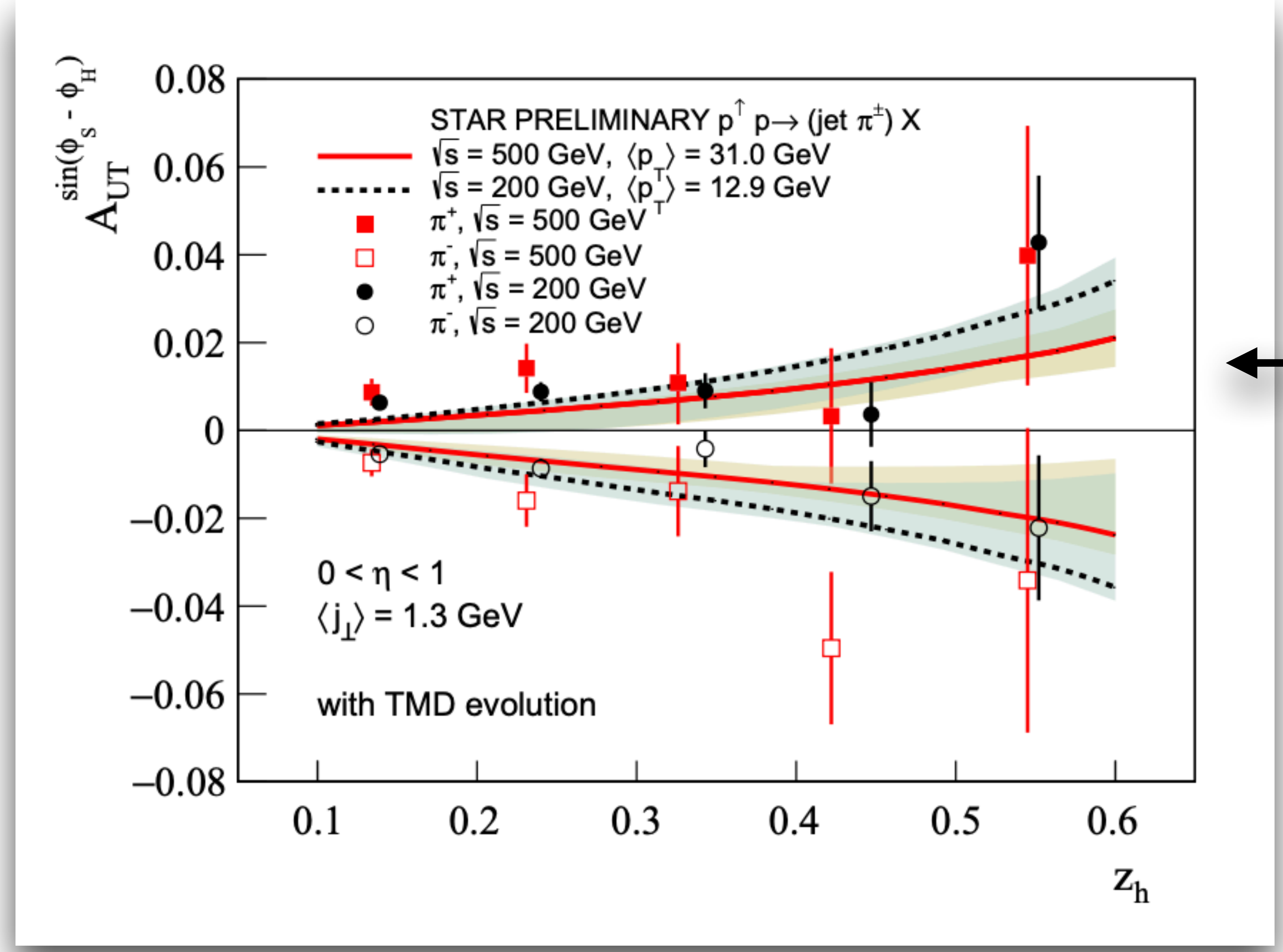
Flavor separation in SIDIS

- Flavor correlated between initial and final
- Tagging final state hadrons for flavor discrimination
- Need TMD FFs / spin counterparts

$$\frac{d\sigma}{dq_T} \sim \hat{\sigma}_{ii}(Q) D_{h/i}^{U/T}(z_h, k_T) \otimes f_{i/P}^{U/T}(x, k_T) \otimes S(k_T)$$



Jets @ EIC

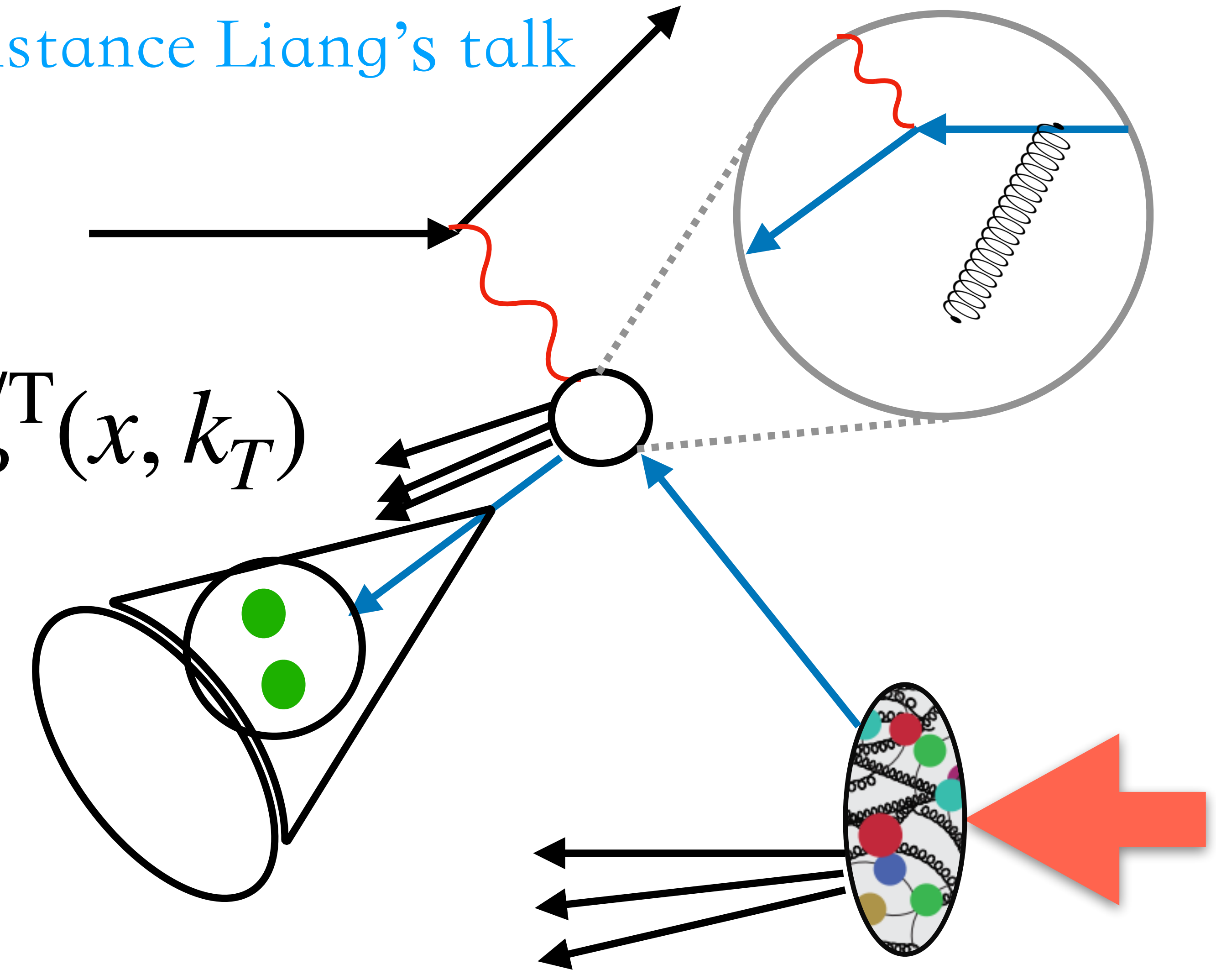


Kang, Prokudind, Ringer, Yuan, 2017

Flavor separation with hadrons in jets

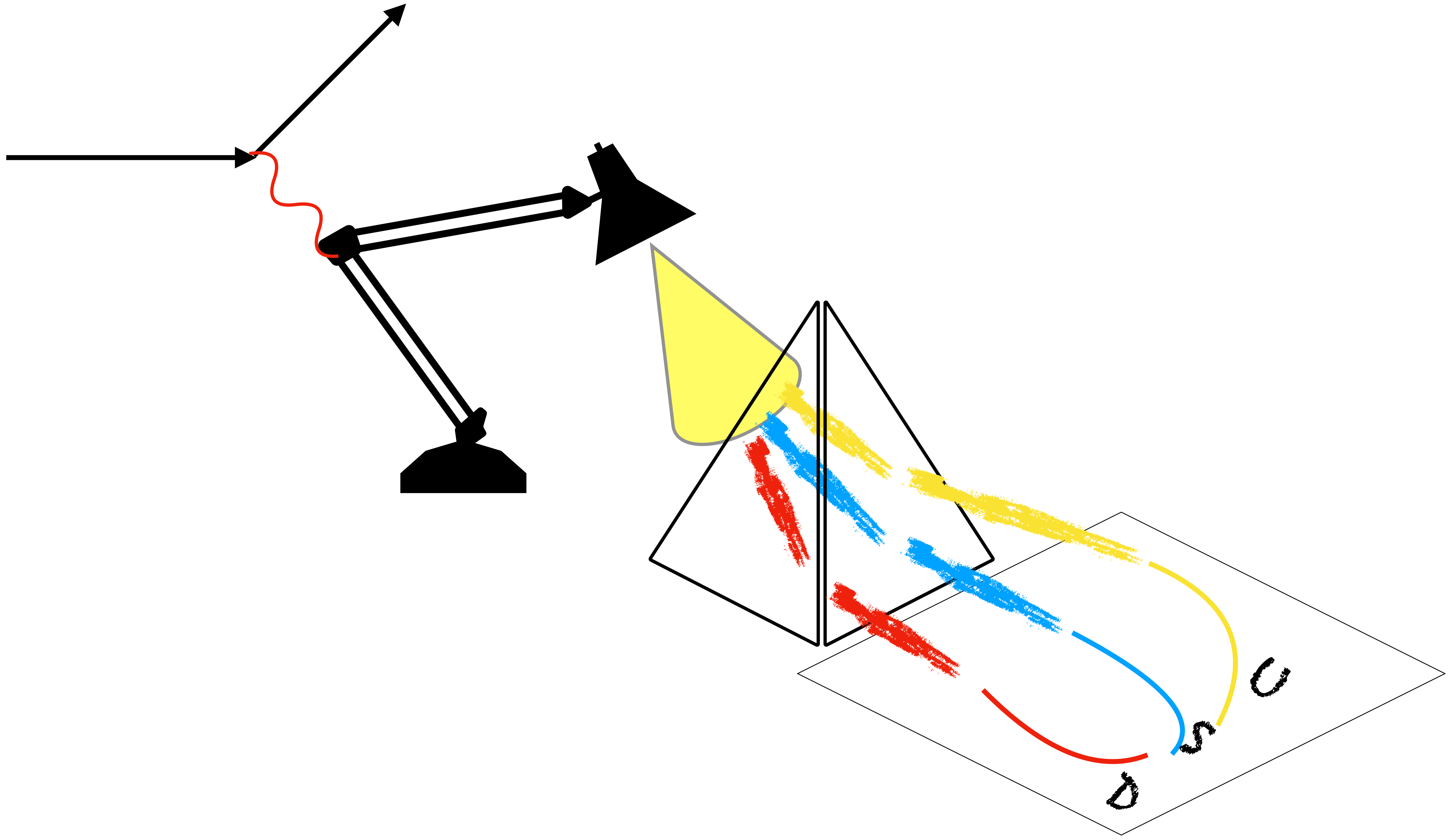
- Tagging hadrons in jet for flavor discrimination
- Applied for the Collins function
- Also good for the flavor separation in Sivers function if small jet-lepton imbalance is measured. For gluon Sivers, see for instance Liang's talk
- Need FFs

$$\frac{d\sigma}{dq_T} \sim \hat{\sigma}_{ii}(Q) D_{h/j}(z_h) J_{ji}(R) \otimes f_{i/P}^{U/T}(x, k_T)$$



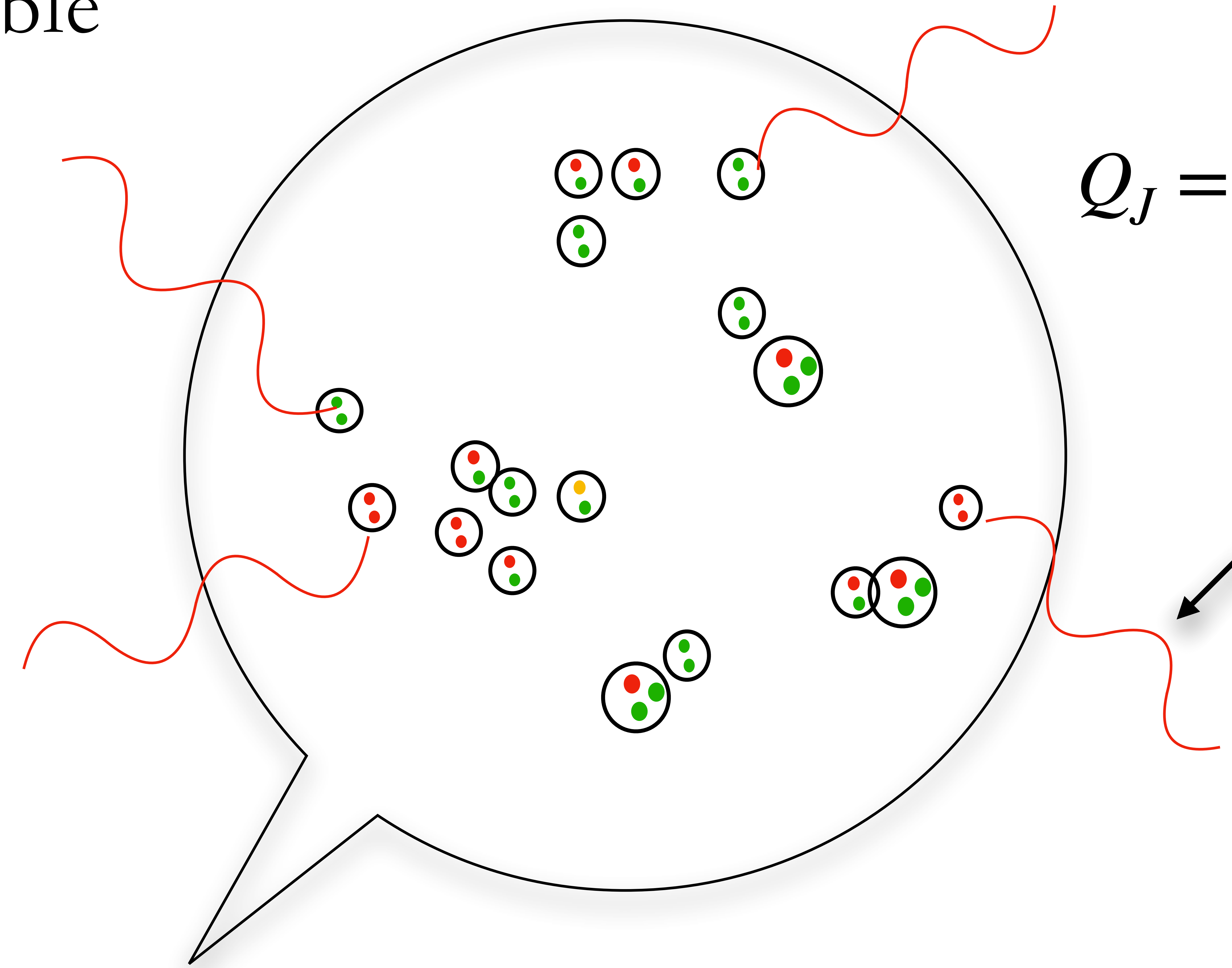
Other alternatives?

- Probe directly the light parton flavors
- No extra non-pert. distributions
- Information beyond QCD
- electro-charge? Robust against the hadronization?



Jet charge as a flavor prism @ EIC

- The observable



$$Q_J = \sum_i Q_i?$$

Too sensitive to the soft contaminations

Jet charge as a flavor prism @ EIC

- The observable

$$Q_\kappa = \sum_i \left(\frac{p_{i,T}}{p_J} \right)^\kappa Q_i$$

hadron transverse momentum

parameter to suppress contaminations $\kappa > 0$

hadron charge

jet transverse momentum

sum over hadrons within the jet. Flexibility to use a specific hadron species, “ the hadron component” of the jet

Field and R. Feynman, 1978

Krohn, Schwartz, Lin, and Waalewijn, 2013

Jet charge as a flavor prism @ EIC

- The observable

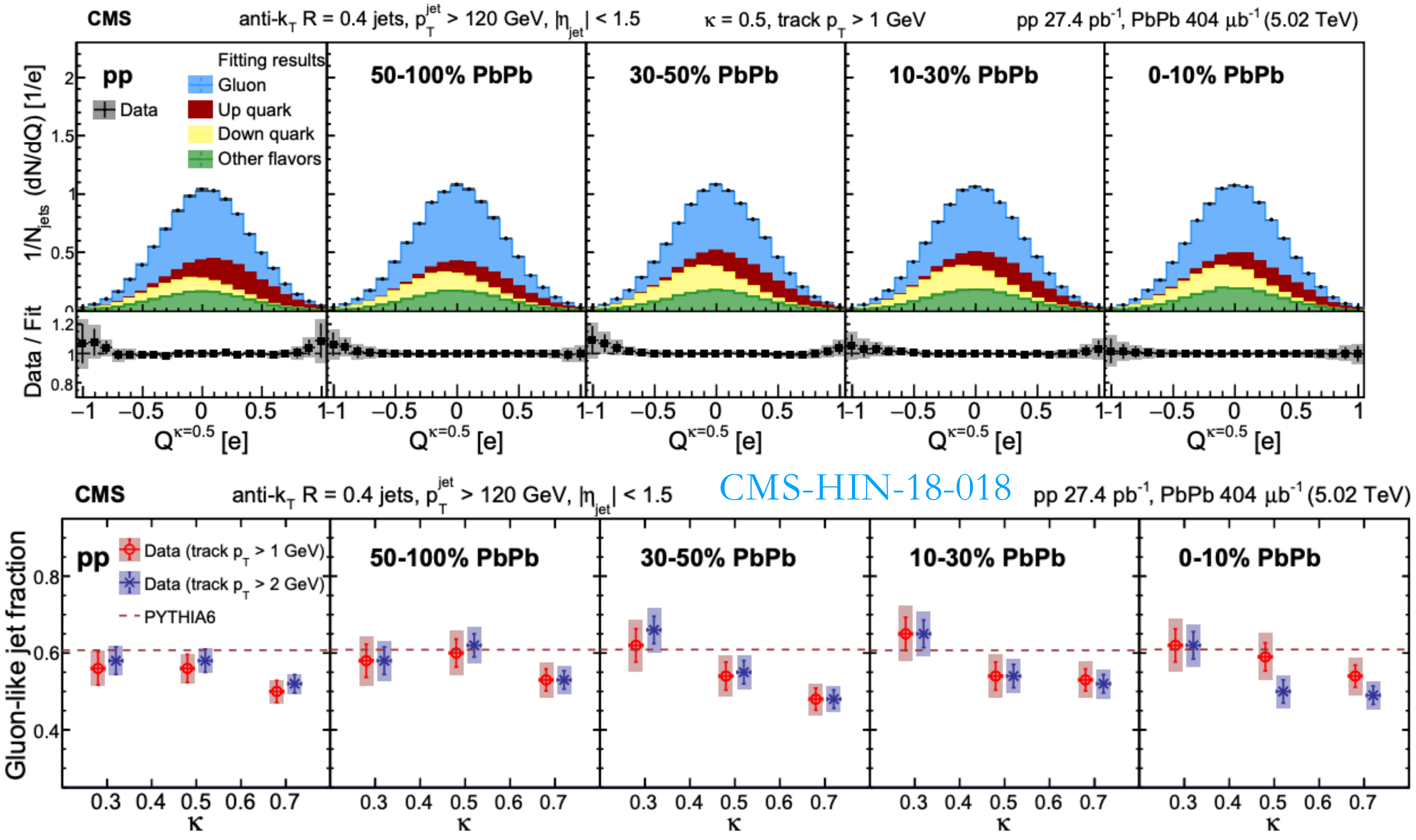
hadron transvers

momentum

Q_κ

sum over hadrons within the jet

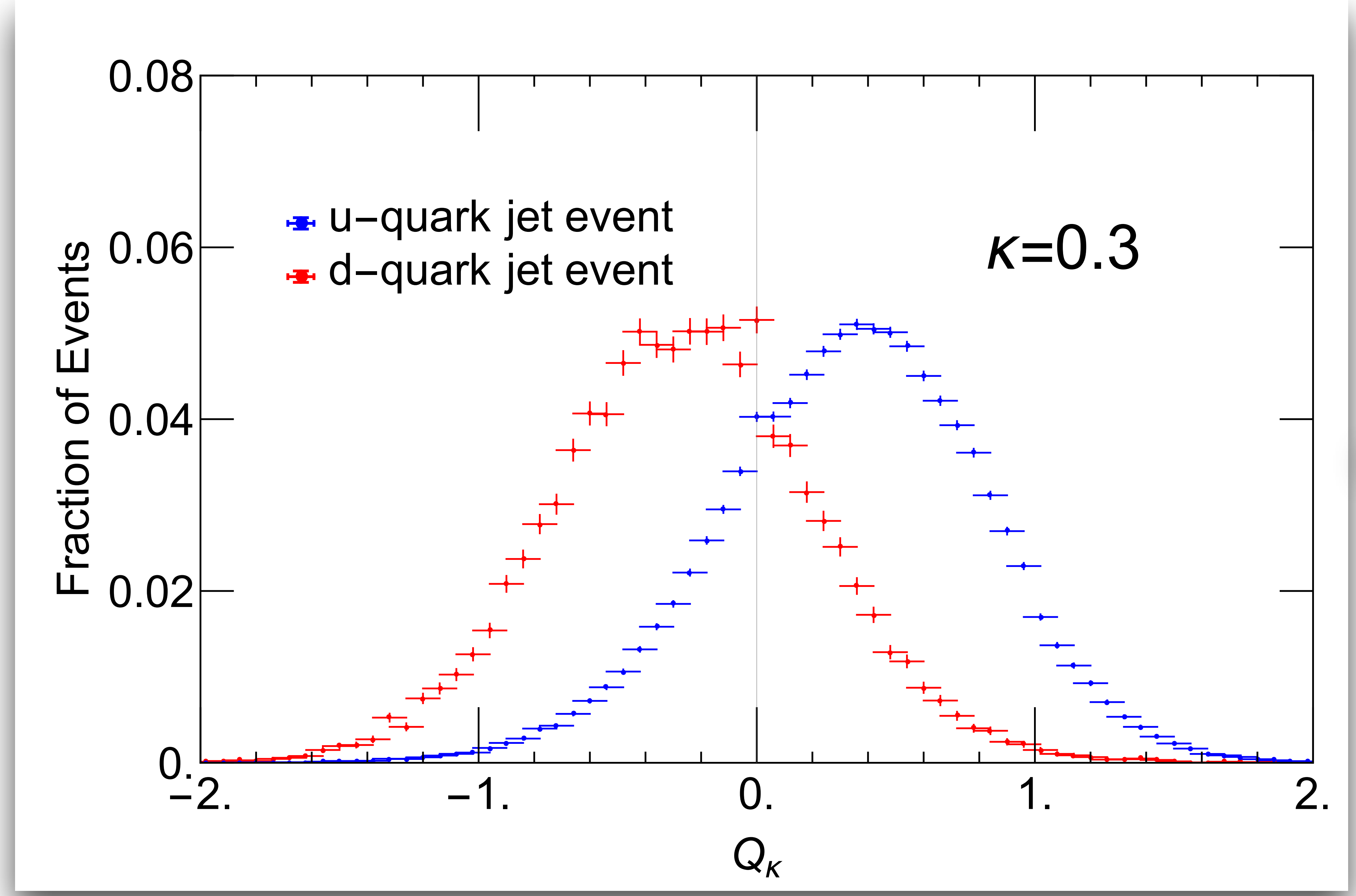
practical applications now



But mostly focus on the quark-gluon discrimination

Jet charge as a flavor prism @ EIC

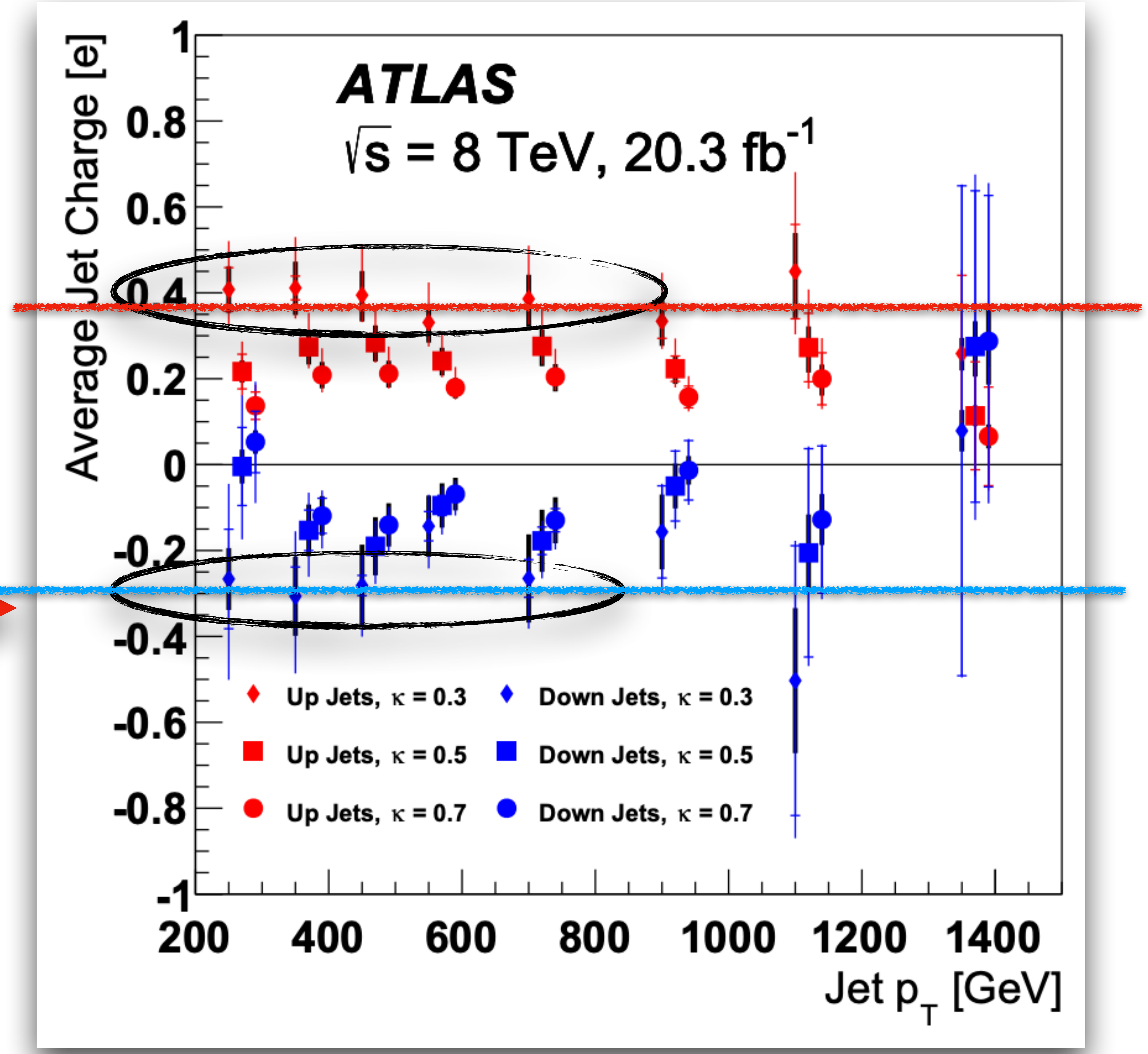
- The observable $Q_\kappa = \sum_i \left(\frac{p_{i,T}}{p_J}\right)^\kappa Q_i$



Pythia simulation

Consistent!

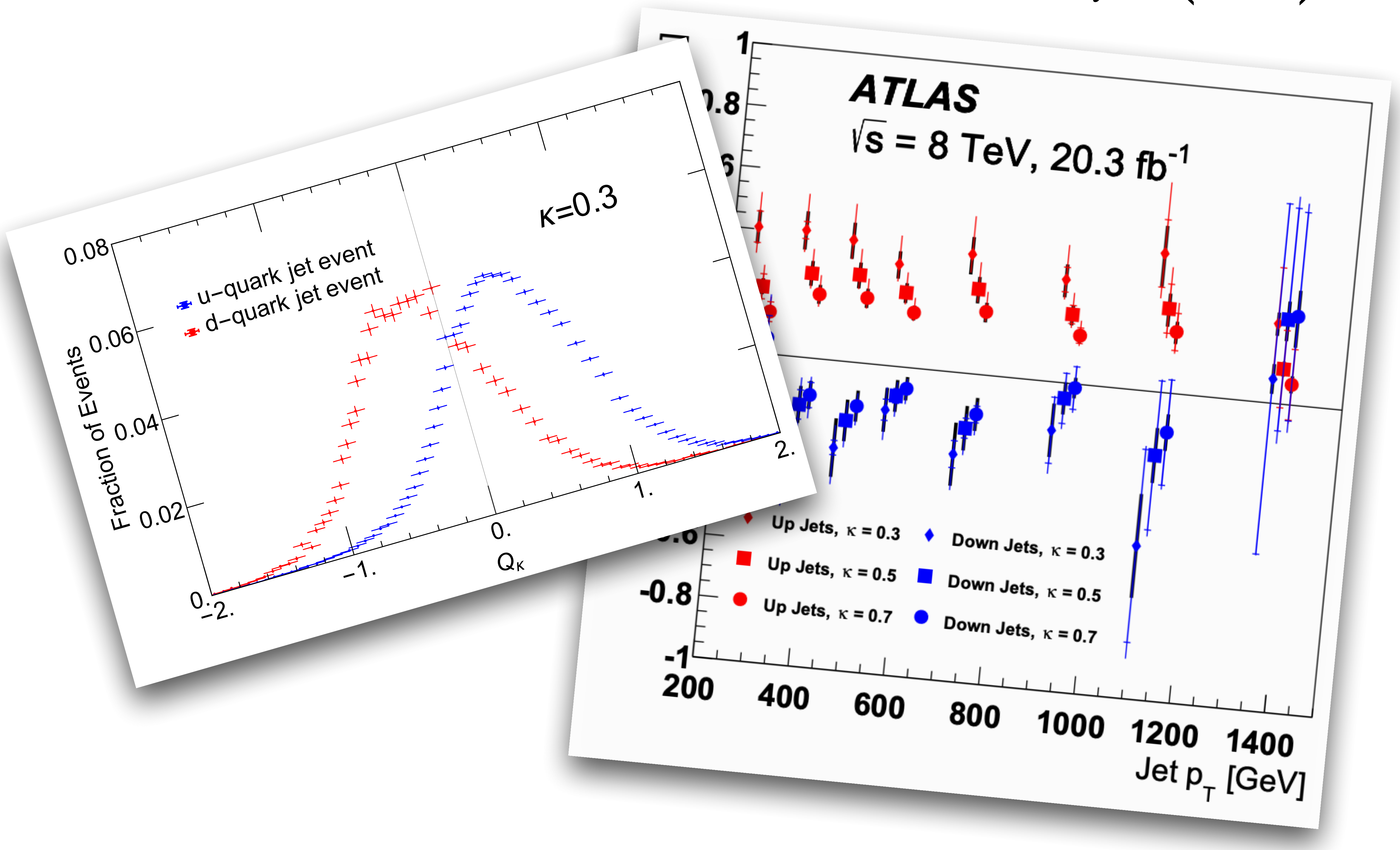
- $\kappa = 0.3$ seems to have the largest separation
- (Almost) independent of the jet pT



The ATLAS Collaboration, 2015

Jet charge as a flavor prism @ EIC

- The observable $Q_\kappa = \sum_i \left(\frac{p_{i,T}}{p_J}\right)^\kappa Q_i$



- The sign of the jet charge is largely inherited from the initiating parton, robust against the hadronization,
- Very good u- and d-quark separation by dividing events into different charge bins

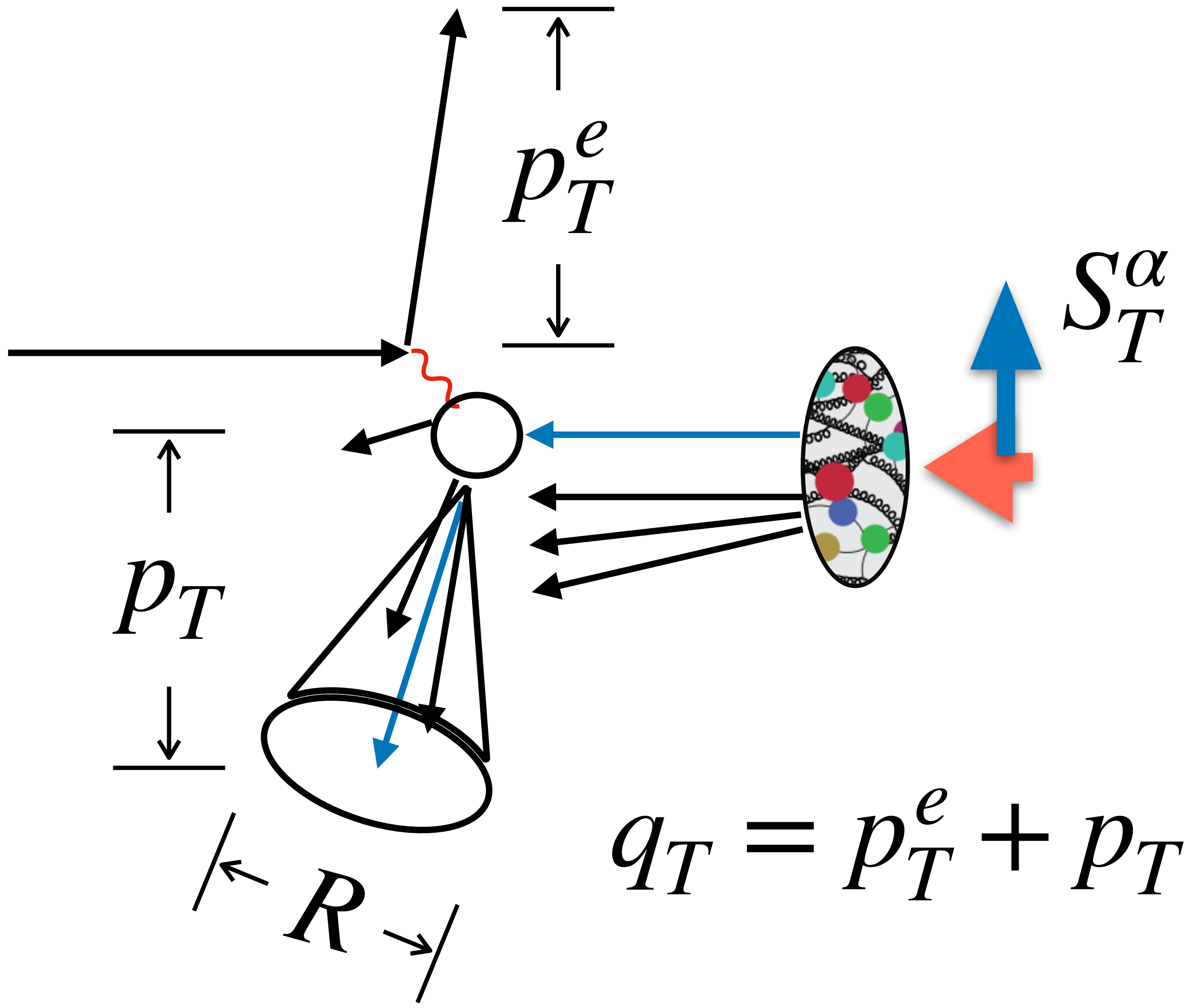
Jet charge as a flavor prism @ EIC

- The factorization Kang, XL, Mantry, Shao, 2020

$$\frac{d^5\sigma^i_{UT}(S_\perp)}{dy_e d^2p^e_T d^2q_T} = e_i^2\sigma_0\epsilon_{\alpha\beta}S^\alpha_\perp \int \frac{db_T^2}{(2\pi)^2} e^{iq_T\cdot b_T}\tilde{W}^\beta_{T,i}$$

$$\tilde{W}^\beta_{T,i} = H(Q)\tilde{f}^{\perp,\beta}_{1T,i}(x,b_T)S_J(b_T,R)\mathcal{J}_i(p_TR)$$

W/O the jet charge observation XL, Ringer, Vogelsang, Yuan, 19



Jet charge as a flavor prism @ EIC

- The factorization Kang, XL, Mantry, Shao, 2020

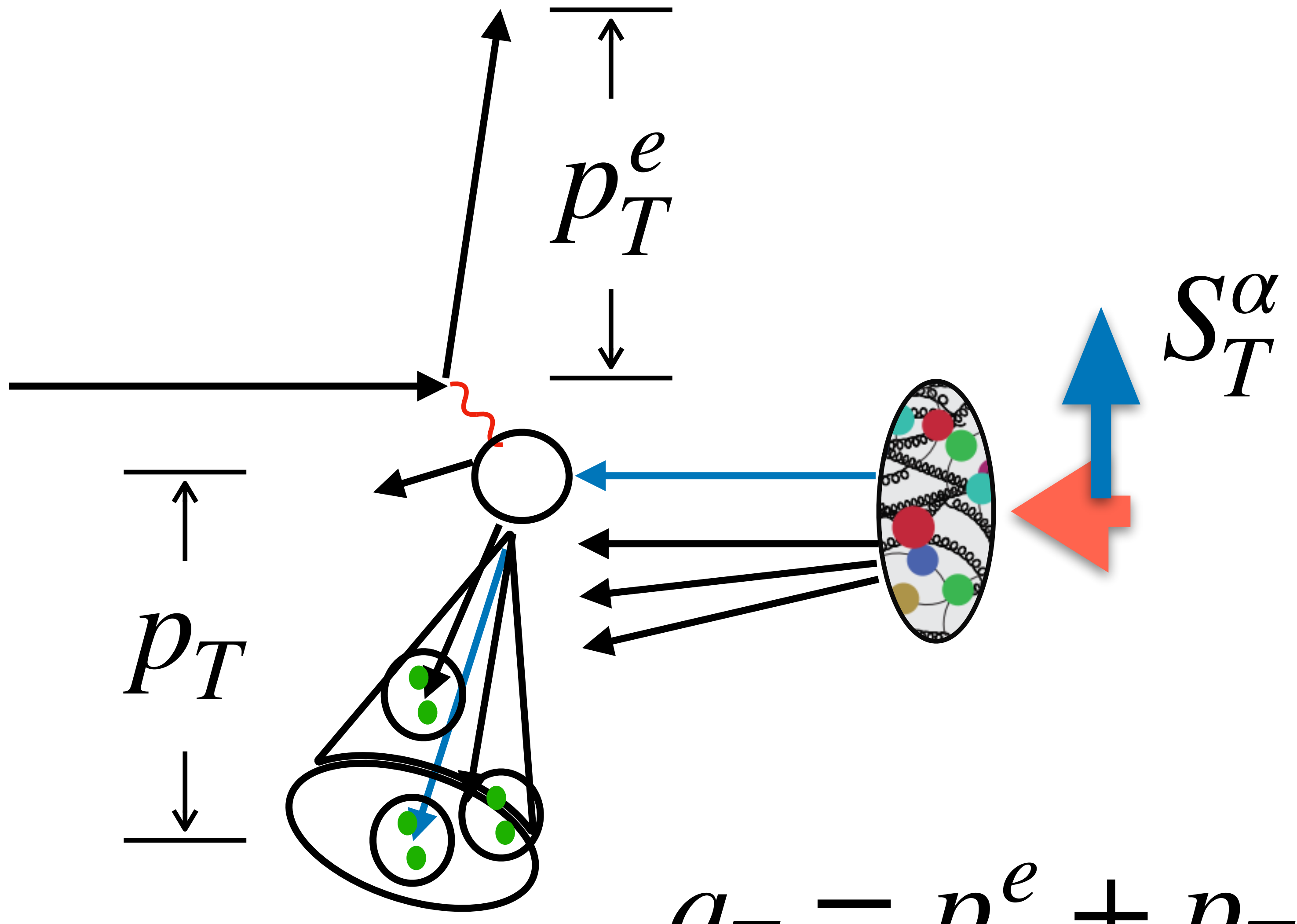
$$\frac{d^6\sigma^i_{UT}(S_\perp)}{dy_e d^2p^e_T d^2q_T dQ_\kappa} = e_i^2\sigma_0\epsilon_{\alpha\beta}S^\alpha_\perp\int\frac{db^2_T}{(2\pi)^2}e^{iq_T\cdot b_T}\tilde{V}^\beta_{T,i}$$

$$\tilde{V}^\beta_{T,i} = H(Q)\tilde{f}^{\perp,\beta}_{1T,i}(x,b_T)S_J(b_T,R)\mathcal{G}_i(Q_\kappa,p_TR)$$

See also Krohn, et. al, 2013 for unpolarized pp

$$\rightarrow \tilde{f}^{\perp,\beta}_{1T,i}(x,b_T)S_J(b_T,R)H(Q)\mathcal{J}_i(p_TR)\frac{\mathcal{G}_i(Q_\kappa,p_TR)}{\mathcal{J}_i(p_TR)}$$

$$\rightarrow W_i\frac{\mathcal{G}_i(Q_\kappa,p_TR)}{\mathcal{J}_i(p_TR)}$$



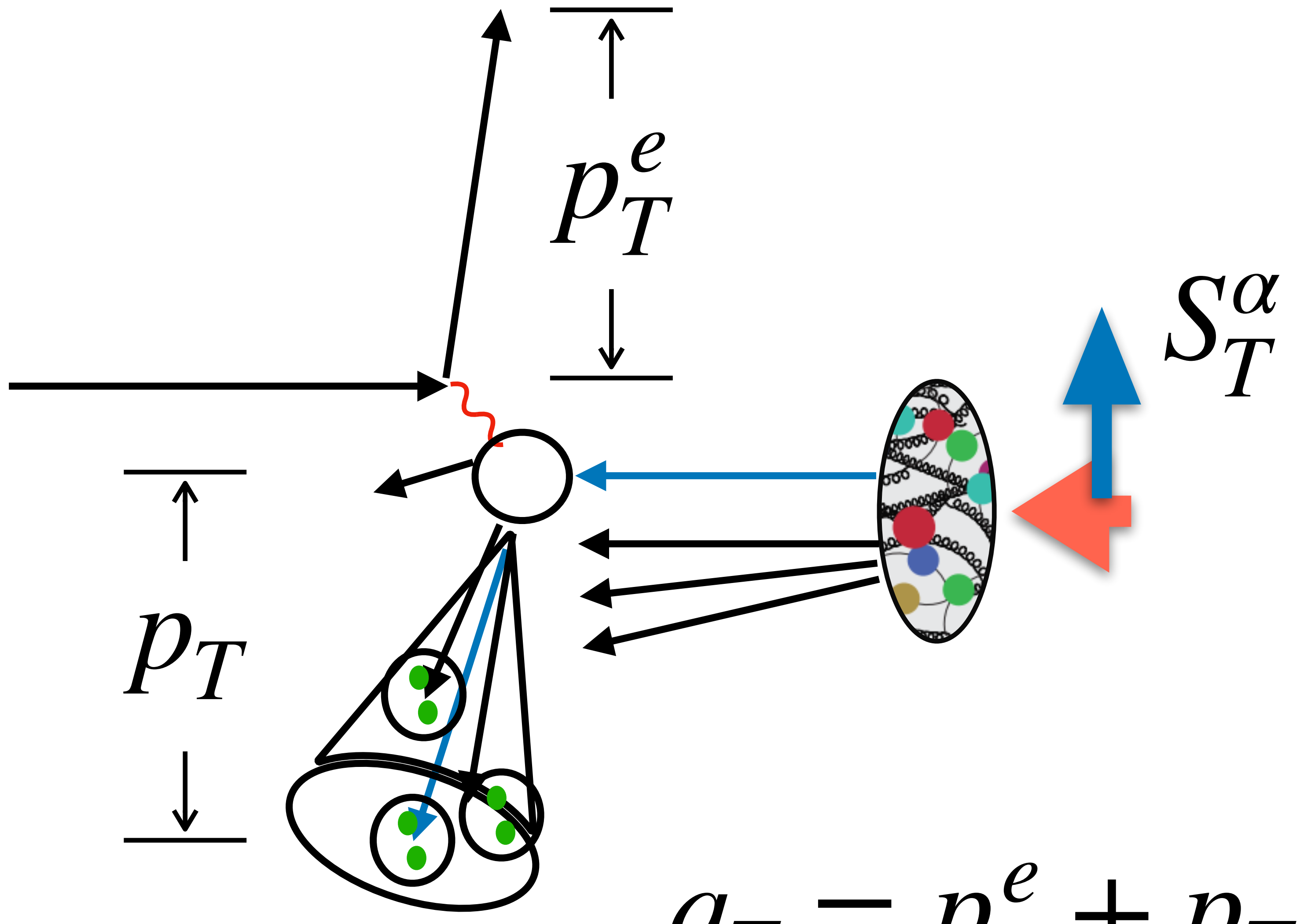
$$q_T = p^e_T + p_T$$

$$Q_\kappa = \sum_i\left(\frac{p_{i,T}}{p_J}\right)^\kappa Q_i$$

Jet charge as a flavor prism @ EIC

- The factorization Kang, XL, Mantry, Shao, 2020

$$\frac{d^6\sigma^i_{UT}(S_\perp)}{dy_e d^2p^e_T d^2q_T dQ_\kappa} = \frac{d^5\sigma^i_{UT}(S_\perp)}{dy_e d^2p^e_T d^2q_T}\frac{\mathcal{G}_i}{\mathcal{J}_i}$$



$$\tilde{V}^\beta_{T,i} = H(Q)\tilde{f}^{\perp,\beta}_{1T,i}(x,b_T)S_J(b_T,R)\mathcal{G}_i(Q_\kappa,p_TR)$$

$$q_T = p_T^e + p_T$$

See also Krohn, et. al, 2013 for unpolarized pp

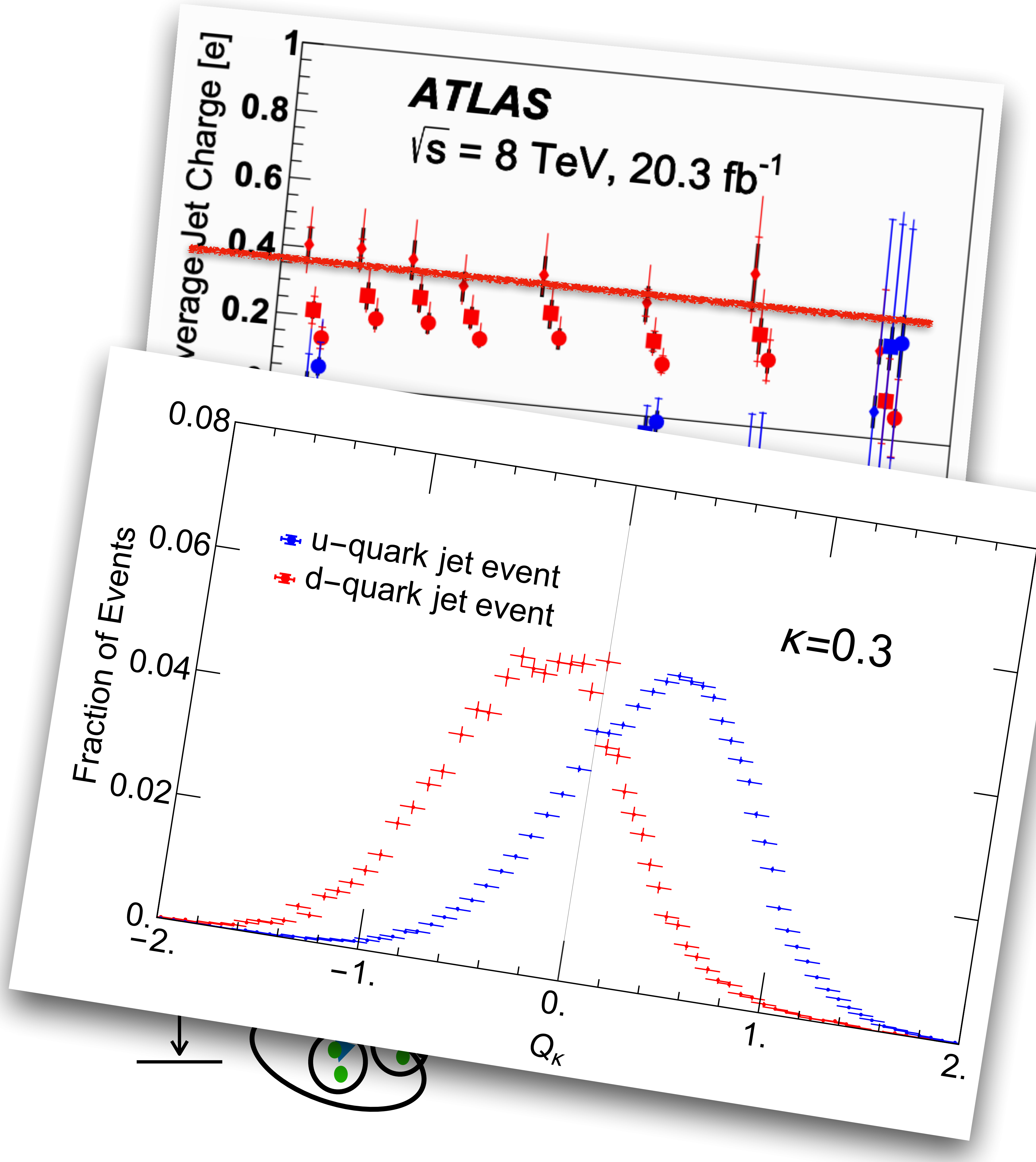
$$Q_\kappa = \sum_i \left(\frac{p_{i,T}}{p_J}\right)^\kappa Q_i$$

$$\to \tilde{f}^{\perp,\beta}_{1T,i}(x,b_T)S_J(b_T,R)H(Q)\mathcal{J}_i(p_TR)\frac{\mathcal{G}_i(Q_\kappa,p_TR)}{\mathcal{J}_i(p_TR)}$$

$$\to W_i\frac{\mathcal{G}_i(Q_\kappa,p_TR)}{\mathcal{J}_i(p_TR)}$$

$$\int Q_\kappa \frac{\mathcal{G}_i(Q_\kappa,p_TR)}{\mathcal{J}_i(p_TR)} = 1$$

Jet charge as a flavor prism @ EIC



- The factorization Kang, XL, Mantry, Shao, 2020

$$\frac{d^5\sigma_{UT}(S_\perp)}{dy_e d^2p_T^e d^2q_T} = \sum_{i=u,d,\cdots} \int_{Q_\kappa \in \text{bin}} dQ_\kappa \frac{\mathcal{G}_i(Q_\kappa, p_T R)}{\mathcal{J}_i(p_T R)} \frac{d^5\sigma^i_{UT}(S_\perp)}{dy_e d^2p_T^e d^2q_T}$$

$$= \sum_{i=u,d,\cdots} r_i \frac{d^5\sigma^i_{UT}(S_\perp)}{dy_e d^2p_T^e d^2q_T}$$

r_i the event fraction in a given charge bin

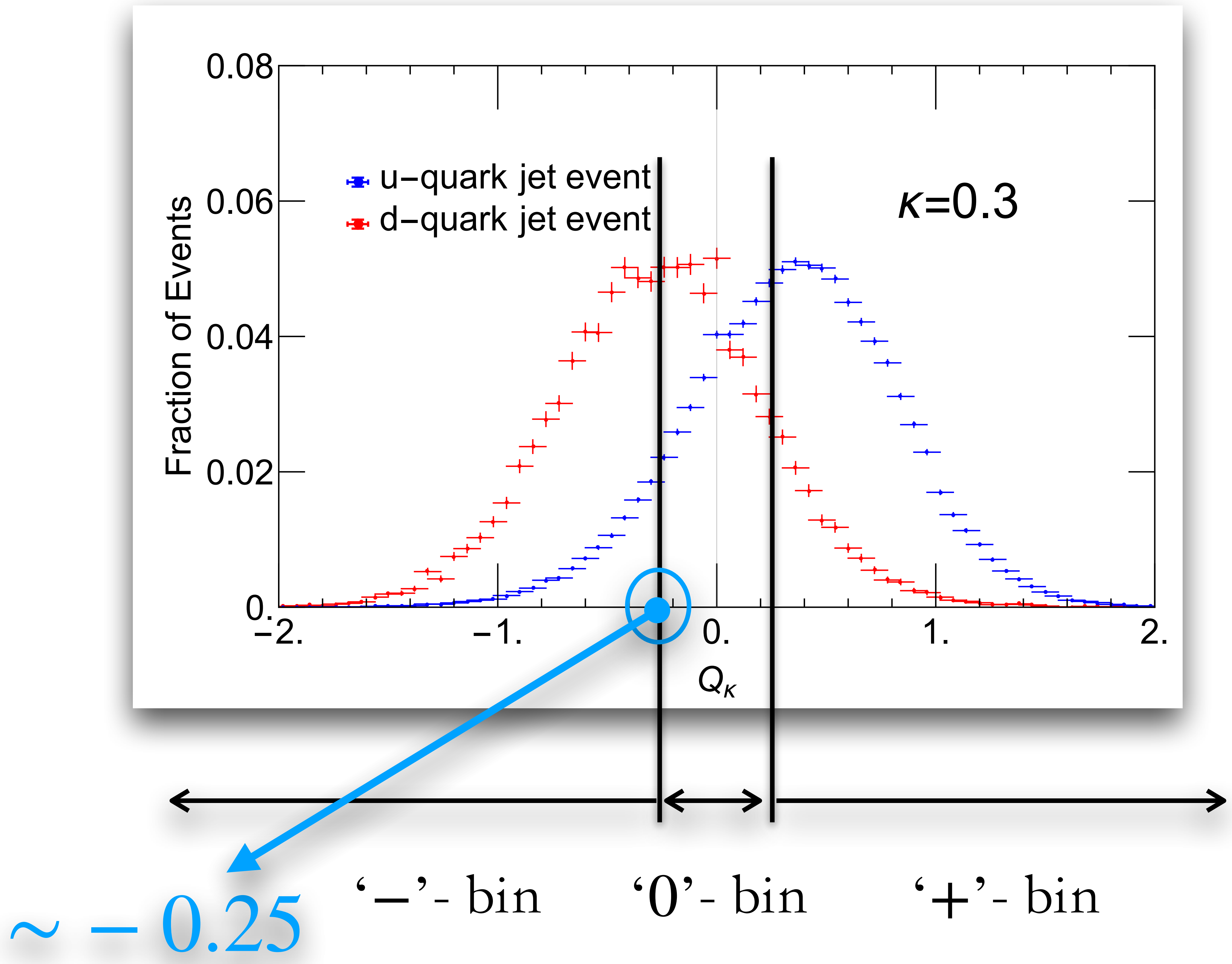
- A non-perturbative number
- Scale independent
- mild $p_T R$ dependence via loops, small for small κ
- Universal, similar to the NRQCD quarkonium matrix element; with flavor symmetry

$$\int Q_\kappa \frac{\mathcal{G}_i(Q_\kappa, p_T R)}{\mathcal{J}_i(p_T R)} = 1 \quad \rightarrow \quad \sum_{\text{bin}} r_i = 1$$

By choosing the charge bin, we can control the sensitivity to different quark flavors

Jet charge as a flavor prism @ EIC

- As a flavor prism Kang, XL, Mantry, Shao, 2020, see also STAR collaboration



	u	$\bar{u}$	d	$\bar{d}$	s	$\bar{s}$
$r_{i,+}$	0.52	0.17	0.15	0.53	0.30	0.34
$r_{i,-}$	0.15	0.49	0.52	0.15	0.36	0.32
$r_{i,0}$	0.33	0.35	0.33	0.32	0.35	0.34

$$Q_\kappa = \sum_i \left(\frac{p_{i,T}}{p_J}\right)^\kappa Q_i$$

choose $\kappa = 0.3$, large separation

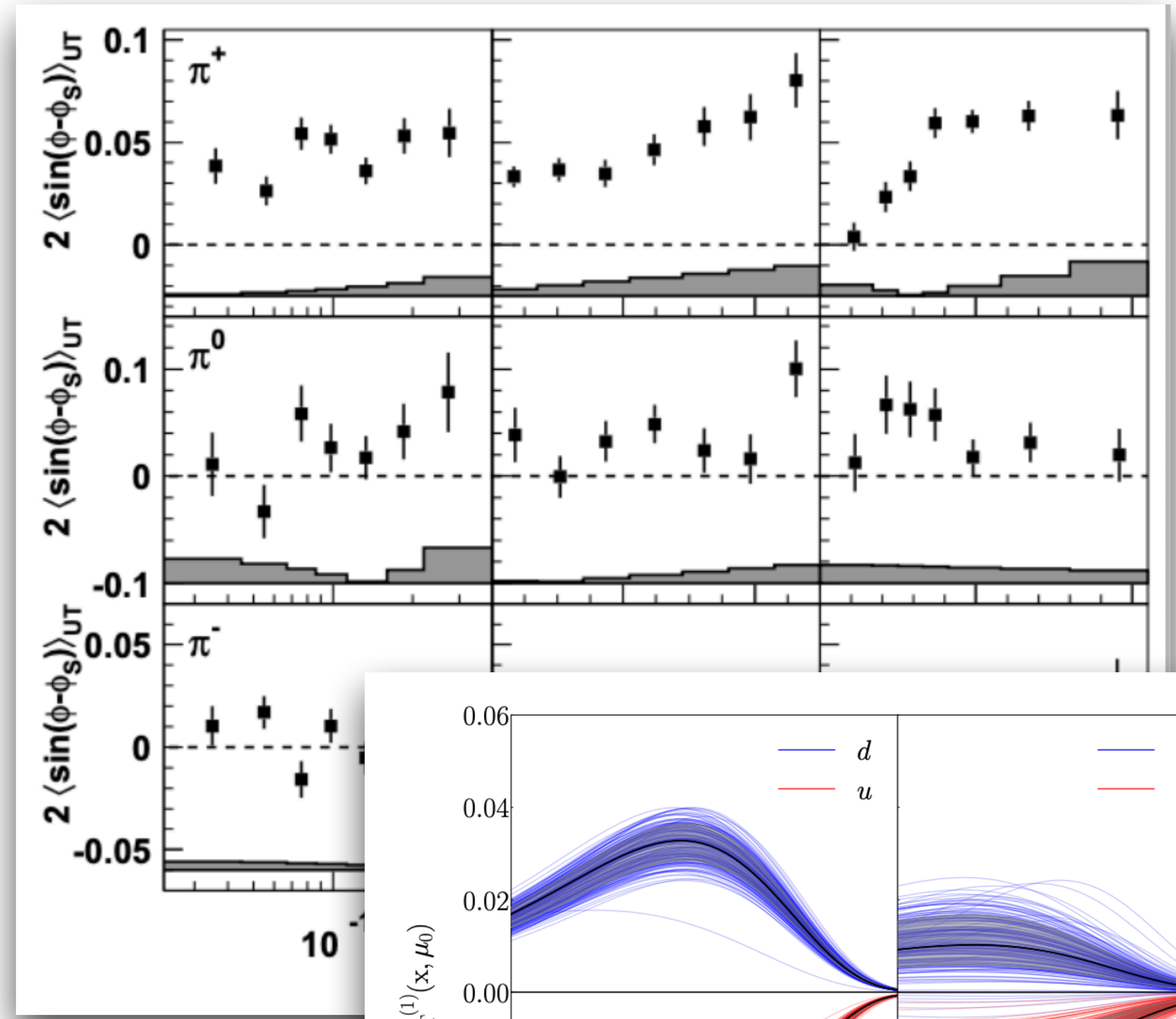
choose π's in this study
"π"-jet

- Obvious flavor symmetries
- Expect enhancement of the d quark in the −-bin
- Expect enhancement of the s quark if the kaon component used

Jet charge as a flavor prism @ EIC

- As a flavor prism

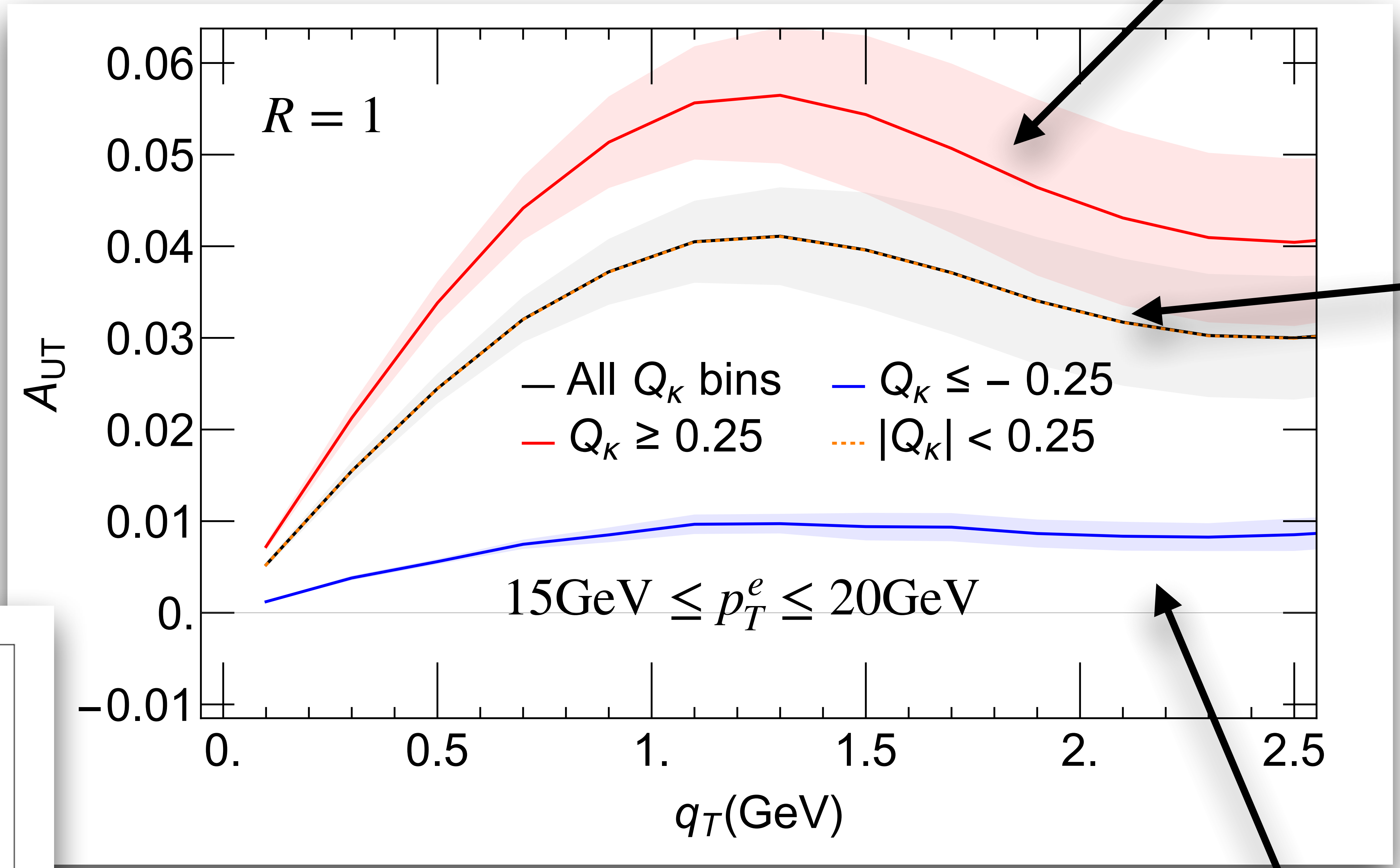
Kang, XL, Mantry, Shao, 2020, see also STAR collaboration



$\sqrt{s} = 105\text{GeV}$,

$Q^2 \geq 10\text{GeV}^2$,

$0.1 \leq y \leq 0.9$

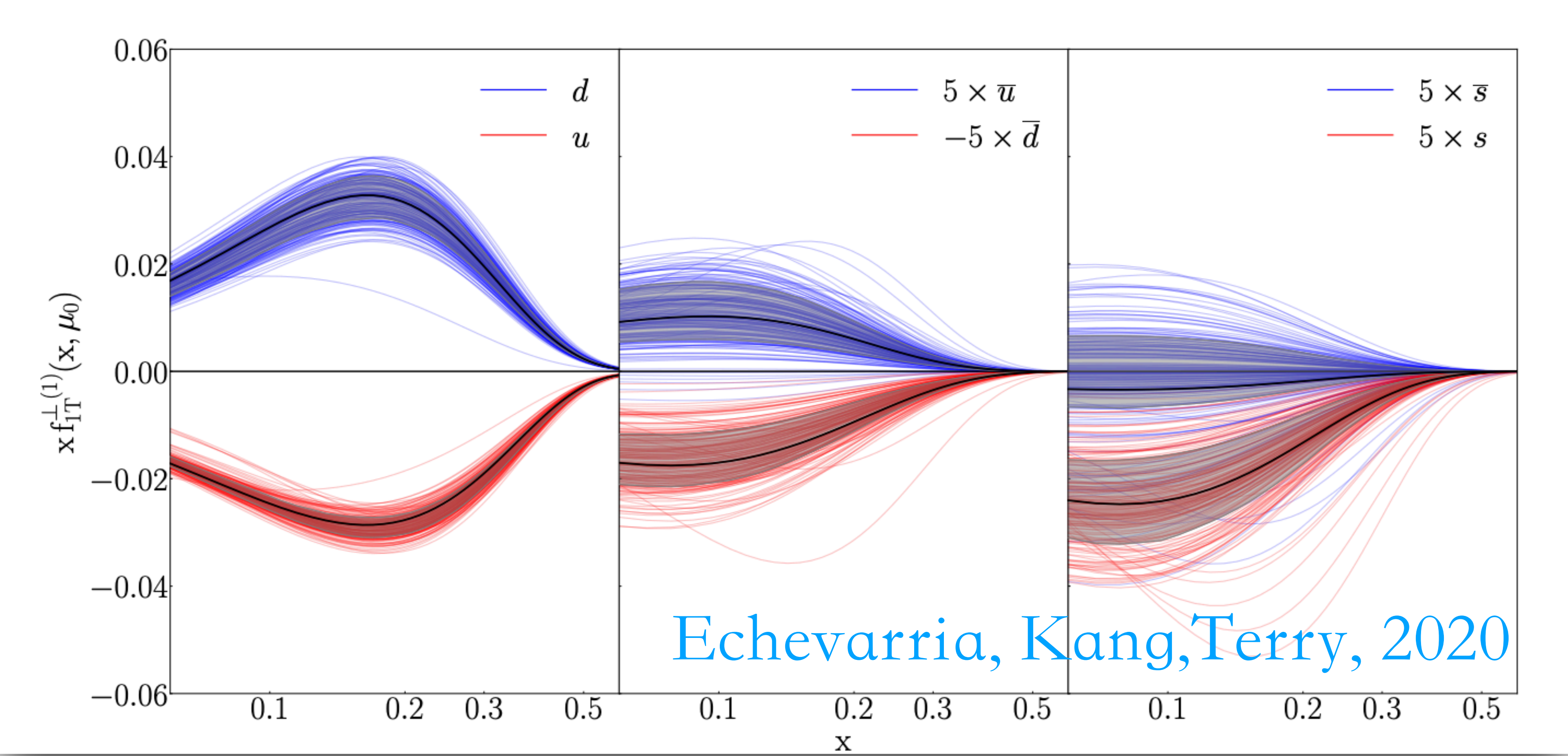


u-quark enhanced

u-quark dominant due to its charge

d-quark dominant

Cancellation between u and d



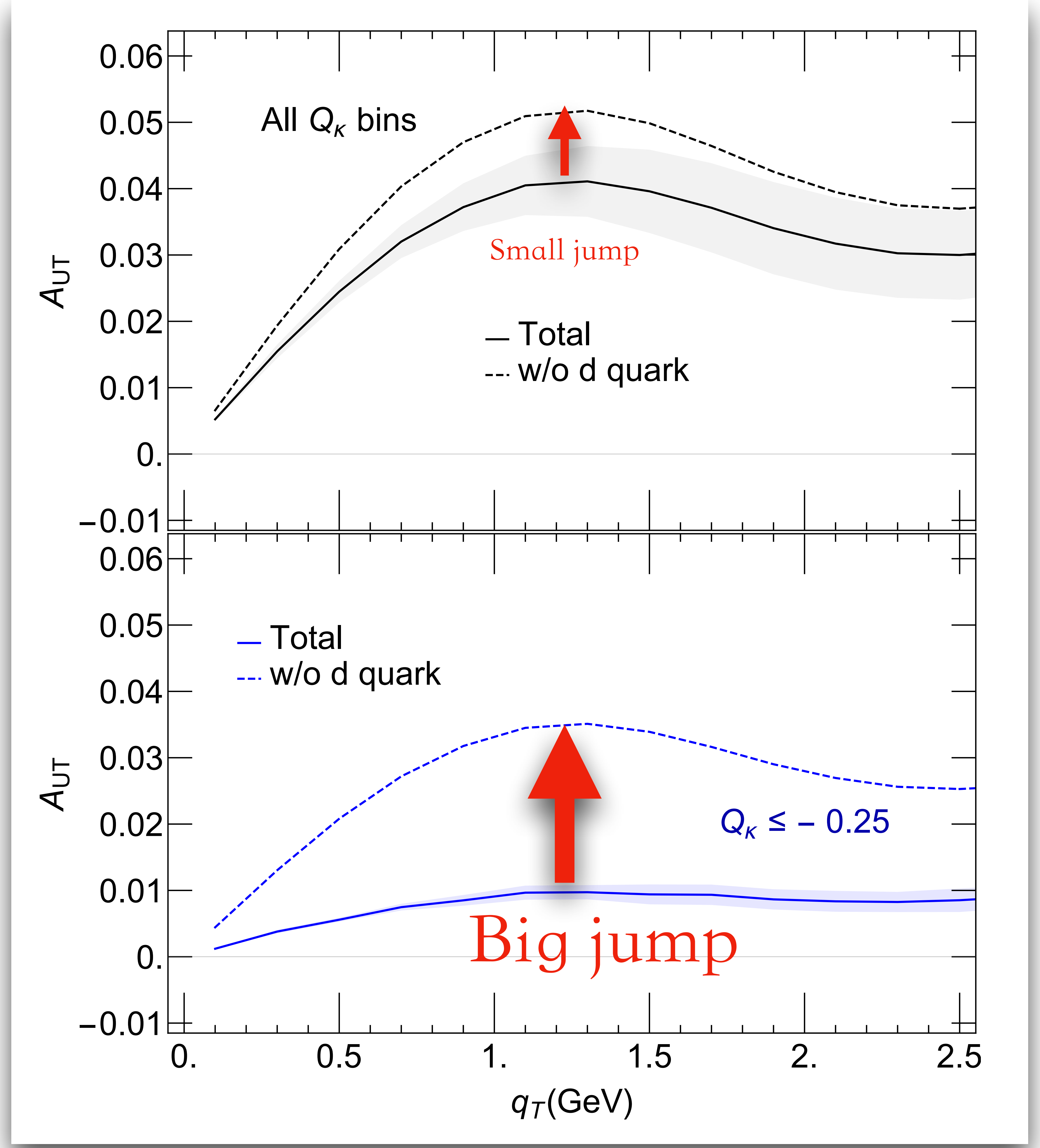
Very similar behavior as SIDIS, map out the pion component of the jet

Jet charge as a flavor prism @ EIC

- As a flavor prism

Kang, XL, Mantry, Shao, 2020, see also STAR collaboration

Dramatically improved sensitivity to the d quark in the negative charge bin



Conclusions

- The jet charge is sensitive to the parton species
- Maps out flavors; maps a specific hadron component of the jet
- Demonstrate its power in the flavor separation
- Expect to have applications in all hadron structure studies at EIC and other colliders

Happy HOLIDAYS