One Point Charge Correlation in deep-inelastic scattering

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H.C., Liu, Petriello, arXiv:2605.15280
H.C., Petriello, coming soon

Light Cone, June 23, 2026

Outline

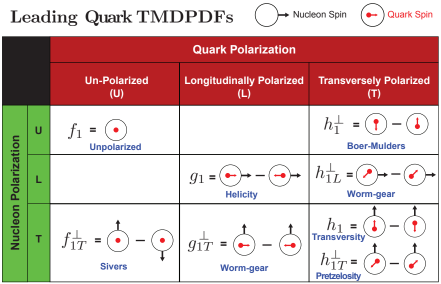
1. The concept and features of the one point charge correlation

2. Numerical result

3. Conclusion and Outlook

Outline

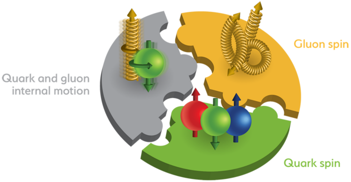
Proton Structure



[Boussarie et al.](2023)

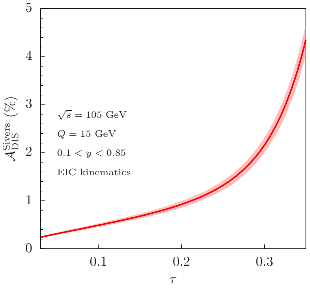
Major focus of the EicC, EIC

...



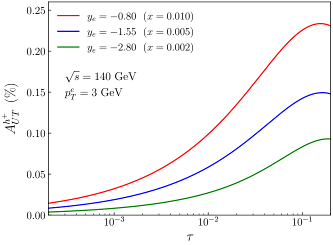
Energy Correlator(EC) in DIS

Energy correlators in DIS[Li, Makris, Vitev](2021) measures angular patterns in the flow of final-state energy.
It has been used as a probe of the Sivers function



EC Sivers asymmetry in DIS

[Kang, Lee, Shao, Zhao] (2023)

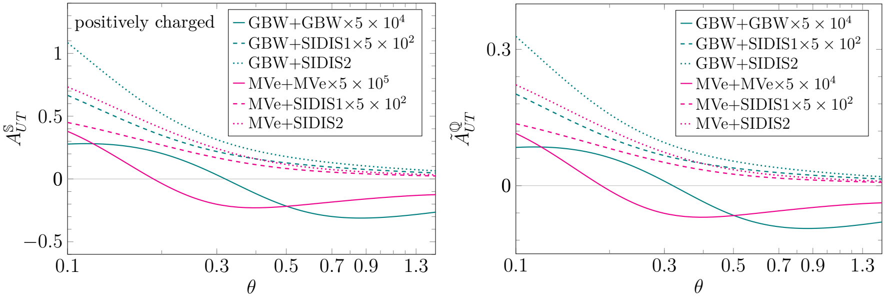


TEEC Sivers asymmetry in the Small-x Regime

[Bhattacharya, Kang, Padilla, Penttala](2025)

Nucleon Energy Correlator in DIS

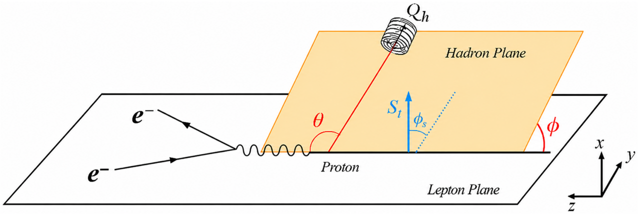
The nucleon energy correlator (NEC)[Liu, Zhu](2023) describes the physics in the forward region. Studying the Sivers Asymmetry of NEC can help us study the odderon.



[Mäntysaari, Tawabutr, Tong](2025)

A subset in the hadron is needed.

Definition of Charge Correlation

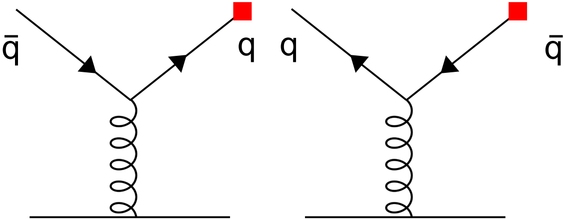


Measurement in DIS

$$\Sigma(\vec{n}, x_B, Q^2) = \sum_h \int d\sigma_{ep^\uparrow \to eh+X}\, Q_h\, \delta(\vec{n} - \vec{n}_h)$$

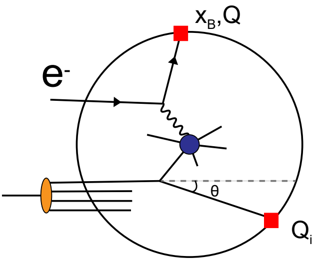
Only need charge and angular directions of charged tracks , no jet/hadrons, no energy

Physics of QC

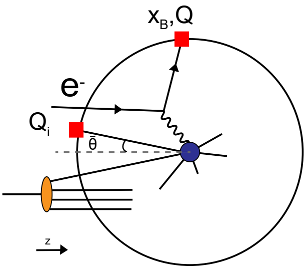


The charge conservation ensures that the resulting contribution to the QC vanishes upon summing over q and $\bar{q}$ [Monni, Vita, Xu, Zhu](2025)

TMD region and Target Fragmentation Region



In TFR $\theta \ll 1$

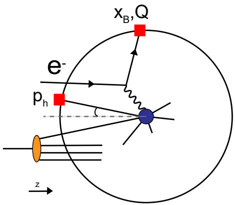


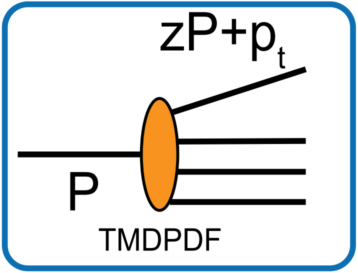
In TMD region $\bar{\theta} = \pi - \theta \ll 1$

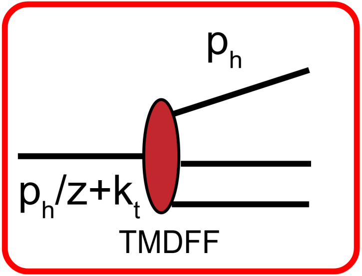
Factorization in TMD region

I. SIDIS

$$d\sigma_{un} = H\, f_q \otimes S \otimes D_{h/q}$$







Factorization in TMD region

I. SIDIS

$$d\sigma_{un} = H \boxed{f_q} \otimes S \otimes \boxed{D_{h/q}}$$

II. Charge Correlators

$$\Sigma_{un} = \sum_h Q_h \int d\sigma_{un}\, \delta(\vec{n} - \vec{n}_h)$$

$$\Sigma_{un} = H \boxed{f_q} \otimes S \otimes \boxed{J_q}$$

$$J_q(k_t) \equiv \sum_a \int_0^1 dz\, Q_a D_{a/f}(z, k_t)$$

$$J_q = -J_{\bar{q}}$$

$$J_q = \sum_{h,i} \int dz_h Q_h \int_{z_h}^1 \frac{dz}{z} D_{h/i}\left(\frac{z_h}{z}\right) \times \mathcal{I}_{i/q}(z, k_t)$$

$$= \sum_{h,i} \int dz_h Q_h D_{h/i}(z_h) \int dz \mathcal{I}_{i/f}(z, k_t)$$

$$= \sum_i \int dz\, Q_i\, \mathcal{I}_{i/q}(z, k_t)$$

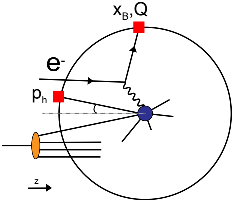
QC jet functions known up to N^{4}LO[Monni, Vita, Xu, Zhu](2025)

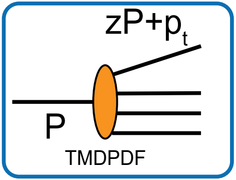
I. SIDIS

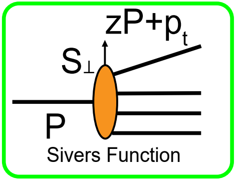
$$d\sigma_{pol} = F_{UU} + |S_\perp| \sin(\phi - \phi_S)\, F_{UT}^{\sin(\phi-\phi_S)}$$

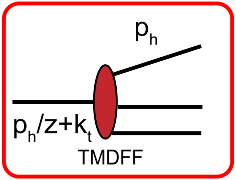
$$F_{UU} = H\, \boxed{f_q} \otimes S \otimes \boxed{D_{h/q}}$$

$$F_{UT} = H\, \boxed{f_{1T,q}^{\perp}} \otimes S \otimes \boxed{D_{h/q}}$$









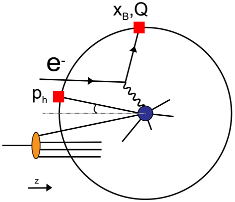
Factorization in TMD region

I. SIDIS

$$d\sigma_{pol} = F_{UU} + |S_\perp| \sin(\phi - \phi_S)\, F_{UT}^{\sin(\phi-\phi_S)}$$

$$F_{UU} = H\, \boxed{f_q} \otimes S \otimes \boxed{D_{h/q}}$$

$$F_{UT} = H\, \boxed{f_{1T,q}^{\perp}} \otimes S \otimes \boxed{D_{h/q}}$$



II. Charge Correlators

$$\Sigma_{pol} = \sum_h Q_h \int d\sigma_{pol}\, \delta(\vec{n} - \vec{n}_h)$$

$$\Sigma_{pol} = \Sigma_{UU} + |S_\perp| \sin(\phi - \phi_S)\, \Sigma_{UT}^{\sin(\phi-\phi_S)}$$

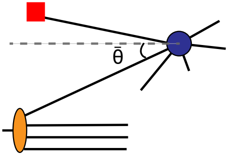
$$\Sigma_{UU} = H\, \boxed{f_q} \otimes S \otimes \boxed{J_q}$$

$$\Sigma_{UT} = H\, \boxed{f_{1T,q}^{\perp}} \otimes S \otimes \boxed{J_q}$$

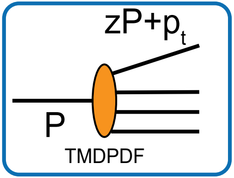
$$A^{\text{Sivers}}(\theta) = \frac{\Sigma_{UT}(\theta)}{\Sigma_{UU}(\theta)}$$

Transverse Moment Dependent PDFs

$$d\sigma_{un} = H \boxed{f_q} \otimes S \otimes D_{h/q}$$



- Major tool for structure studies
- Extra non-perturbative object



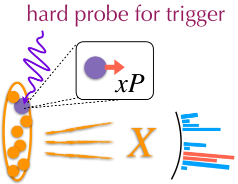
Operator Definition of Nucleon Charge Correlator

To Describe the distribution in TFR, we follow the procedure in Nucleon Energy Correlator[Liu,Zhu](2023) and define the Nucleon Charge Correlator

$$f_{q,\mathrm{QC}}(x,\vec{n}) = \int \frac{dy^-}{4\pi} e^{-ixP^+\frac{y^-}{2}} \langle P|\bar{\chi}_n\left(\frac{y^-}{2}n^\mu\right)\frac{\gamma^+}{2}\hat{\mathcal{Q}}(\vec{n})\chi_n(0)|P\rangle$$

$$\mathcal{Q}(\vec{n}) = \lim_{r\to\infty} r^2 \int_{-\infty}^{\infty} dt\, n^i\, J_i(t, r\vec{n})$$

- Charge correlator in the forward region
- Purely collinear object, insensitive to soft radiations



Factorization in TFR

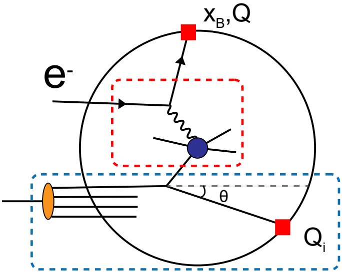
When $\theta \ll 1$

$$\Sigma(\theta) = \sum_{i=q,g} \int \frac{dz}{z} \hat{\sigma}_i \left(\frac{x_B}{z}, Q^2 \right) f_{i,\mathrm{QC}}(z, \theta)$$

This is a DIS type factorization.

The Nucleon Charge Correlators satisfy the DGLAP equation as PDF.

Comparing with NEC in a charged subset, QC don't need to consider energy and expect to get lower uncertainty.



Sivers Asymmetry in TFR

In the TFR, The distribution for polarized proton have the form

$$\Sigma = \Sigma_{UU} + |S_\perp| \sin(\phi - \phi_S) \Sigma_{UT}^{\sin(\phi - \phi_S)}$$

The $\sin(\phi - \phi_S)$ dependent part can be factorized similarly as the unpolarized distribution with the replacement of $f_{q,\mathrm{QC}}$ by $f_{1T,q,\mathrm{QC}}$

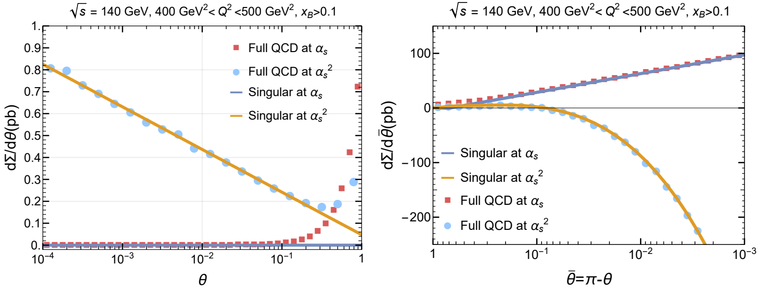
The Sivers-like QC induces a $\sin(\phi - \phi_S)$ azimuthal asymmetry:

$$A^{Sivers} = \frac{\Sigma(S_T) - \Sigma(-S_T)}{\Sigma(S_T) + \Sigma(-S_T)}$$

The prediction relies on the non-perturbative input of the $f_{1T,q,\mathrm{QC}}$ which requires further studies in the future.

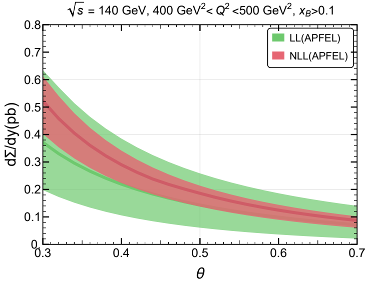
Outline

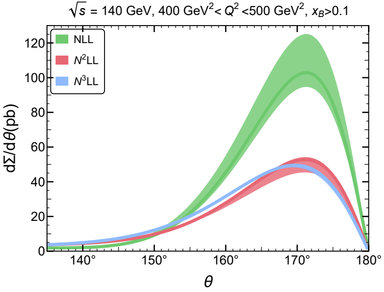
Validity of SCET



The two calculations agree very well in TMD region and TFR.
Potentially dangerous soft gluon splitting $g \to q\bar{q}$ singular contribution cancels after the charge-conjugate integration.

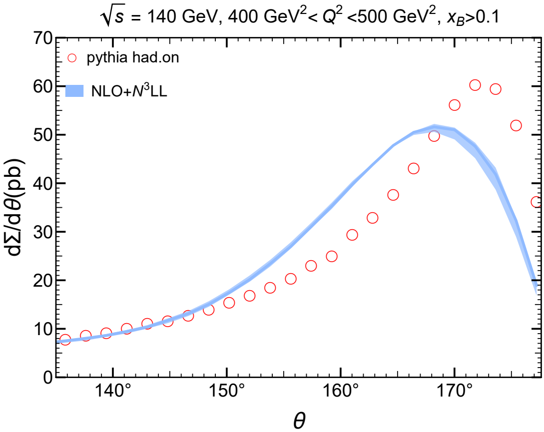
Resummation





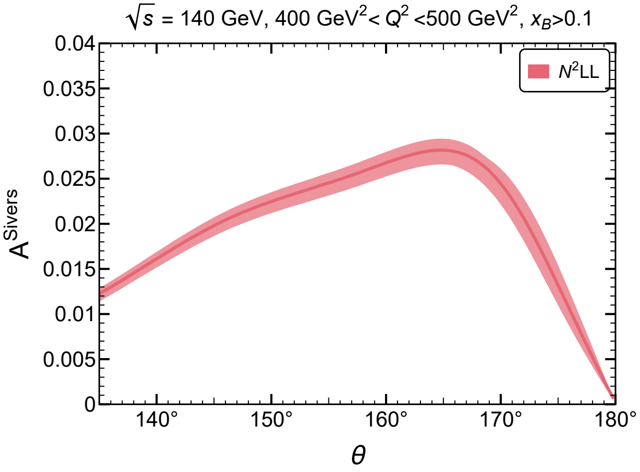
The perturbative series stabilizes as the logarithmic accuracy is increased, and the scale uncertainty is correspondingly reduced

Resummation



The resummed result accounting for the effects of large logarithms to all orders correctly captures the behavior of PYTHIA in this region.

Sivers Asymmetry



The QC probe predicts a sizeable Sivers asymmetry.

Outline

Conclusions

(1) The charge correction is introduced.

(2) Factorization in both TFR and TMD region is introduced.

(3) The charge correction could be used to probe Sivers function.

(4) The logic of the QC is more broadly applicable to other similar observables.

Outlook

The relation between Nucleon QC and fracture function?

Probing Odderon with QC?

Hadron-in-jet measurements?

Thank You!

Backup

To calculate the TFR result, we are actually using

$$\Sigma(\theta,\phi) = \sum_i \int d\sigma_{ep\to e+i+X}\, Q_i\, \Theta(\theta-\theta_i)\delta(\phi-\phi_i)$$

and taking derivative.
When $\theta Q \gg \Lambda_{QCD}$ have α_s^0 level contribution from $\mathrm{SCET}_{\mathrm{II}}$ region and have
$f^{(0)}_{i,\mathrm{QC}}(z,\theta) = (Q_P - Q_i) f(z)$

Backup

In the TMD region

$$\frac{d\Sigma_{UT}^{\sin(\phi_h-\phi_s)}(\theta)}{d\theta} = \sigma_0 H(Q^2,\mu)\sum_f Q_f^2 \int \mathbf{q}_T d\mathbf{q}_T \int_0^\infty \frac{b^2\,db}{4\pi} J_1\left(b|\mathbf{q}_T|\right) \times f_{1T,f/p}(x_B,b,\mu,\nu) S(b,\mu,\nu) J_{f,\mathsf{QC}}(b,\mu,\nu)\delta\left(\frac{2|\mathbf{q}_T|}{Q}-\bar{\theta}\right)$$

$$\frac{d\Sigma(\theta)}{d\theta} = H(Q^2,\mu_H)\sum_f Q_f^2 \int d^2\mathbf{q}_T \frac{d^2\mathbf{b}}{(2\pi)^2} \times \exp[-i\mathbf{q}_T\cdot\mathbf{b}] U_{tot} B_{f/p}(x_B,b,\mu_B,\nu_B) \times S(b,\mu_S,\nu_S) J_{f,\mathsf{Q}}(b,\mu_J,\nu_J)\delta\left(\frac{2|\mathbf{q}_T|}{Q}-\bar{\theta}\right)$$

Backup

$$\Sigma = Q_q \int \frac{d^3p_q}{p_q^0}\frac{d^3p_{q'}}{p_{\bar{q}'}^0}\frac{d^3p_{\bar{q}'}}{p_{\bar{q}'}^0}\delta^4(p+q-p_q-p_{q'}-q_{\bar{q}'})\delta(\theta-\theta_q)|M_{\gamma q\to qq'\bar{q}'}|^2$$
$$+ Q_{q'} \int \frac{d^3p_q}{p_q^0}\frac{d^3p_{q'}}{p_{\bar{q}'}^0}\frac{d^3p_{\bar{q}'}}{p_{\bar{q}'}^0}\delta^4(p+q-p_q-p_{q'}-q_{\bar{q}'})\delta(\theta-\theta_{q'})|M_{\gamma q\to qq'\bar{q}'}|^2$$
$$- Q_{q'} \int \frac{d^3p_q}{p_q^0}\frac{d^3p_{q'}}{p_{\bar{q}'}^0}\frac{d^3p_{\bar{q}'}}{p_{\bar{q}'}^0}\delta^4(p+q-p_q-p_{q'}-q_{\bar{q}'})\delta(\theta-\theta_{\bar{q}'})|M_{\gamma q\to qq'\bar{q}'}|^2$$

When q is hard ,q' and $\bar{q}'$ are soft, from Eq.95 in hep-ph/9908523

$$|M_{\gamma q\to qq'\bar{q}'}|^2 \sim (4\pi\mu^{2\epsilon}\alpha_s)^2 T_R \sum_{i,j} |M_{\gamma q\to q}|^2_{ij}\Gamma^{ij}(p_{q'}, p_{\bar{q}'})$$