Transverse Single Spin Asymmetries for Drell-Yan production

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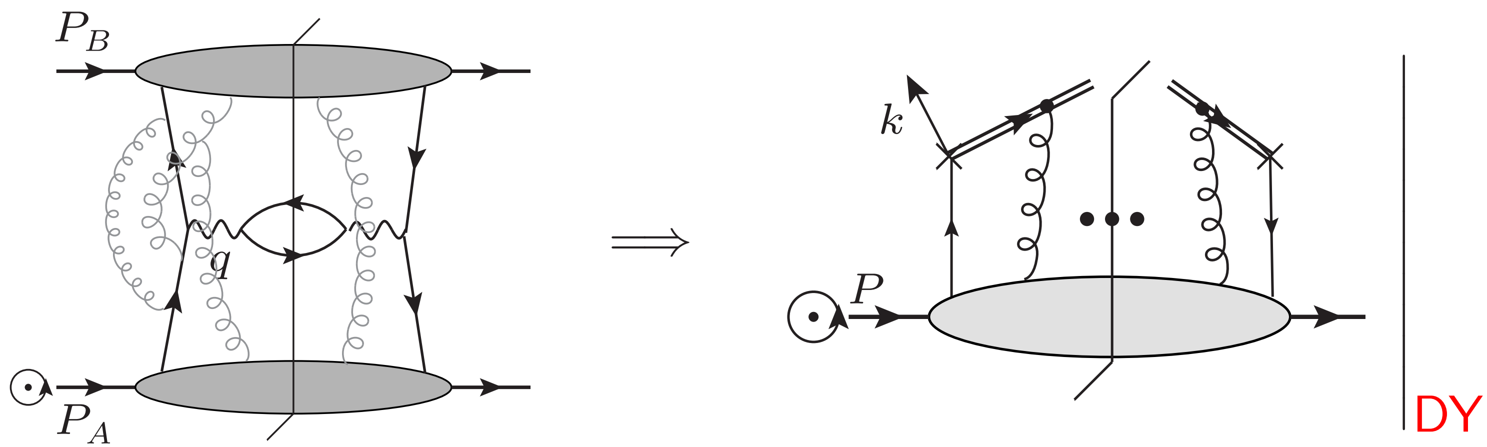
Abstract

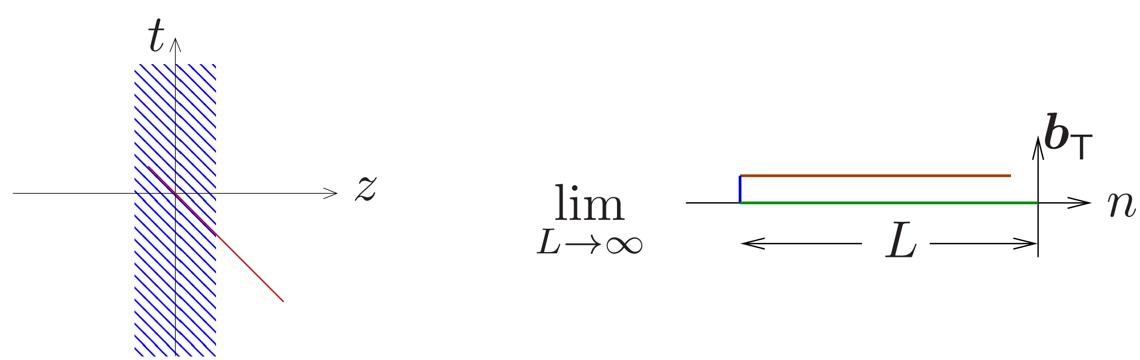
I review the arguments for the importance of measuring transverse single spin asymmetries for the Drell-Yan process. On the theory side, key elements of factorization are Wilson lines in the definition of parton densities; these correspond to partonic color flows relative to a hard scattering. The appropriate choice of the Wilson line directions manifests itself in a testable way in the predicted change in sign of Sivers function between SIDIS and DY.

If experiments find that this prediction fails, and this finding survives close scrutiny, we would have to reconsider our understanding of QCD hard scattering.

Drell-Yan has different pdfs



with past-pointing WLs:



(Need cancellation of f.s.i.; *inclusive* Drell-Yan only.)
(Proof of TMD factorization — JCC's "Foundations of perturbative QCD".)

Experimentally accessible consequence of WL: Sign change of Sivers function

Relate pdfs in SIDIS and DY by TP transformation

Changes:

- Wilson lines:

$$\text{Future-pointing for SIDIS pdfs} \quad \overset{TP}{\Longleftrightarrow} \quad \text{past-pointing for DY pdfs}$$

- States:

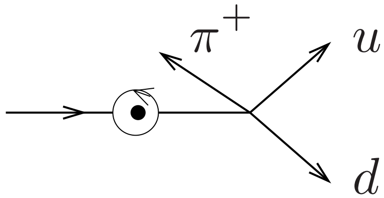
$$|\mathbf{P}, \boldsymbol{s}_{\mathsf{T}}\rangle \quad \overset{P}{\Longleftrightarrow} \quad |-\mathbf{P}, \boldsymbol{s}_{\mathsf{T}}\rangle \quad \overset{T}{\Longleftrightarrow} \quad |\mathbf{P}, -\boldsymbol{s}_{\mathsf{T}}\rangle$$

- Hence for pdfs:
  - normal $\text{pdf}_{\mathrm{DY}} = \text{normal pdf}_{\mathrm{DIS}}$
  - But $\text{Sivers}_{\mathrm{DY}} = -\text{Sivers}_{\mathrm{DIS}}$

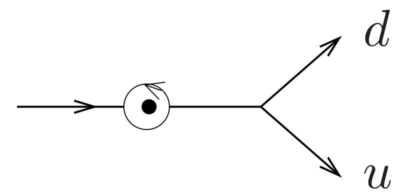
Prediction for DY

To have a prediction, $x_{\text{in polarized proton}}$ *must be in Hermes region*

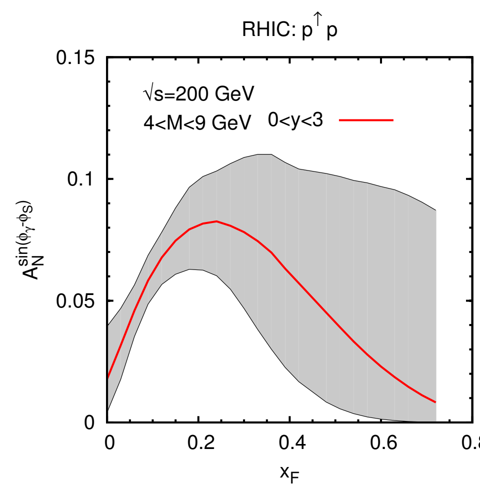
SIDIS



DY



Prediction *w/o (CSS) evolution for TMDs*



(Anselmino et al. Phys.Rev. D79 (2009) 054010)

For $\mathrm{d}\sigma \,/\, \mathrm{d}q\, \mathrm{d}\Omega$: distribution $\propto \sin(\phi_q - \phi_s)(1 + \cos^2\theta) +$ Boer-Mulders term

Reliability of theoretical framework

QCD

↓ Kinematic approximations

Disentangle gluons into Wilson lines

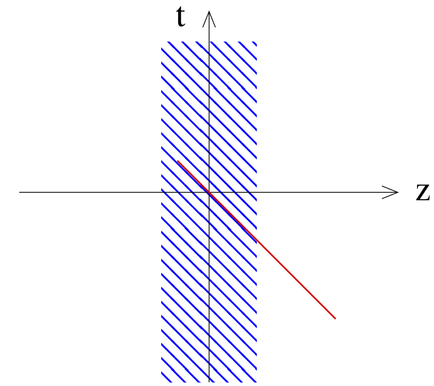
Cancellation of spectator interactions

factorization

→ TMD, incl. Sivers

→ Cancellation of soft ints.

Collinear factorization



Any problems with Sivers function impact issues critical to all kinds of factorization.

(Unpolarized) factorization survived many tests, so probability of failure is low.

Wilson lines encode space-time locations of color flow relative to hard scattering.

Conclusions

- Sivers function gives stress test of our understanding of QCD parton dynamics in hard scattering, especially of space-time locations of color flows

  (Key issues were hidden until recently!)

- SSA in Drell-Yan is clean test case with predictions deduced from SIDIS data and unpolarized Drell-Yan

  But remember CSS evolution (or equivalent) in making predictions.

- Disquieting data for $p^{\uparrow}p \to \pi X$
- But than $p^{\uparrow}p \to \pi X$ is harder for theory than Drell-Yan