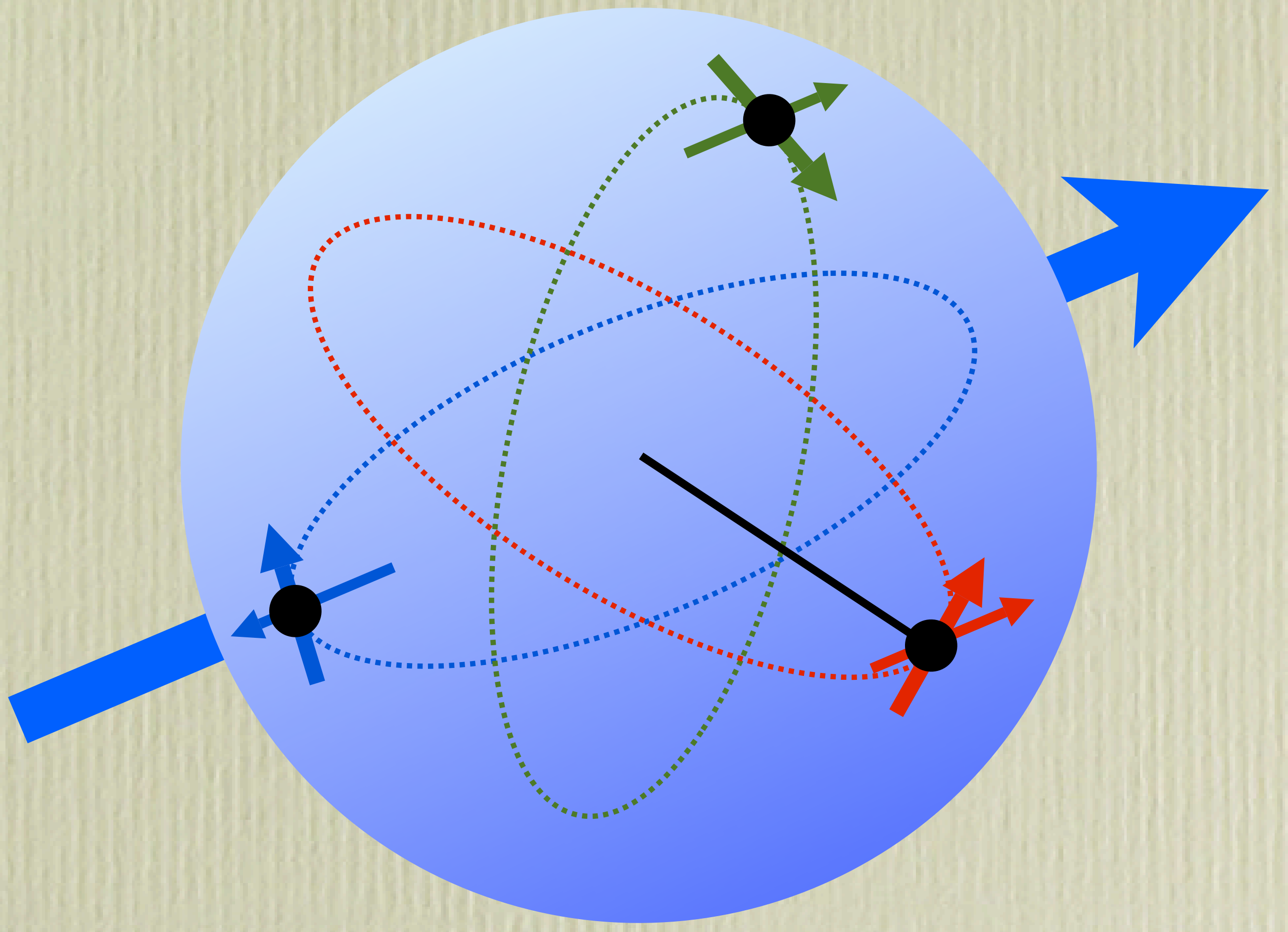
Round table on global fits



Transversity 2011 - August 29- September 2,
Veli Lošinj, Croatia

Mauro Anselmino, Werner Vogelsang

open issues on global fits and related problems ....

Fit of SIDIS data and TMD extraction: x-$k_\perp$
factorization, gaussian dependence, etc...
Flavour separation, role of sea quarks....

TMD evolution: importance for predictions of Sivers asymmetry in D-Y processes

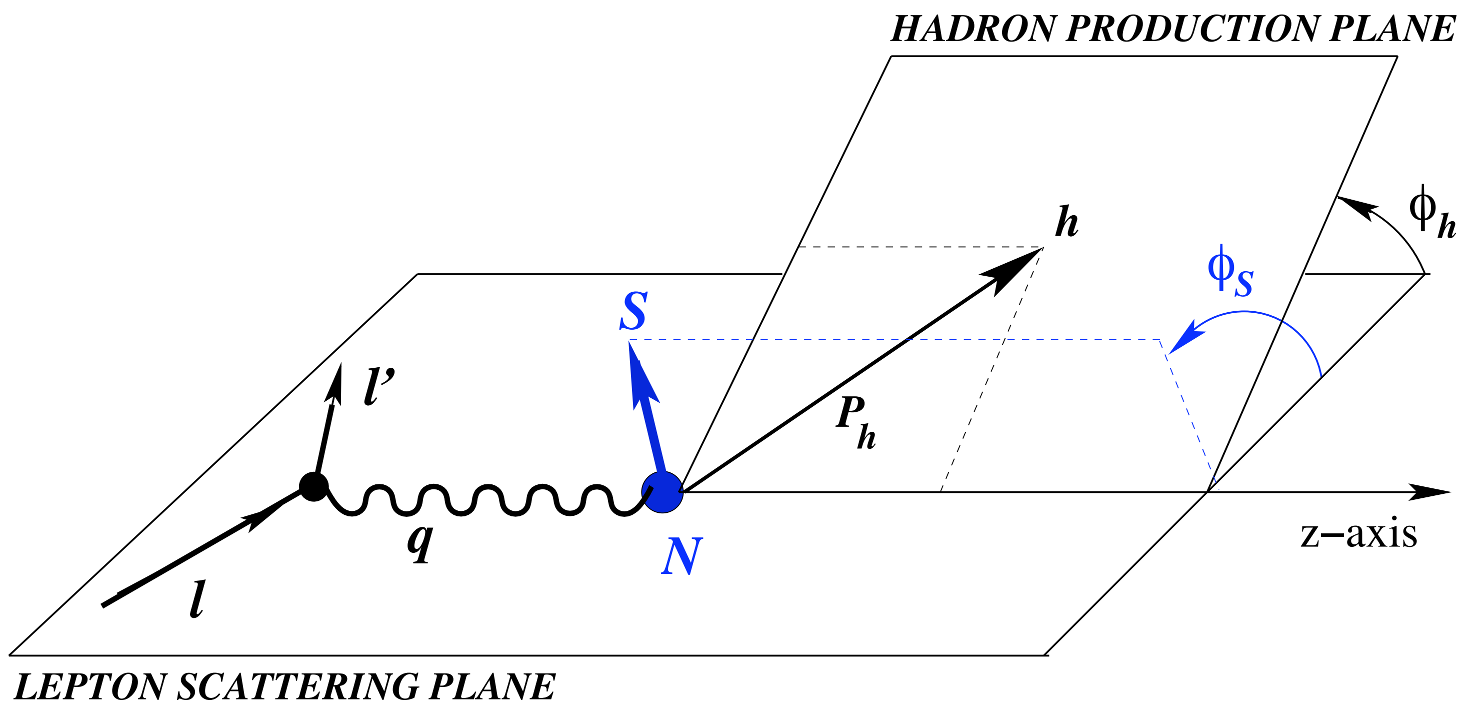
SSAs in pp, quark gluon correlation T_q and the Sivers function: sign mismatch

the contribution of strange quarks to longitudinal spin

....

TMDs from fits of SIDIS data

$$\mathrm{d}^6\sigma \equiv \frac{\mathrm{d}^6\sigma^{\ell p^\uparrow \to \ell h X}}{\mathrm{d}x_{_B}\, \mathrm{d}Q^2\, \mathrm{d}z_h\, \mathrm{d}^2\boldsymbol{P}_T\, \mathrm{d}\phi_S}$$



$$\mathrm{d}\sigma^{\ell p \to \ell h X} = \sum_q f_q(x, \boldsymbol{k}_\perp; Q^2) \otimes \mathrm{d}\hat{\sigma}^{\ell q \to \ell q}(y, \boldsymbol{k}_\perp; Q^2) \otimes D_q^h(z, \boldsymbol{p}_\perp; Q^2)$$

$$\boldsymbol{p}_\perp \simeq \boldsymbol{P}_T - z_h\, \boldsymbol{k}_\perp$$

Sivers and Collins effects well established

Sivers and Collins functions extracted with most simple assumptions

x-$k_\perp$ factorization of TMDs?

functional form of TMDs (nodes)?

Gaussian $k_\perp$ distribution of TMDs?

$$\langle k_\perp^2\rangle(x,Q^2) \quad \langle p_\perp^2\rangle(z,Q^2)$$

x, z dependence?

flavour dependence?

energy dependence?

$k_\perp$ dependence of Δq vs. q?

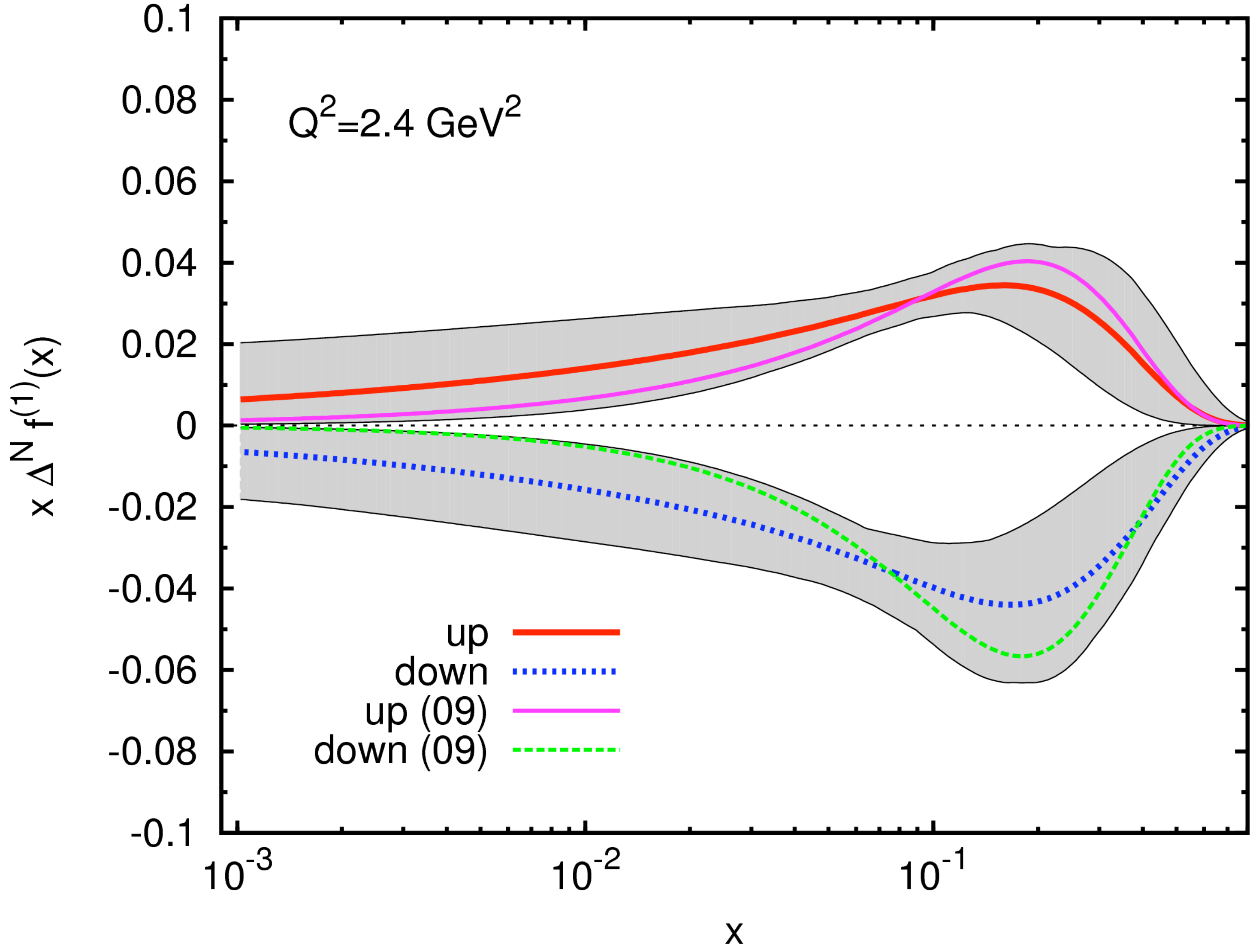
role of higher twists

....

simple Sivers functions for u and d quarks are sufficient to fit the available SIDIS data

large and very small x dependence not constrained by data

talk by S. Melis



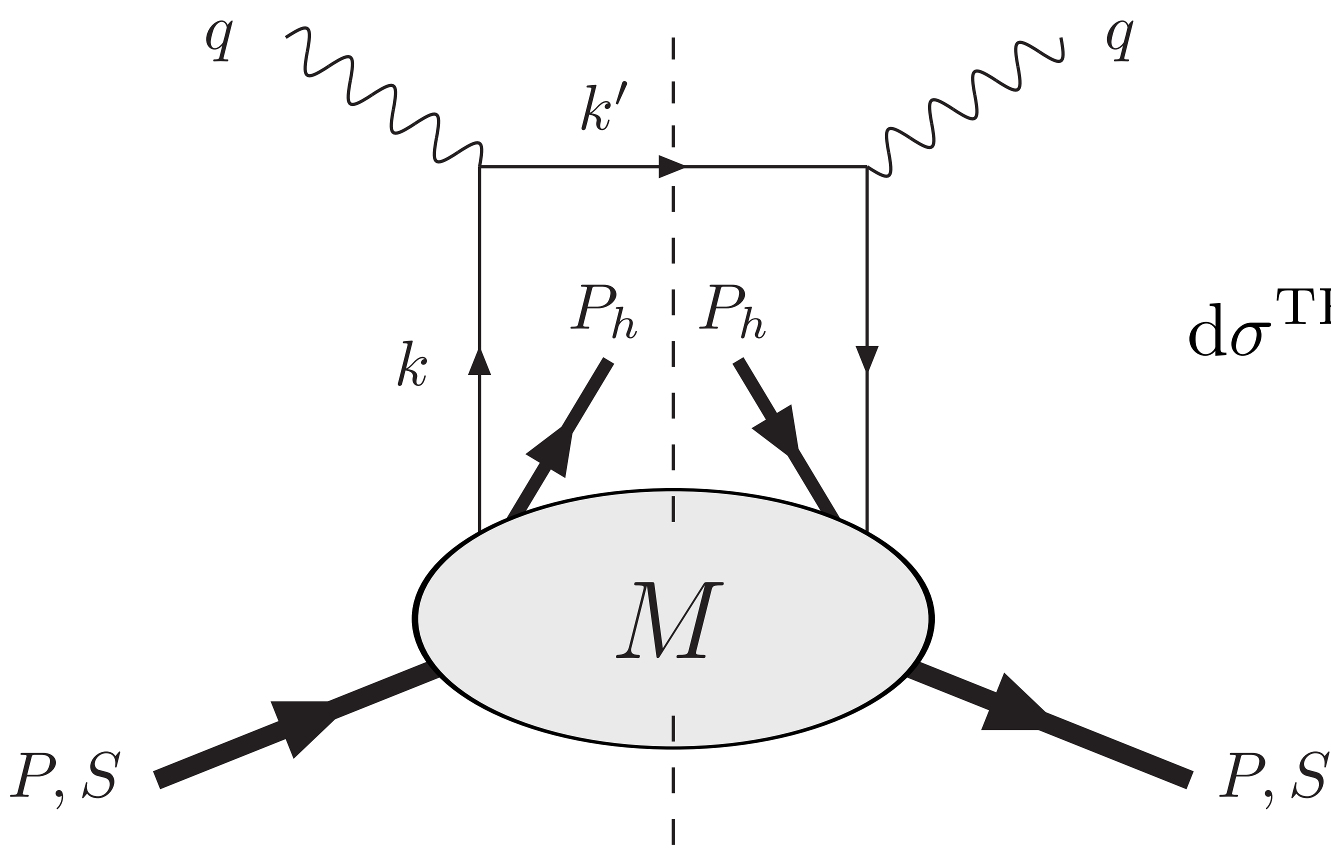
new and previous extraction of u and d Sivers functions

S. Melis and A. Prokudin, preliminary results

Anselmino et al. Eur. Phys. J. A39,89 (2009)

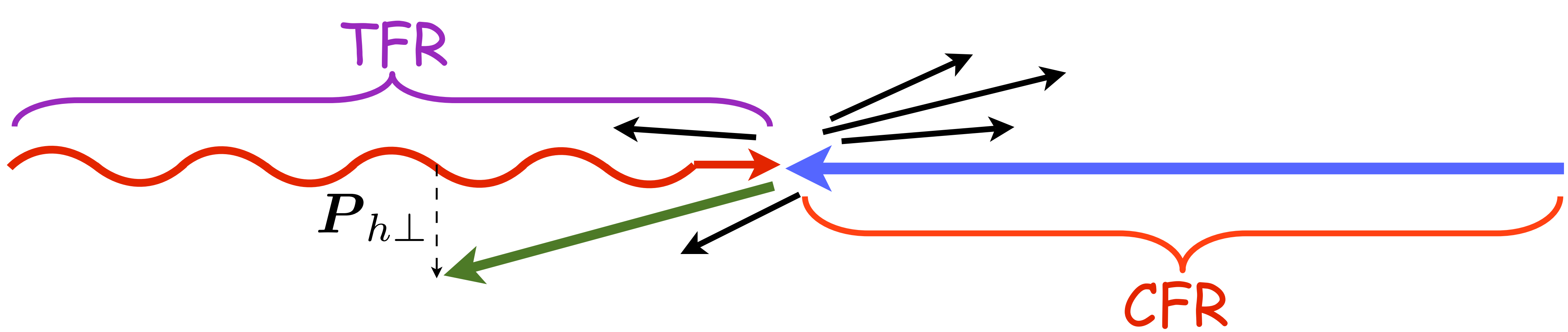
azimuthal dependences from target fragmentation region

(fracture functions, talk by A. Kotzinian)



$$\mathrm{d}\sigma^{\mathrm{TFR}} = \sum_a \underbrace{M_a(x_B, \zeta, \boldsymbol{P}_{h\perp}^2)}_{\text{fracture functions}} \otimes \mathrm{d}\hat{\sigma}(y)$$

$$\zeta \simeq \frac{E_h}{E} \simeq (1 - x_B)|x_F|$$



azimuthal modulations in TFR

(M.A, V. Barone, A. Kotzinian, PL B699 (2011) 108)

cross section for lepto-production of an unpolarized or spinless hadron in the TFR

$$\frac{\mathrm{d}\sigma^{\mathrm{TFR}}}{\mathrm{d}x_B\,\mathrm{d}y\,\mathrm{d}\zeta\,\mathrm{d}^2\boldsymbol{P}_{h\perp}\,\mathrm{d}\phi_S} = \frac{2\alpha_{\mathrm{em}}^2}{Q^2 y}\left\{\left(1-y+\frac{y^2}{2}\right)\right.$$
$$\times\sum_a e_a^2\left[M(x_B,\zeta,\boldsymbol{P}_{h\perp}^2) - |\boldsymbol{S}_\perp|\,\frac{|\boldsymbol{P}_{h\perp}|}{m_h}\,M_T^h(x_B,\zeta,\boldsymbol{P}_{h\perp}^2)\sin(\phi_h-\phi_S)\right]$$
$$+\lambda_l\,y\left(1-\frac{y}{2}\right)\sum_a e_a^2\left[S_\parallel\,\Delta M_L(x_B,\zeta,\boldsymbol{P}_{h\perp}^2)\right.$$
$$\left.\left.+\;|\boldsymbol{S}_\perp|\,\frac{|\boldsymbol{P}_{h\perp}|}{m_h}\,\Delta M_T^h(x_B,\zeta,\boldsymbol{P}_{h\perp}^2)\,\cos(\phi_h-\phi_S)\right]\right\}.$$

possible Sivers-like azimuthal dependence from target fragmentation region

Transversity & Collins function phenomenology in SIDIS and e+e-

Same simple parametrization as for Sivers
Collins effect has been clearly observed by four independent experiments:
HERMES, COMPASS, Belle, BaBar

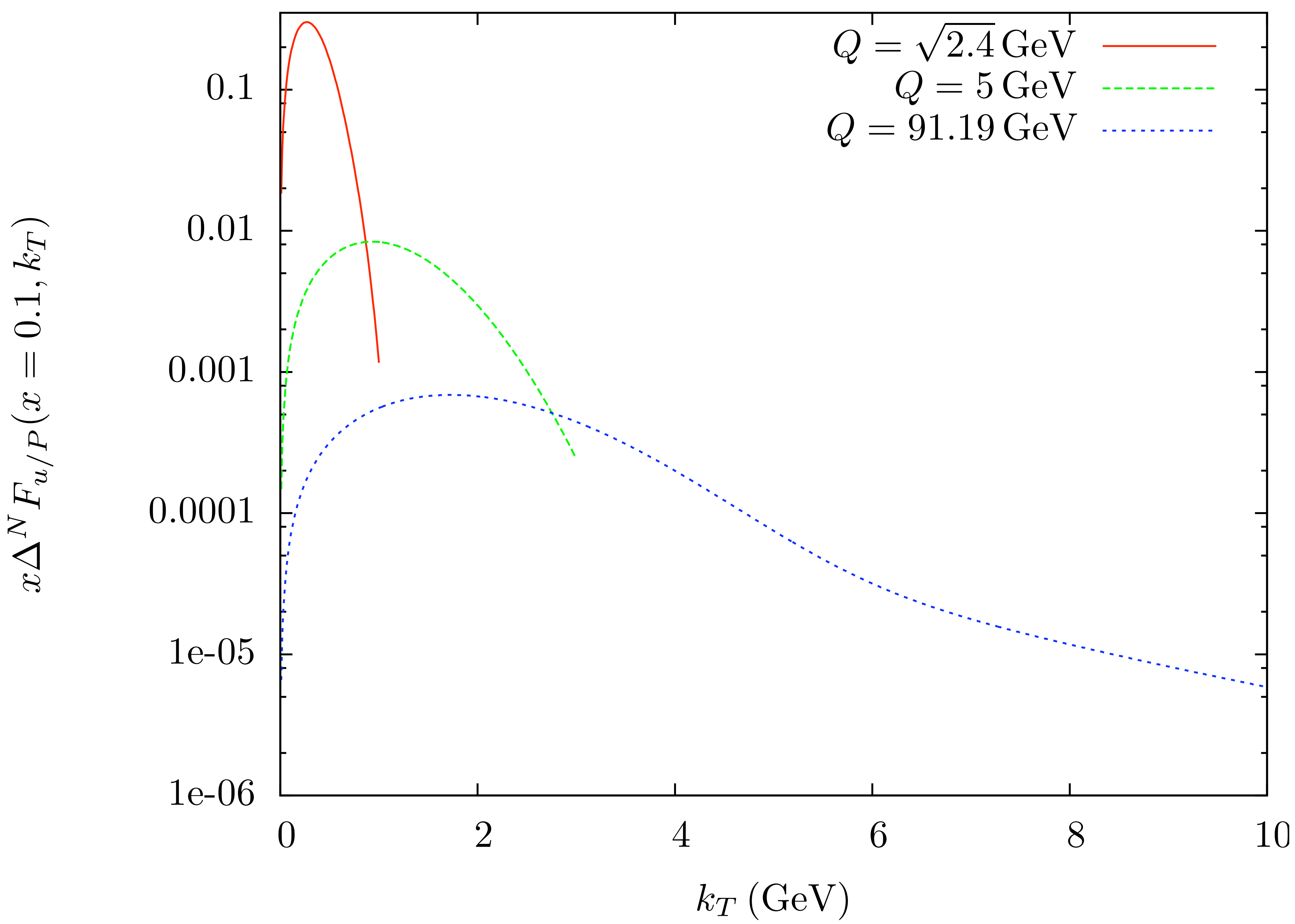
Collins function expected to be universal

QCD evolution important, as Belle data are at a much higher energy than SIDIS data

Two different (?) sets of Belle data, A_{12} and A_0, some inconsistencies. $P_\perp$ dependence?

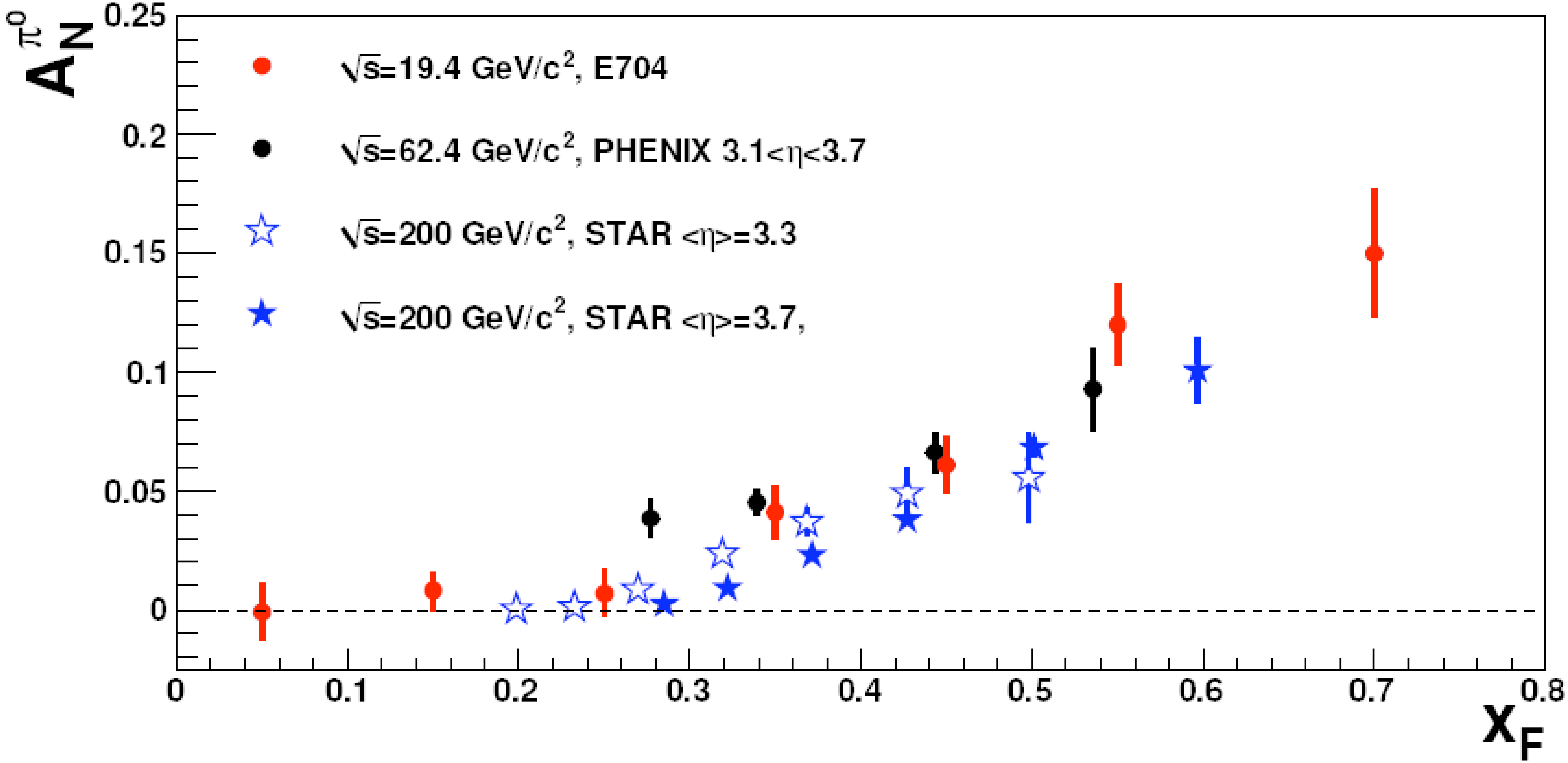
great improvement in study of QCD evolution
(talk by Aybat)

strong Sivers evolution, might affect D-Y predictions



A_N in $p^{\uparrow}p \to \pi\, X$, the big challenge

$$A_N \equiv \frac{d\sigma^{\uparrow} - d\sigma^{\uparrow}}{d\sigma^{\uparrow} + d\sigma^{\uparrow}}$$

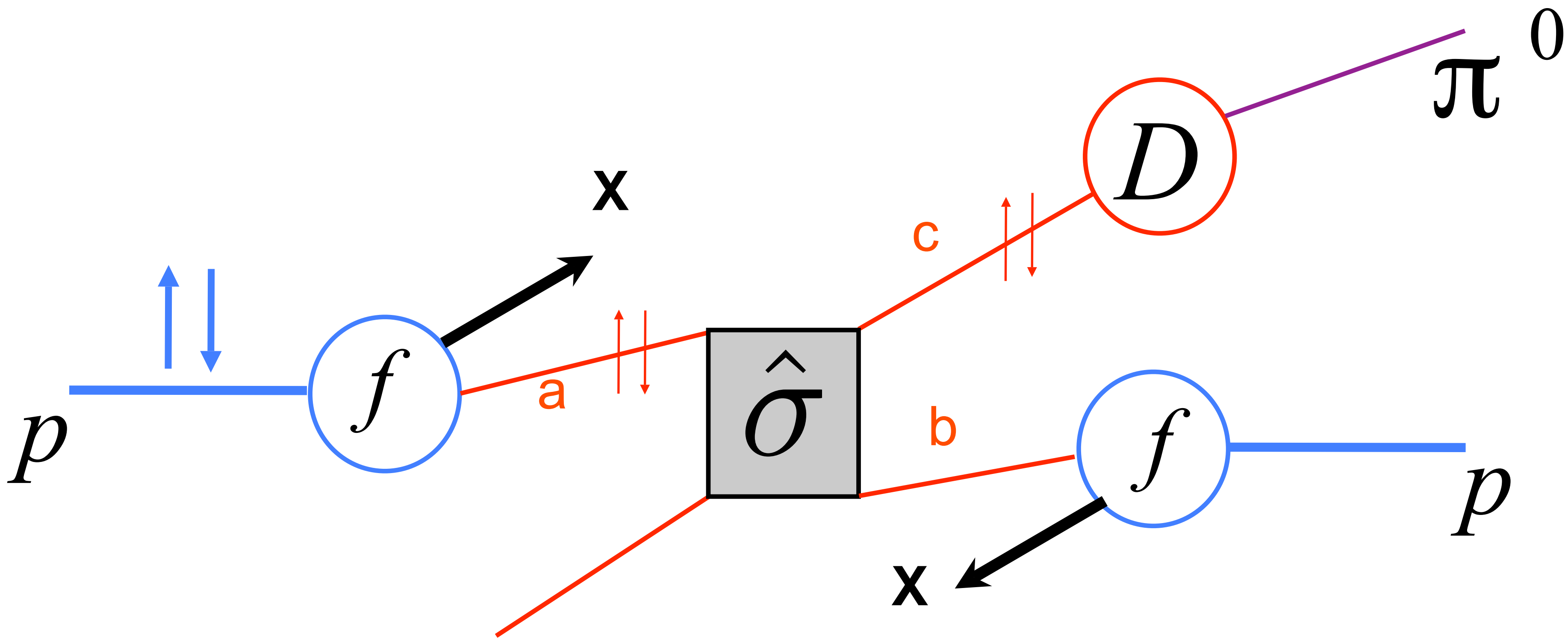


John Koster talk

Only one large scale, P_T. Any role for TMDs?

TMD factorization not proven

1. Generalization of collinear scheme (assuming factorization)



$$\mathrm{d}\sigma^{\uparrow} = \sum_{a,b,c=q,\bar{q},g} \underbrace{f_{a/p^{\uparrow}}(x_a, \boldsymbol{k}_{\perp a})} \otimes \underbrace{f_{b/p}(x_b, \boldsymbol{k}_{\perp b})} \otimes \mathrm{d}\hat{\sigma}^{ab\to cd}(\boldsymbol{k}_{\perp a}, \boldsymbol{k}_{\perp b}) \otimes \underbrace{D_{\pi/c}(z, \boldsymbol{p}_{\perp \pi})}$$

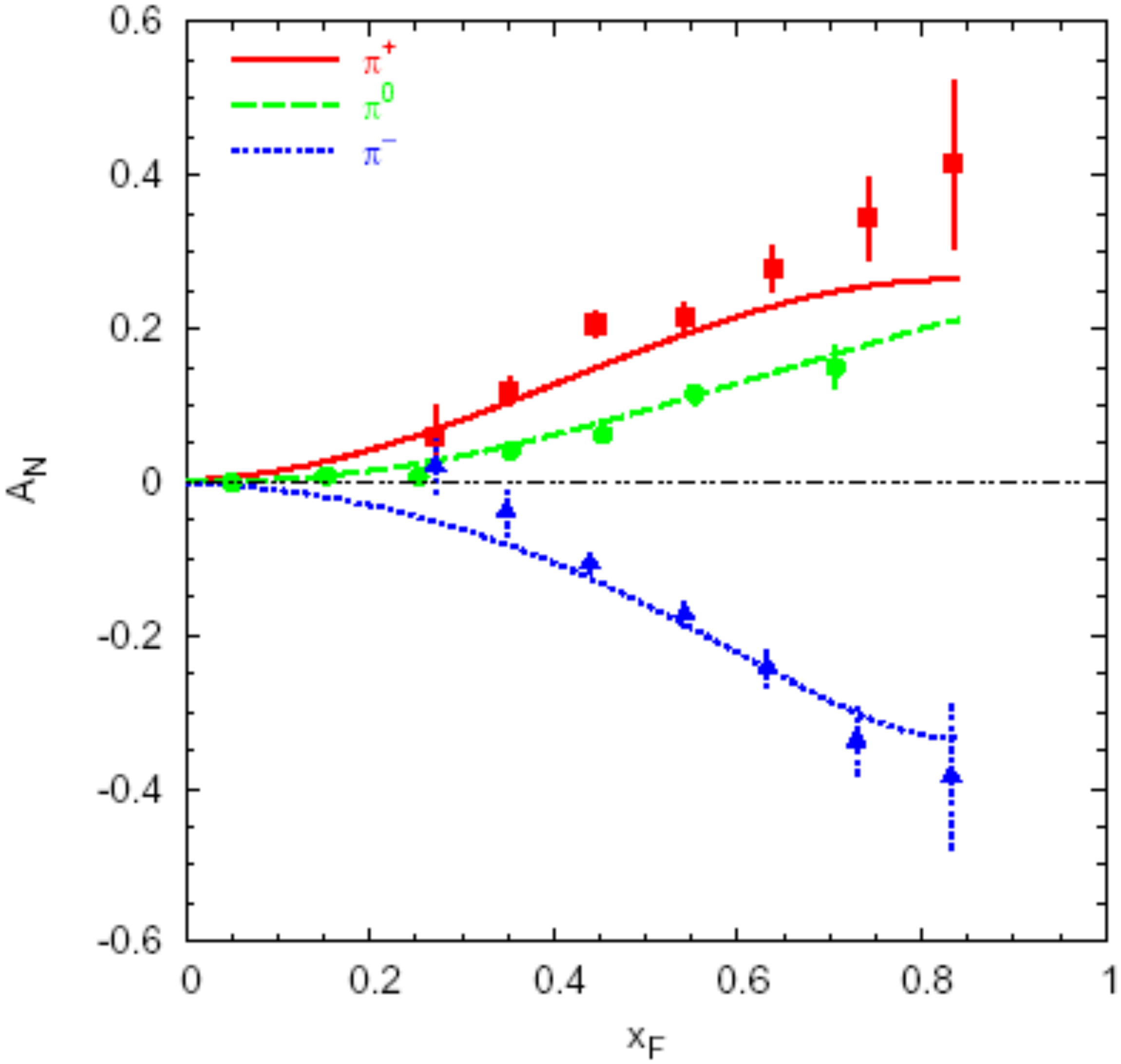
single spin effects in TMDs

M.A., M. Boglione, U. D'Alesio, E. Leader, S. Melis, F. Murgia, A. Prokudin, ...
(Field-Feynman in unpolarized case)

TMD factorization at work ....

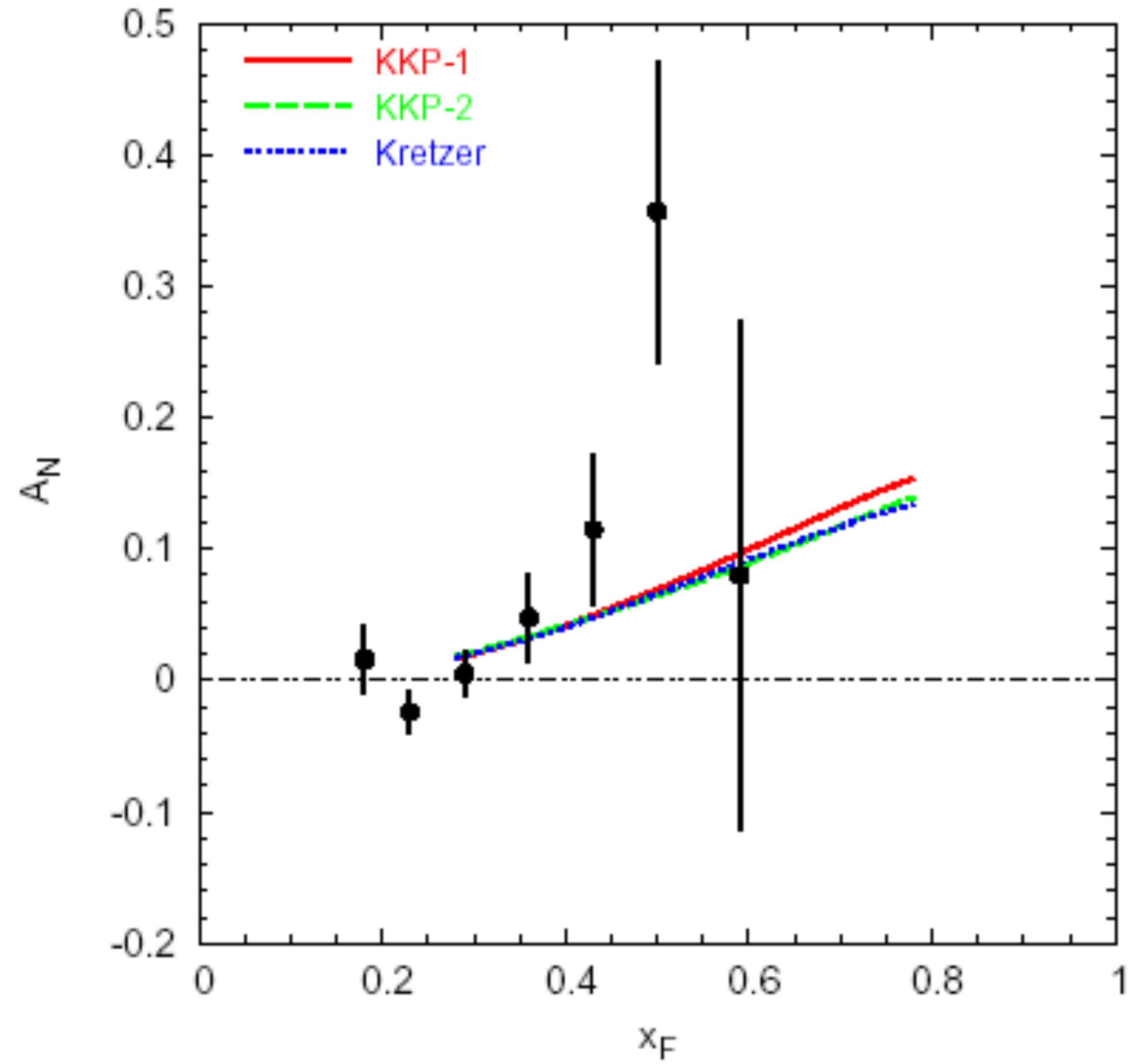
U. D'Alesio, F. Murgia

E704 data



fit

STAR data



prediction

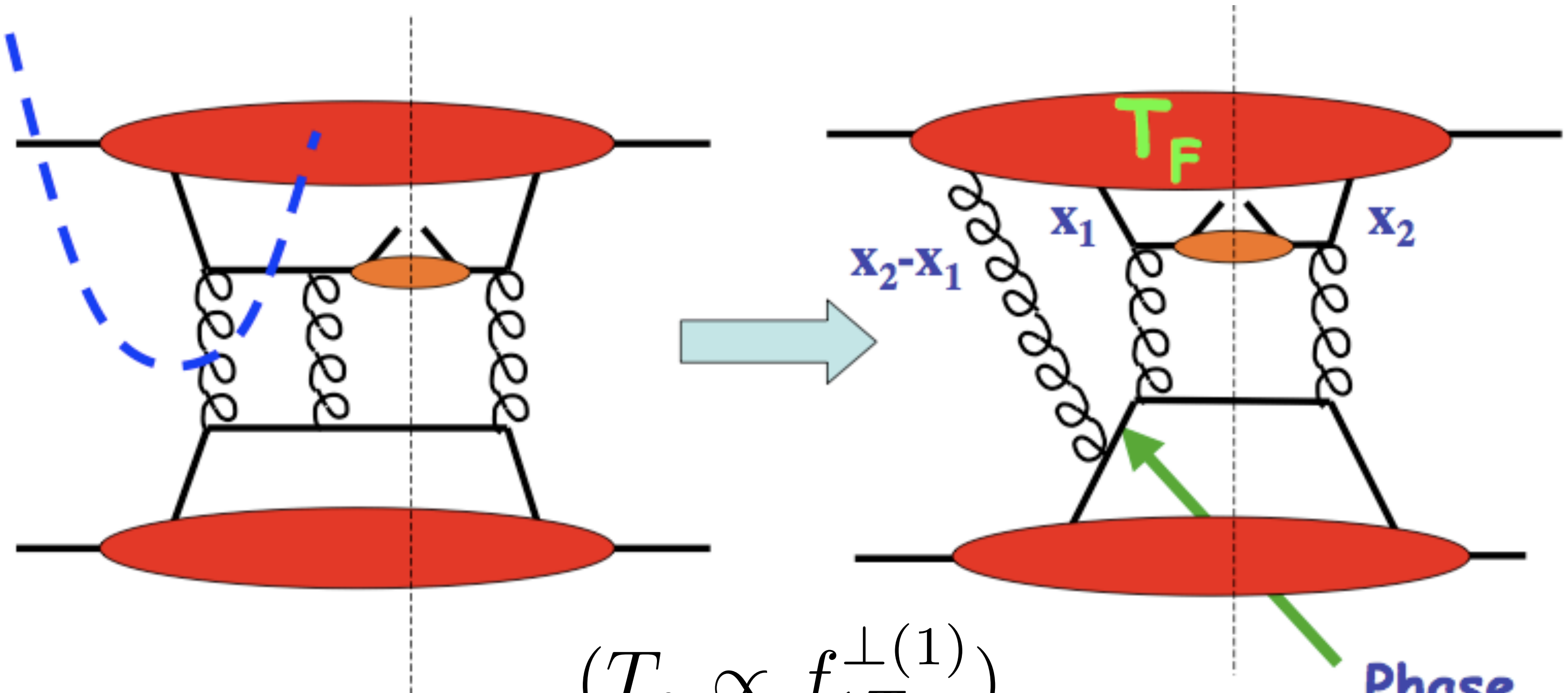
Sivers effect $p\,p \to \pi\,X$

2. Higher-twist partonic correlations

(Efremov, Teryaev; Qiu, Sterman; Kouvaris, Vogelsang, Yuan; Bacchetta, Bomhof, Mulders, Pijlman; Koike ...)

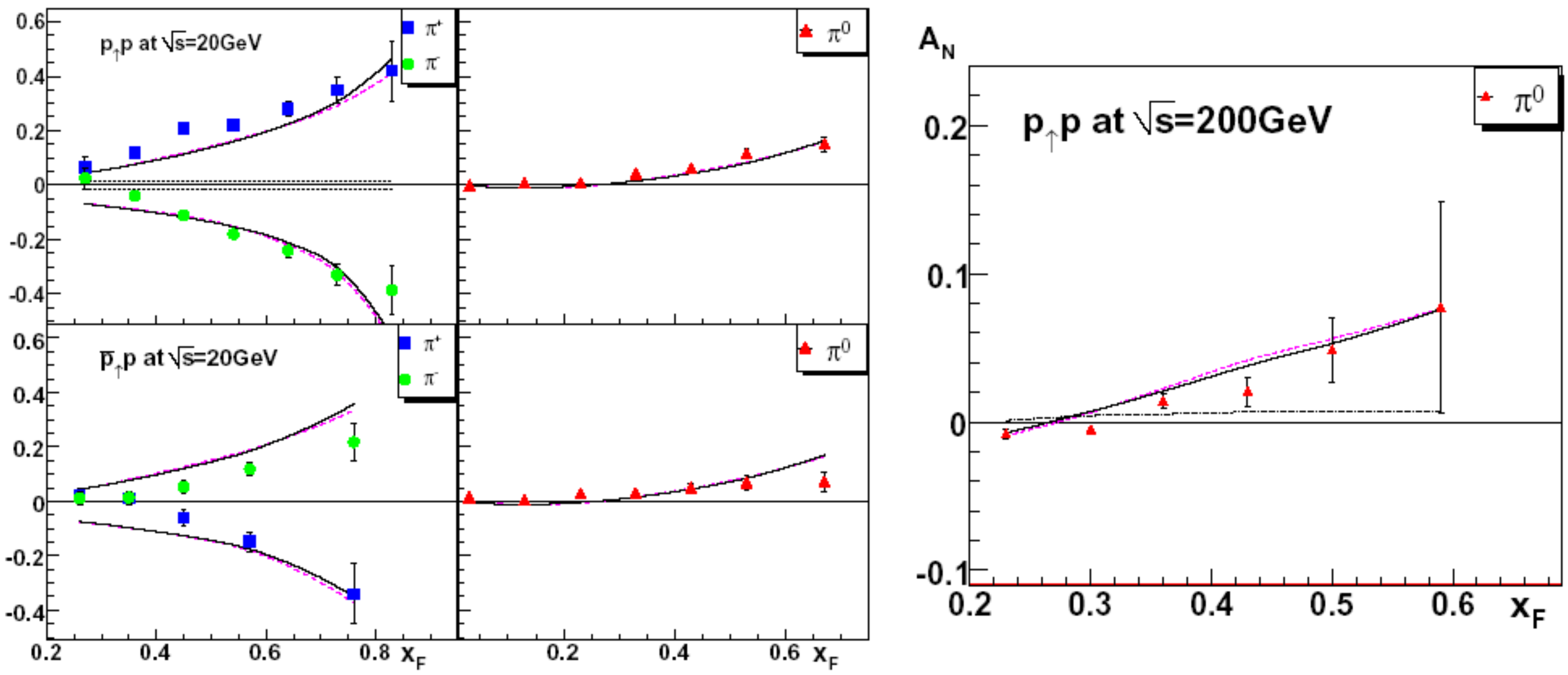
higher-twist partonic correlations - factorization OK

$$\mathrm{d}\Delta\sigma \propto \sum_{a,b,c} \underbrace{T_a(k_1, k_2, \boldsymbol{S}_\perp)}_{\text{twist-3 functions}} \otimes f_{b/B}(x_b) \otimes \underbrace{H^{ab\to c}(k_1, k_2)}_{\text{hard interaction, not a cross section}} \otimes D_{h/c}(z)$$



$(T_a \propto f_{1T}^{\perp(1)})$

possible project: compute T_a using SIDIS extracted Sivers functions



fits of E704 and STAR data

Kouvaris, Qiu, Vogelsang, Yuan

sign mismatch

(Kang, Qiu, Vogelsang, Yuan)

compare

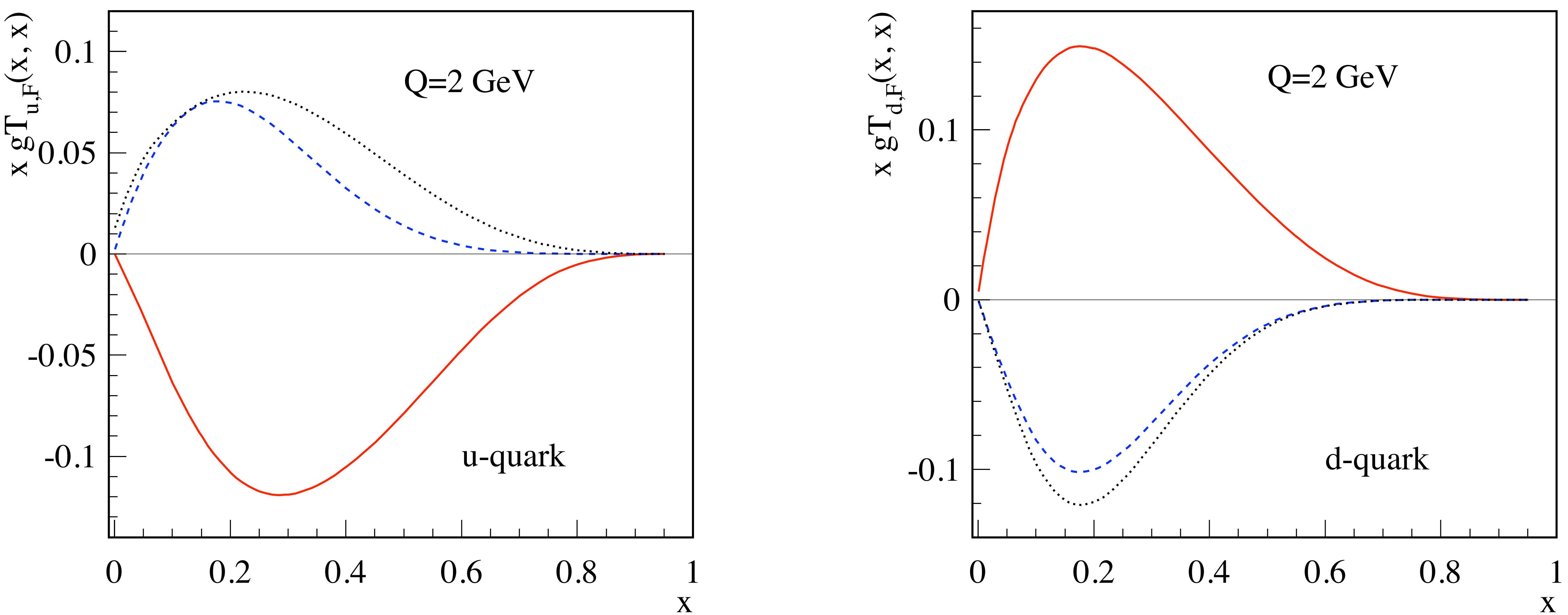
$$gT_{q,F}(x,x) = -\int d^2k_\perp \frac{|k_\perp|^2}{M} f_{1T}^{\perp q}(x,k_\perp^2)|_{\rm SIDIS}$$

as extracted from fitting A_N data, with that obtained by inserting in the the above relation the SIDIS extracted Sivers functions

similar magnitude, but opposite sign!

the same mismatch does not occurr adopting TMD factorization; the reason is that the hard scattering part in higher-twist factorization is negative

$$E_h \frac{d\Delta\sigma(s_\perp)}{d^3P_h} = \frac{\alpha_s^2}{S}\sum_{a,b,c}\int\frac{dz}{z^2}D_{c\to h}(z)\int\frac{dx'}{x'}f_{b/B}(x')\int\frac{dx}{x}\sqrt{4\pi\alpha_s}\left(\frac{\epsilon^{P_{h\perp}s_\perp n\bar{n}}}{z\hat{u}}\right)$$
$$\times\left[T_{a,F}(x,x) - x\frac{d}{dx}T_{a,F}(x,x)\right]H_{ab\to c}(\hat{s},\hat{t},\hat{u})\delta\left(\hat{s}+\hat{t}+\hat{u}\right),$$

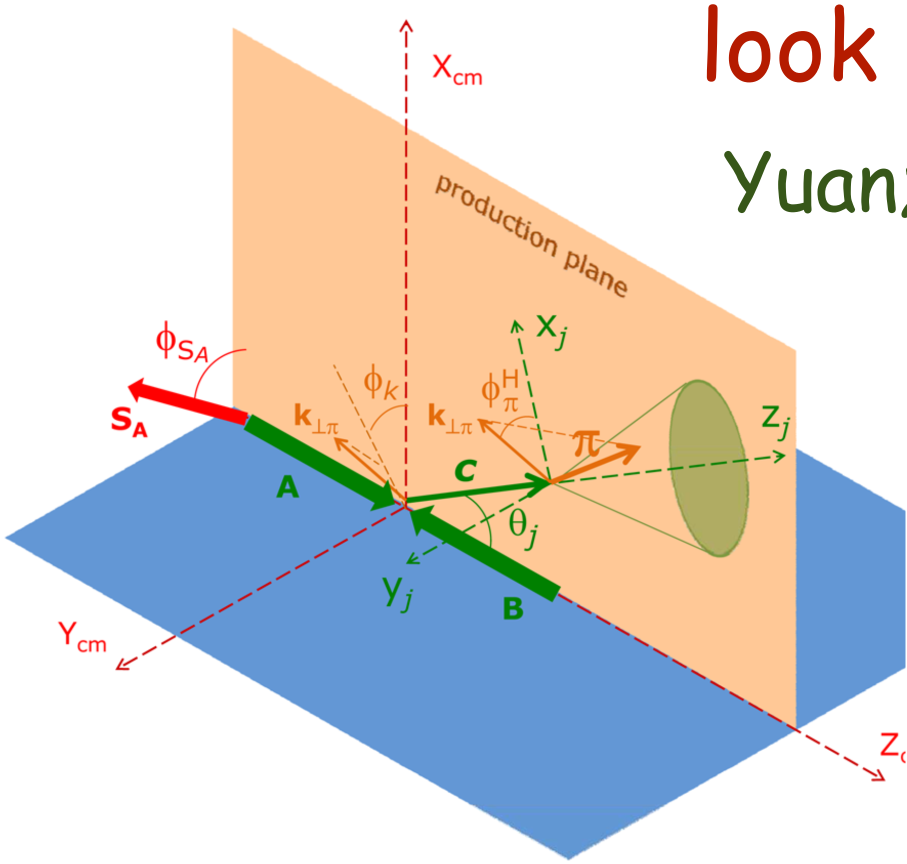


disentangle the role of Collins effect in A_N

$p^{\uparrow}p \to \pi$, jet + X

look at pion inside the jet

Yuan; D'Alesio, Murgia, Pisano

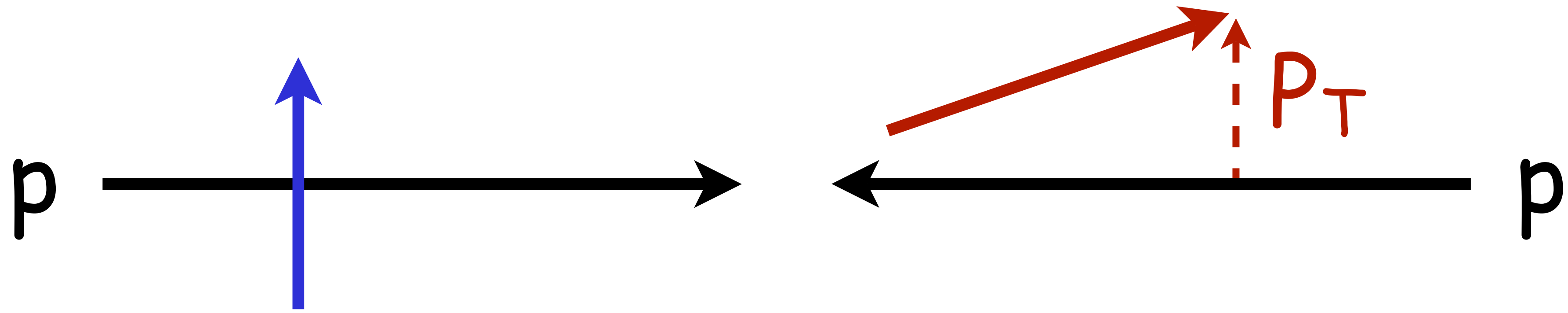


$$
\begin{aligned}
2d\sigma(\phi_{S_A}, \phi_\pi^H) \sim{}& d\sigma_0 + d\Delta\sigma_0 \sin\phi_{S_A} + d\sigma_1 \cos\phi_\pi^H \\
&+ d\Delta\sigma_1^- \sin(\phi_{S_A} - \phi_\pi^H) + d\Delta\sigma_1^+ \sin(\phi_{S_A} + \phi_\pi^H) \\
&+ d\sigma_2 \cos 2\phi_\pi^H + d\Delta\sigma_2^- \sin(\phi_{S_A} - 2\phi_\pi^H) \\
&+ d\Delta\sigma_2^+ \sin(\phi_{S_A} + 2\phi_\pi^H).
\end{aligned}
$$

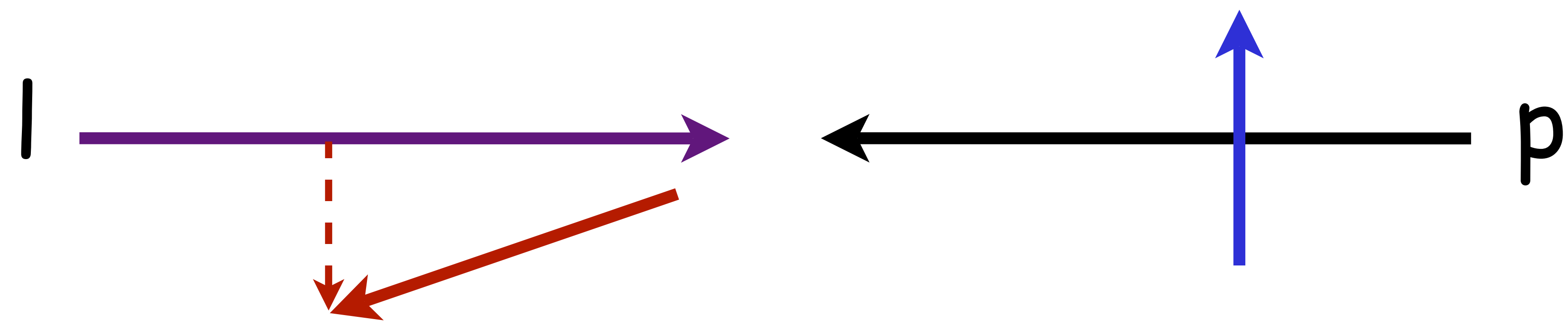
$$
A_N^{W(\phi_{S_A},\phi_\pi^H)}(\boldsymbol{p}_{\rm j}, z, k_{\perp\pi}) \equiv 2\langle W(\phi_{S_A}, \phi_\pi^H)\rangle(\boldsymbol{p}_{\rm j}, z, k_{\perp\pi}) =
$$

$$
2\,\frac{\int d\phi_{S_A} d\phi_\pi^H W(\phi_{S_A}, \phi_\pi^H)[d\sigma(\phi_{S_A}, \phi_\pi^H) - d\sigma(\phi_{S_A} + \pi, \phi_\pi^H)]}{\int d\phi_{S_A} d\phi_\pi^H [d\sigma(\phi_{S_A}, \phi_\pi^H) + d\sigma(\phi_{S_A} + \pi, \phi_\pi^H)]}
$$

$p^{\uparrow} p \rightarrow \pi X$ vs. $l\, p^{\uparrow} \rightarrow \pi X$

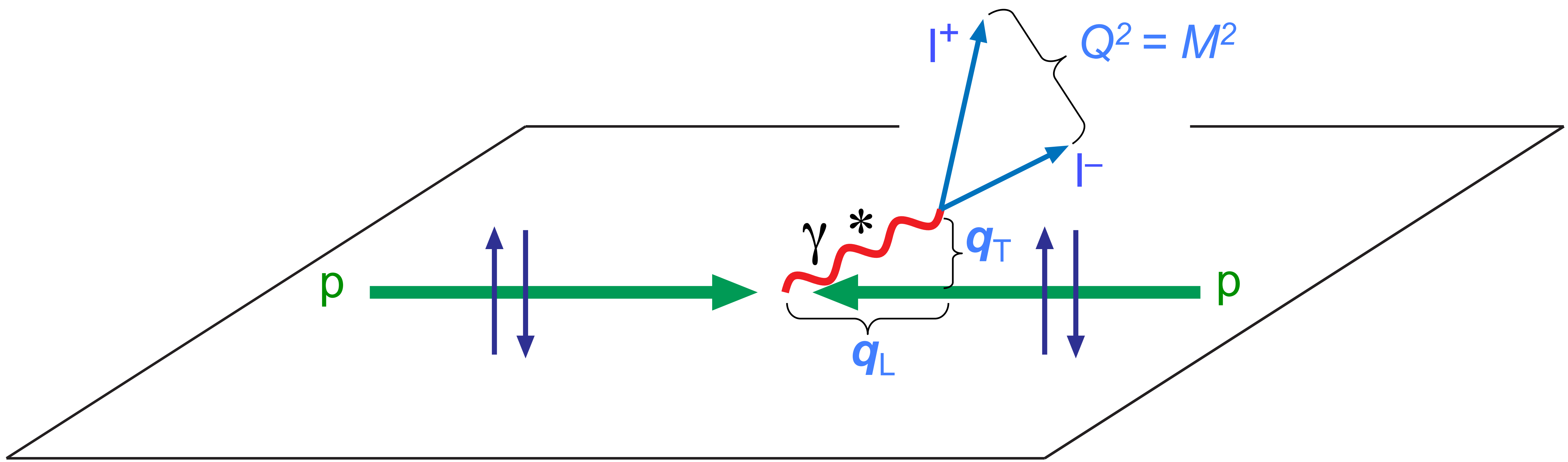


$p^{\uparrow} p \rightarrow \pi X$, large P_T, positive and large x_F



$l\, p^{\uparrow} \rightarrow \pi X$, large P_T, negative and large x_F

TMDs in Drell-Yan processes



factorization holds, two scales, M^2, and $q_T \ll M$

$$d\sigma^{D-Y} = \sum_a f_q(x_1, \boldsymbol{k}_{\perp 1}; Q^2) \otimes f_{\bar{q}}(x_2, \boldsymbol{k}_{\perp 2}; Q^2)\, d\hat{\sigma}^{q\bar{q}\to\ell^+\ell^-}$$

direct product of TMDs, no fragmentation process

$$[f_{1T}^{q\perp}]_{\text{SIDIS}} = -[f_{1T}^{q\perp}]_{\text{DY}}$$

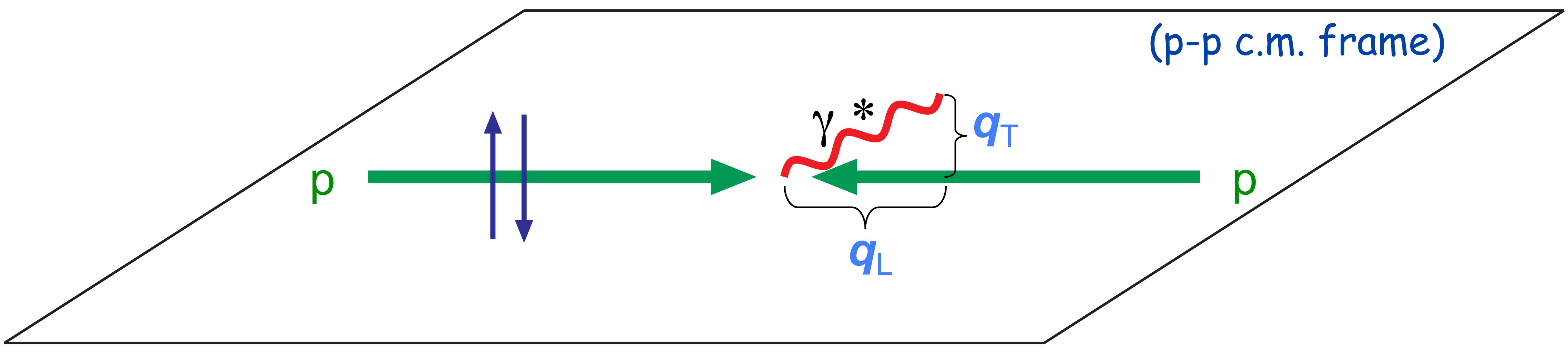
Sivers effect in D-Y processes

By looking at the $d^4\sigma/d^4q$ cross section one can single out the Sivers effect in D-Y processes

$$\mathrm{d}\sigma^{\uparrow} - \mathrm{d}\sigma^{\downarrow} \propto \sum_q \Delta^N f_{q/p^{\uparrow}}(x_1, \boldsymbol{k}_{\perp}) \otimes f_{\bar{q}/p}(x_2) \otimes \mathrm{d}\hat{\sigma}$$

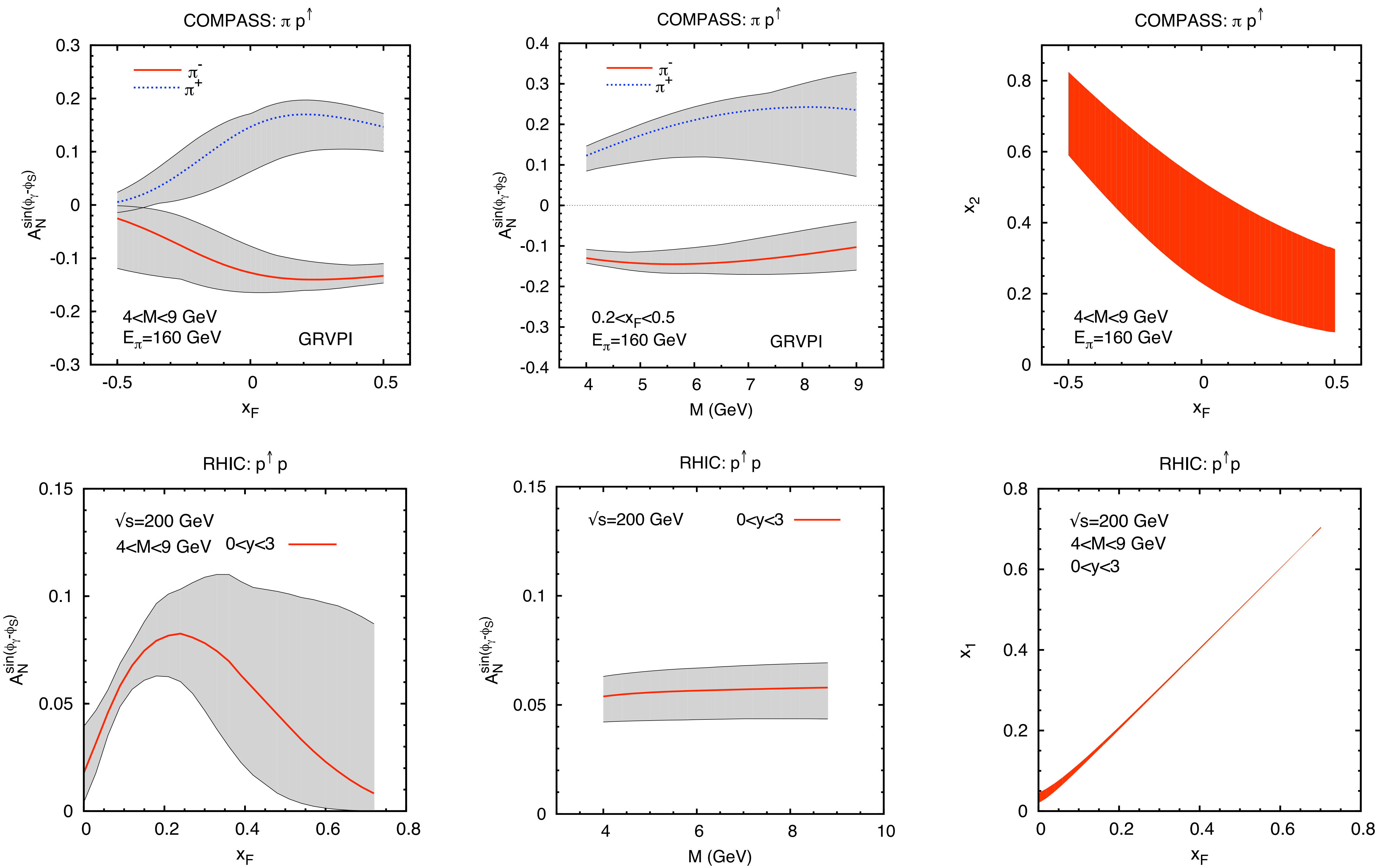
$q = u, \bar{u}, d, \bar{d}, s, \bar{s}$

$$A_N^{\sin(\phi_S - \phi_\gamma)} \equiv \frac{2\int_0^{2\pi} \mathrm{d}\phi_\gamma \, [\mathrm{d}\sigma^{\uparrow} - \mathrm{d}\sigma^{\downarrow}] \, \sin(\phi_S - \phi_\gamma)}{\int_0^{2\pi} \mathrm{d}\phi_\gamma \, [\mathrm{d}\sigma^{\uparrow} + \mathrm{d}\sigma^{\downarrow}]}$$



Predictions for A_N

Sivers functions as extracted from SIDIS data, **with opposite sign**



M.A., M. Boglione, U. D'Alesio, S. Melis, F. Murgia, A. Prokudin, e-Print: arXiv:0901.3078

global analysis

more and more data available

more precise determination of TMDs is becoming possible

study role of TMDs in different processes

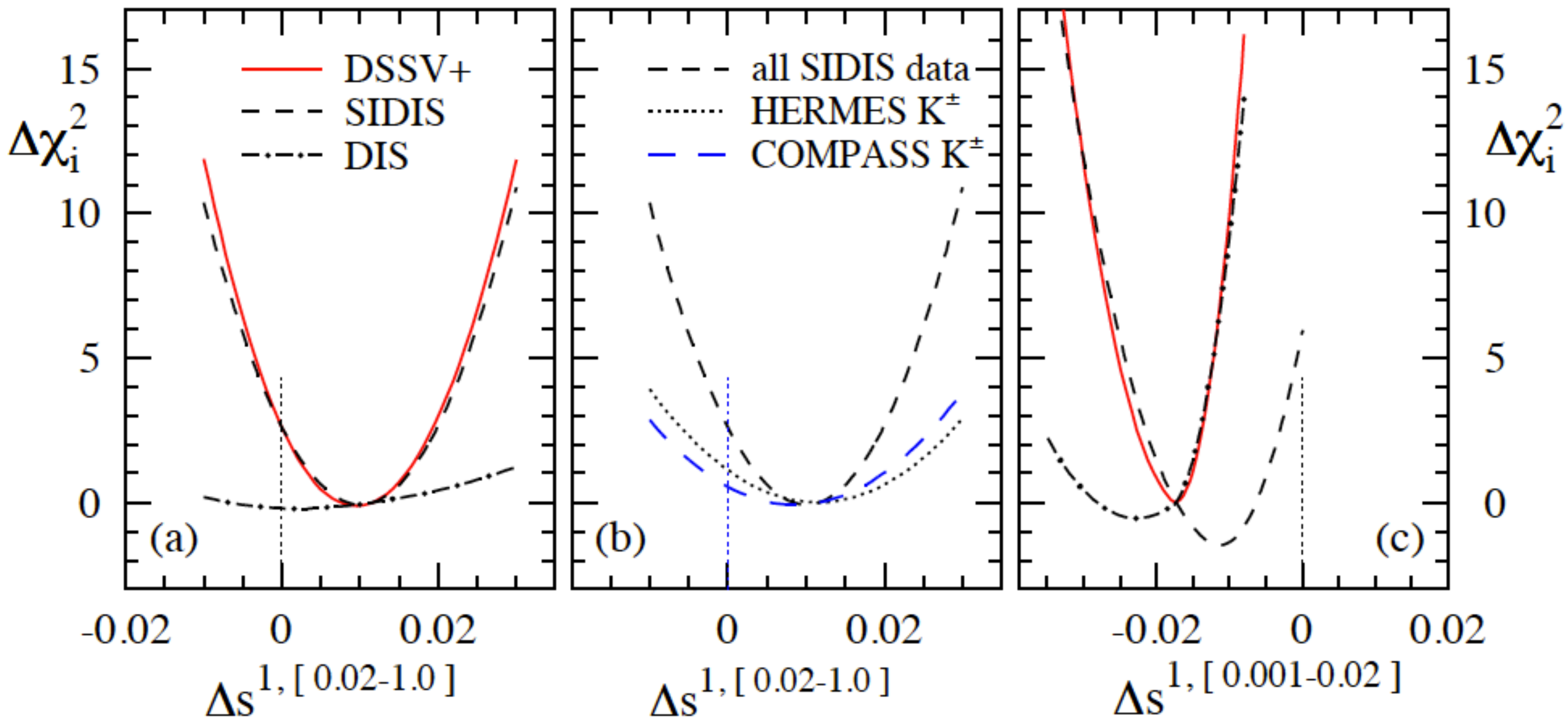
is there a basic QCD mechanism to generate SSAs?

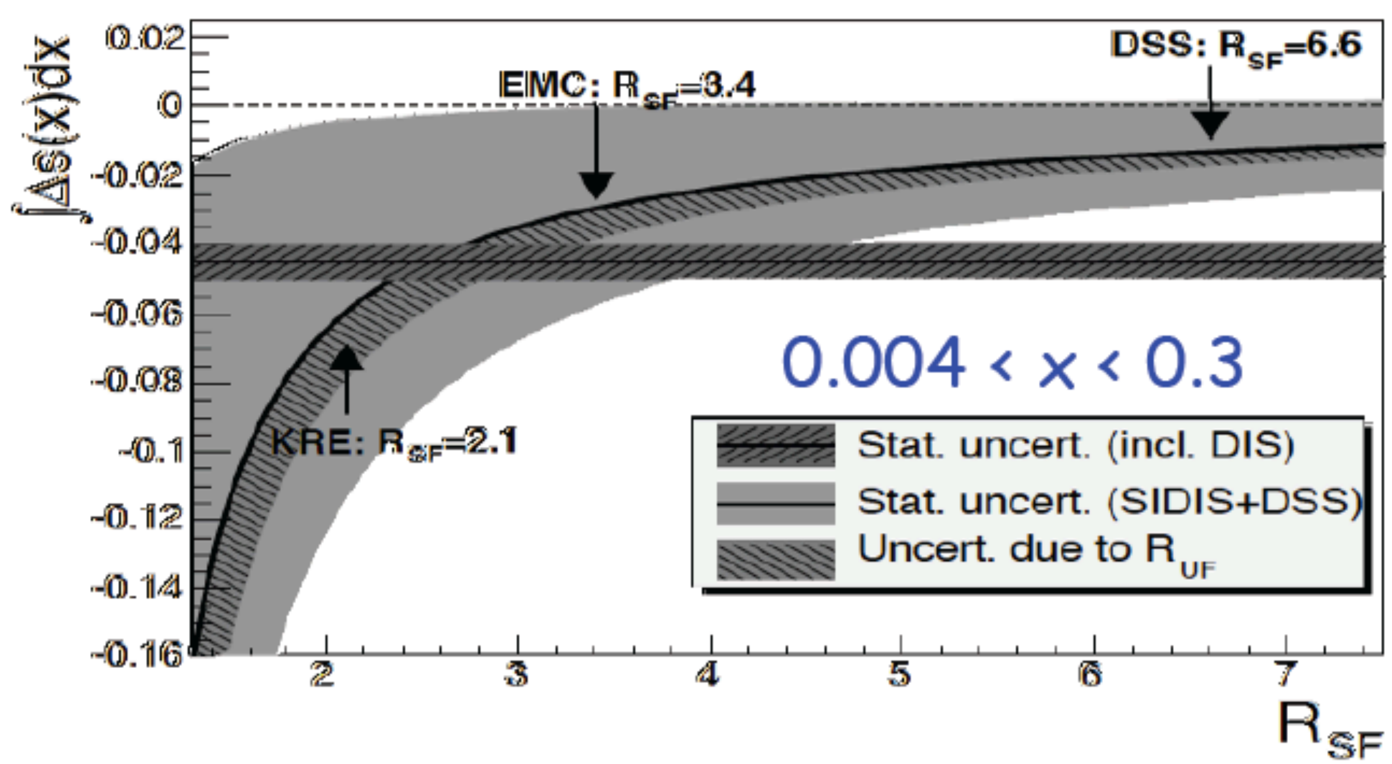
TMDs and the partonic momentum structure of nucleons, orbital motion ....

TMDs, GPDs and the full 3-dimensional momentum and space distribution of partons

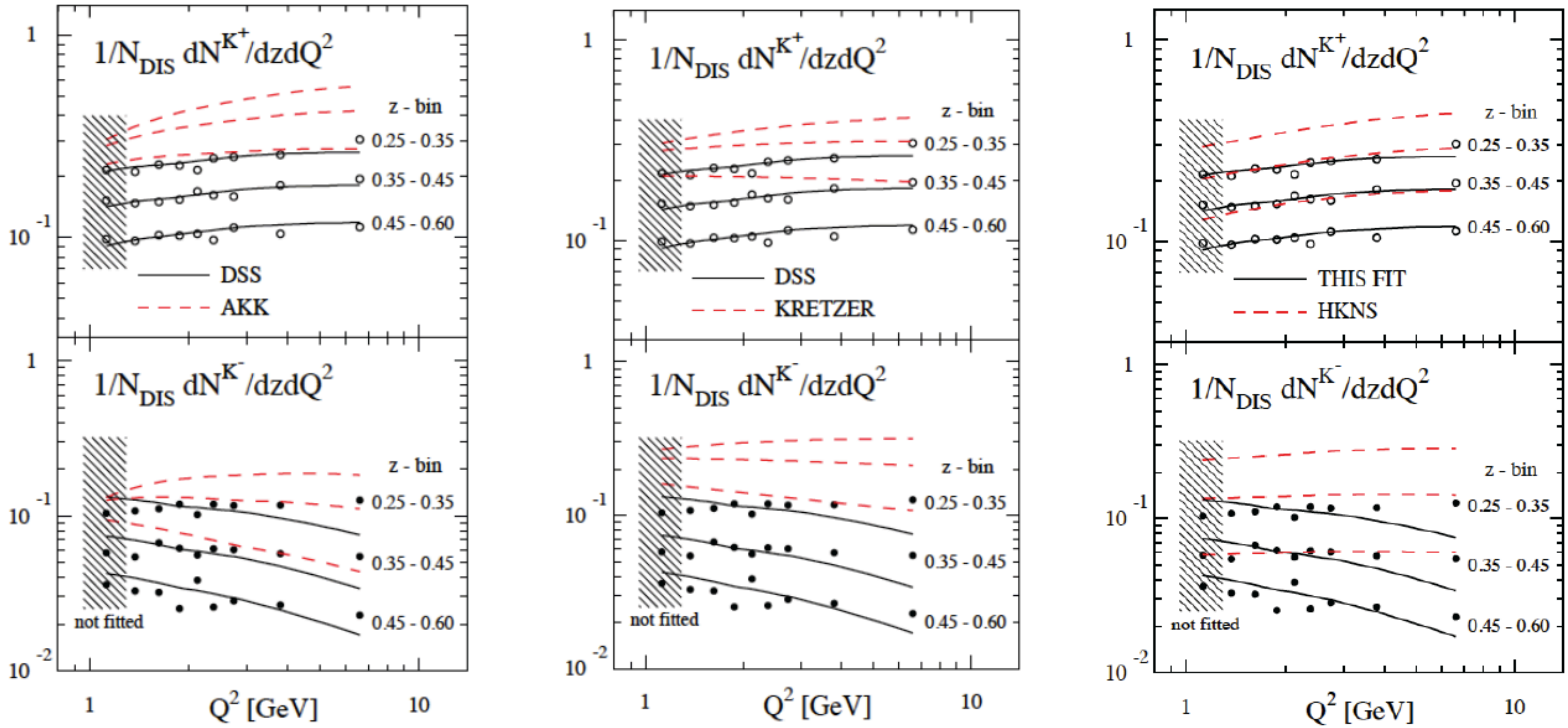
....

Stratmann at DIS 2011





$$R_{SF} \equiv \frac{\int D_{\bar{s}}^{K^+}(z)dz}{\int D_u^{K^+}(z)dz}$$


1/N_DIS dN^K+/dzdQ^2
z - bin
0.25 - 0.35
0.35 - 0.45
0.45 - 0.60
DSS
AKK
1/N_DIS dN^K-/dzdQ^2
not fitted
KRETZER
THIS FIT
HKNS
Q^2 [GeV]

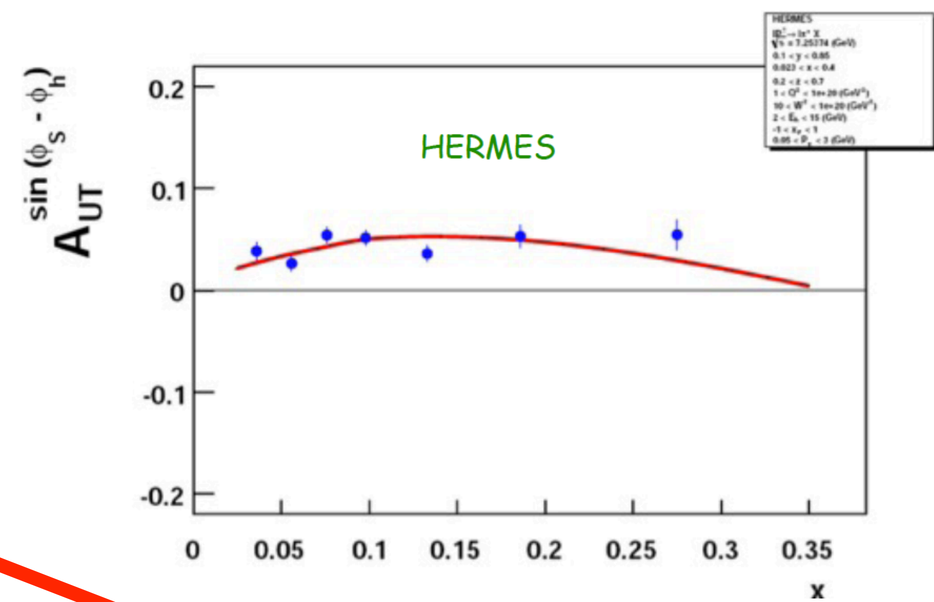
DSS

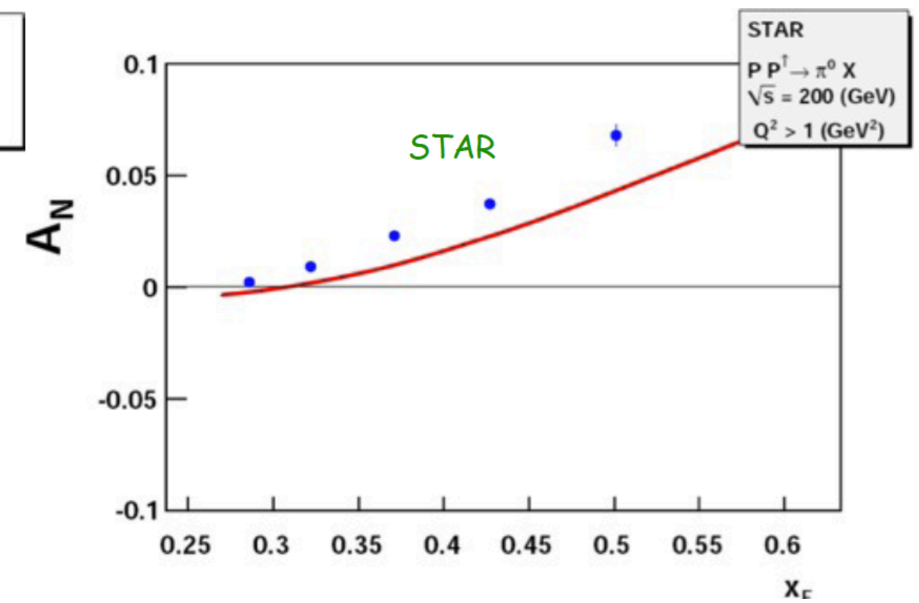
- Perhaps $T_F(x,x)$ has node in x?

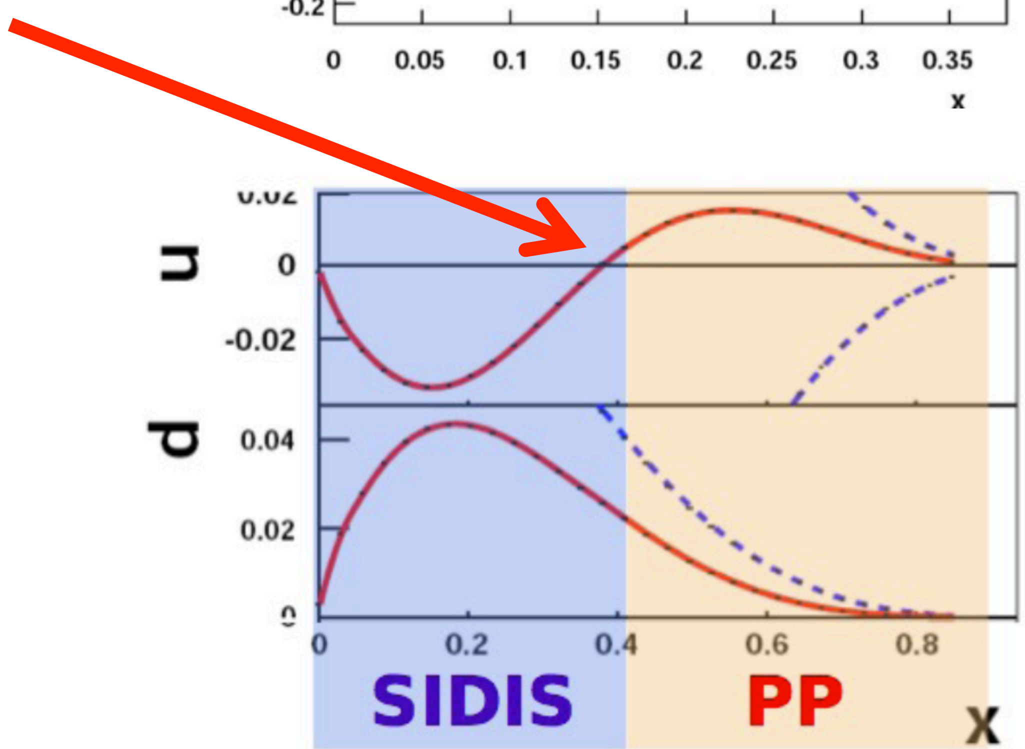
Boer
Kang,Prokudin

joint fit to SIDIS and pp data:

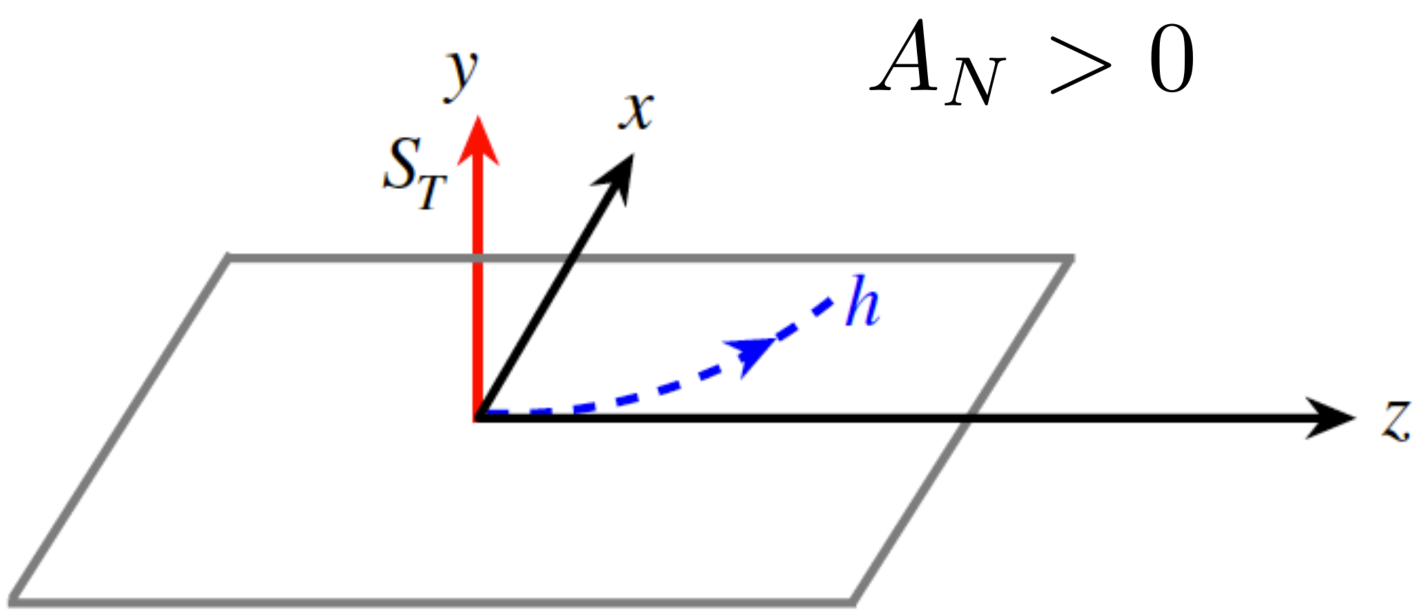
Kang, shown at RHIC Users meeting 2011







(conflict with BRAHMS data?)



$$\epsilon^{P_{h\perp} s_\perp n \bar{n}} = -|P_{h\perp}||s_\perp| \quad < 0$$