Sivers effect: from SIDIS to pp
- sign change and sign mismatch

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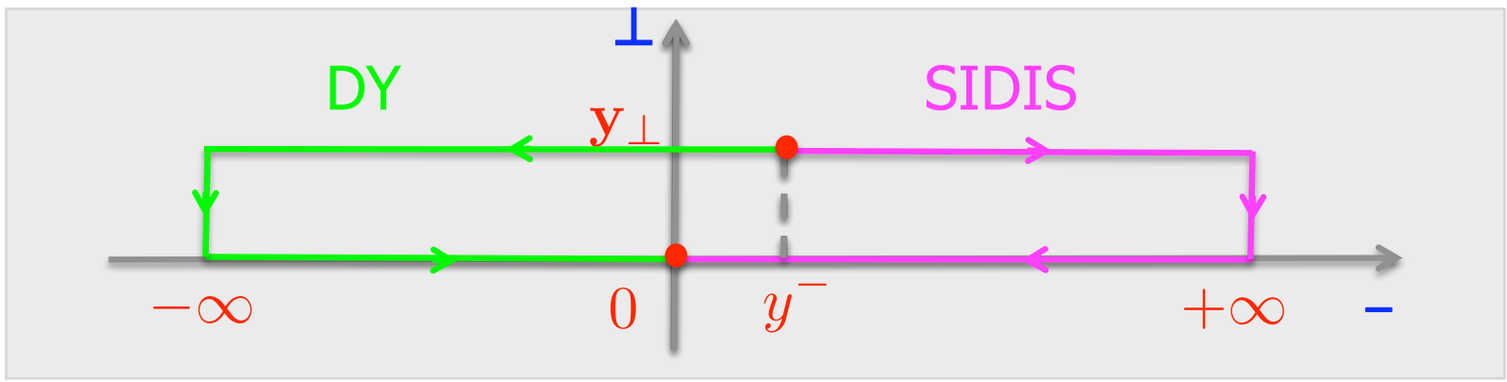
Abstract: The $k_\perp$-moment of a quark's Sivers function is known to be related to the corresponding twist-three quark-gluon correlation function $T_{q,F}(x, x)$. The two functions have been extracted from data for single-spin asymmetries in semi-inclusive deep inelastic scattering and in single-inclusive hadron production in pp collisions, respectively. Performing a consistent comparison of the extracted functions, we find that they show a “sign mismatch”: while the magnitude of the functions is roughly consistent, the $k_\perp$-moment of the Sivers function has opposite sign from that of $T_{q,F}(x, x)$, both for up and for down quarks. Barring any inconsistencies in our theoretical understanding of the Sivers functions and their process dependence, the implication of this mismatch is that either, the Sivers effect is not dominantly responsible for the observed single-spin asymmetries in pp collisions or, the current semi-inclusive lepton scattering data do not sufficiently constrain the $k_\perp$-moment of the quark Sivers functions. Both possibilities strengthen the case for further experimental investigations of single-spin asymmetries in high-energy pp and ep scattering.

Kang, Qiu, Vogelsang, Yuan, arXiv: 1103.1591, PRD 83, 2011
Kang, Prokudin, 2011, in preparation

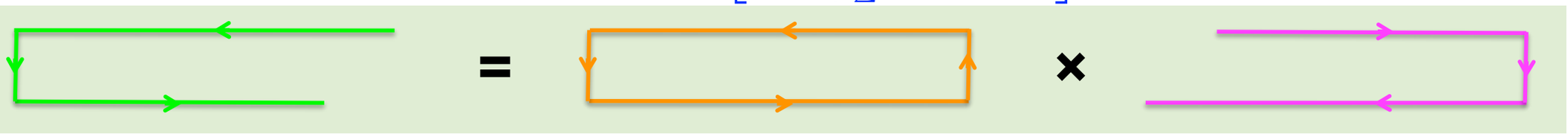
Time-reversal modified universality of the Sivers function

- Different gauge link for gauge-invariant TMD distribution in SIDIS and DY

$$f_{q/h^\uparrow}(x,\mathbf{k}_\perp,\vec{S}) = \int \frac{dy^- d^2y_\perp}{(2\pi)^3} e^{ixp^+y^- - i\,\mathbf{k}_\perp\cdot\mathbf{y}_\perp} \langle p,\vec{S}|\overline{\psi}(0^-,\mathbf{0}_\perp)\boxed{\text{Gauge link}}\frac{\gamma^+}{2}\psi(y^-,\mathbf{y}_\perp)|p,\vec{S}\rangle$$



Wilson Loop ~ $\exp\left[-ig\int_\Sigma d\sigma^{\mu\nu}F_{\mu\nu}\right]$ Area is NOT zero



- Parity and time-reversal invariance:

$$\Delta^N f^{\text{SIDIS}}_{q/h^\uparrow}(x,k_\perp) = -\Delta^N f^{\text{DY}}_{q/h^\uparrow}(x,k_\perp)$$

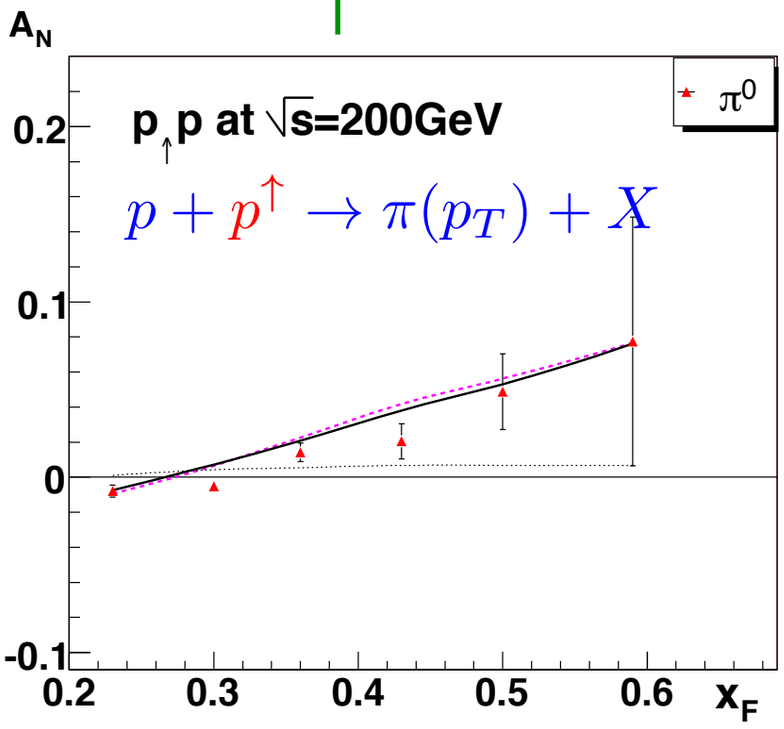
Most critical test for TMD approach to SSA

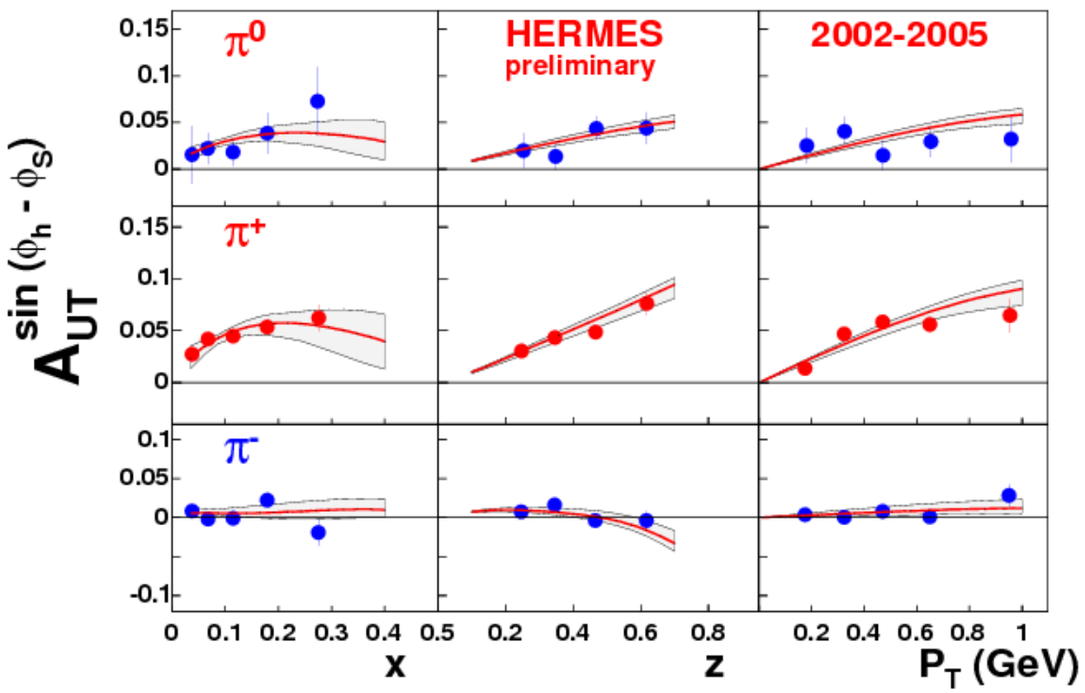
What about the connections?

- Both seem to describe the data well (in their own kinematic region), but what about their connections?
  - At the operator level, ETQS function is related to the first kt-moment of the Sivers function

Boer, Mulders, Pijlman, 2003
Ji, Qiu, Vogelsang, Yuan, 2006

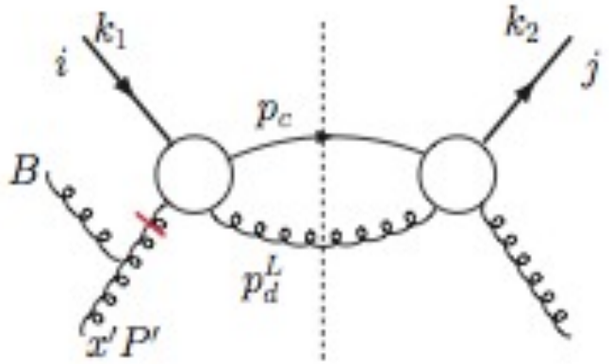
$$gT_{q,F}(x,x) = -\int d^2k_\perp \frac{|k_\perp|^2}{M} f_{1T}^{\perp q}(x,k_\perp^2)|_{\rm SIDIS}$$

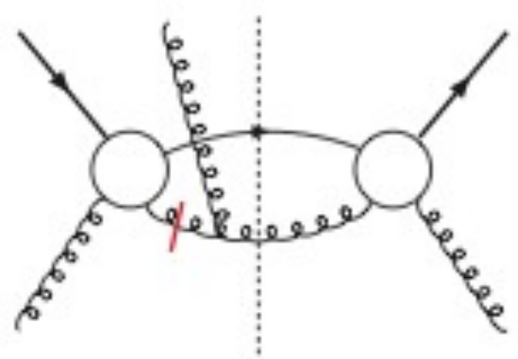




Initial- and final-state interaction in pp collisions

- The dominant channel is qg → qg





$$H^U_{qg\to qg} = \frac{N_c^2-1}{2N_c^2}\left[-\frac{\hat{s}}{\hat{u}}-\frac{\hat{u}}{\hat{s}}\right]\left[1-\frac{2N_c^2}{N_c^2-1}\frac{\hat{s}\hat{u}}{\hat{t}^2}\right] \xrightarrow{|\hat{t}|\ll\hat{s}\sim|\hat{u}|} \left[\frac{2\hat{s}^2}{\hat{t}^2}\right]$$

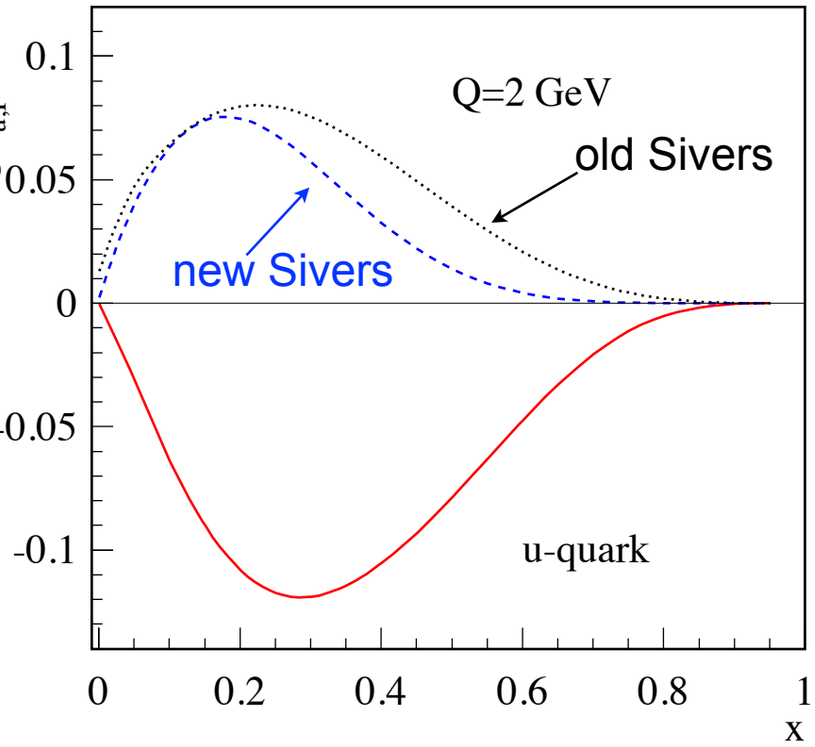
$$H^I_{qg\to qg} = \frac{1}{2(N_c^2-1)}\left[-\frac{\hat{s}}{\hat{u}}-\frac{\hat{u}}{\hat{s}}\right]\left[1-N_c^2\frac{\hat{u}^2}{\hat{t}^2}\right] \xrightarrow{|\hat{t}|\ll\hat{s}\sim|\hat{u}|} \left[-\frac{N_c^2}{2(N_c^2-1)}\right]\left[\frac{2\hat{s}^2}{\hat{t}^2}\right]$$

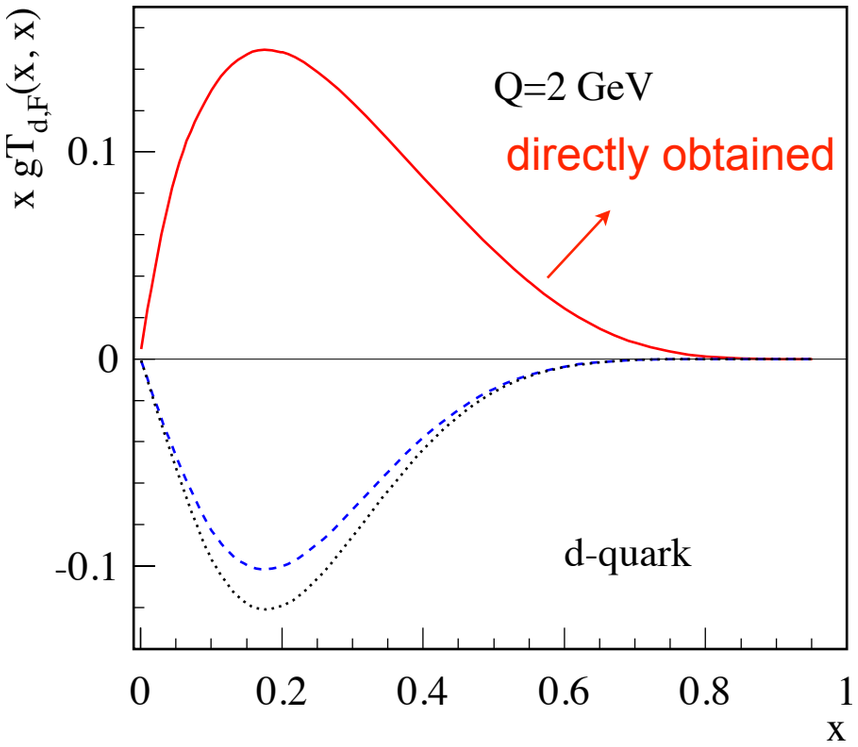
$$H^F_{qg\to qg} = \frac{1}{2N_c^2(N_c^2-1)}\left[-\frac{\hat{s}}{\hat{u}}-\frac{\hat{u}}{\hat{s}}\right]\left[1+2N_c^2\frac{\hat{s}\hat{u}}{\hat{t}^2}\right] \xrightarrow{|\hat{t}|\ll\hat{s}\sim|\hat{u}|} \left[-\frac{1}{N_c^2-1}\right]\left[\frac{2\hat{s}^2}{\hat{t}^2}\right]$$

- Sivers effect in single hadron production is more similar to DY

Directly obtained ETQS function

- ETQS function could be directly obtained from the global fitting of inclusive hadron production in hadronic collisions





- directly obtained ETQS functions for both u and d quarks are opposite in sign to those indirectly obtained from the kt-moment of the quark Sivers function - "a sign mismatach"

Predictions for jet and direct photon

- at RHIC 200 GeV: