New extraction of the Sivers distribution functions

XIX International Workshop on Deep-Inelastic Scattering and Related Subjects

Stefano Melis
European Centre for Theoretical Studies
in Nuclear Physics And Related Areas
ECT*, Trento

In collaboration with
M. Anselmino, E. Boglione,
U. D'Alesio, F. Murgia, A. Prokudin

Summary

- Review of the previous extraction (2009)
- New data vs old fit
- Analysis of the new data
- Conclusions and open questions

Extracted Sivers Functions

- Anselmino et al. Eur. Phys. J. A39,89 (2009)
  - HERMES DATA 2002-2005 (proton target)
  - COMPASS 2003-2004 (deuteron target)

Extracted Sivers Functions

- Simple parametrization of the Sivers function

$$\Delta^N f_{q/p^\uparrow}(x, k_\perp) = 2\,\mathcal{N}_q(x)\,h(k_\perp)\,f_{q/p}(x, k_\perp)$$

Unpolarized PDF $$f_{q/p}(x, k_\perp) = f(x)\frac{e^{-k_\perp^2/\langle k_\perp^2\rangle}}{\pi\langle k_\perp^2\rangle}$$

✔Torino vs Amsterdam notation $$\boxed{\frac{1}{2}\Delta^N f_{q/p^\uparrow}(x, k_\perp) = -\frac{k_\perp}{m_p} f_{1T}^{\perp q}(x, k_\perp)}$$

Extracted Sivers Functions

- Simple parametrization of the Sivers function

$$\Delta^N f_{q/p^\uparrow}(x, k_\perp) = 2\,\mathcal{N}_q(x)\,h(k_\perp)\,f_{q/p}(x, k_\perp)$$

$$\mathcal{N}_q(x) = N_q\, x^{\alpha_q}(1-x)^{\beta_q}\,\frac{(\alpha_q+\beta_q)^{(\alpha_q+\beta_q)}}{\alpha_q^{\alpha_q}\,\beta_q^{\beta_q}} \leq 1$$

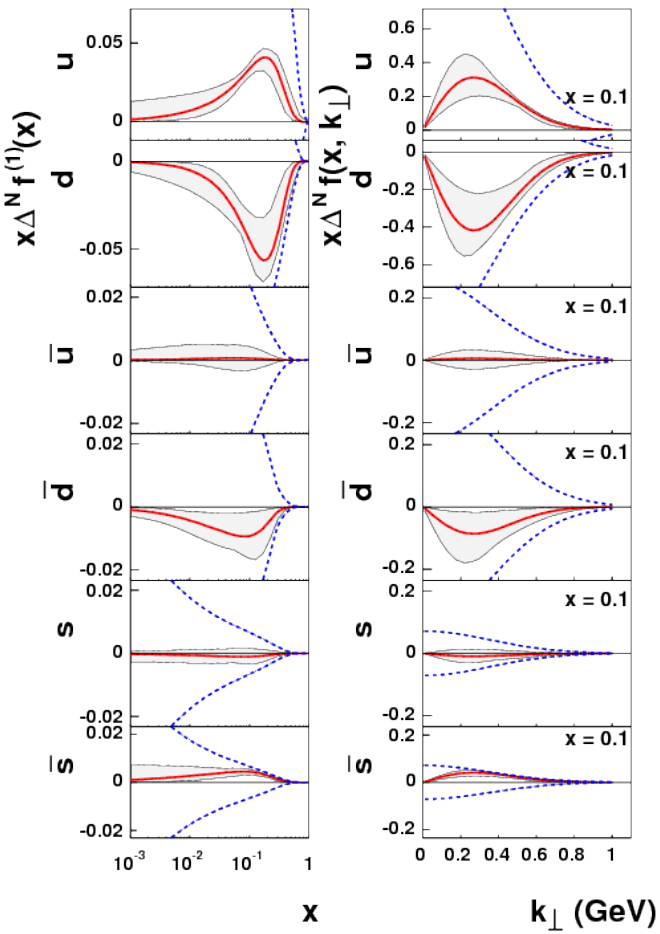
$$h(k_\perp) = \sqrt{2e}\,\frac{k_\perp}{M_1}\,e^{-k_\perp^2/M_1^2} \leq 1$$

N_q, α_q, β_q & M_1 free parameters

Extracted Sivers Functions

HERMES 2002-5 COMPASS 2003-4

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



✔Valence quark

- $\Delta^N f_{u/p^\uparrow} > 0 \quad \Rightarrow f_{1T}^{\perp u} < 0$
- $\Delta^N f_{d/p^\uparrow} < 0 \quad \Rightarrow f_{1T}^{\perp d} > 0$

✔Sea quarks

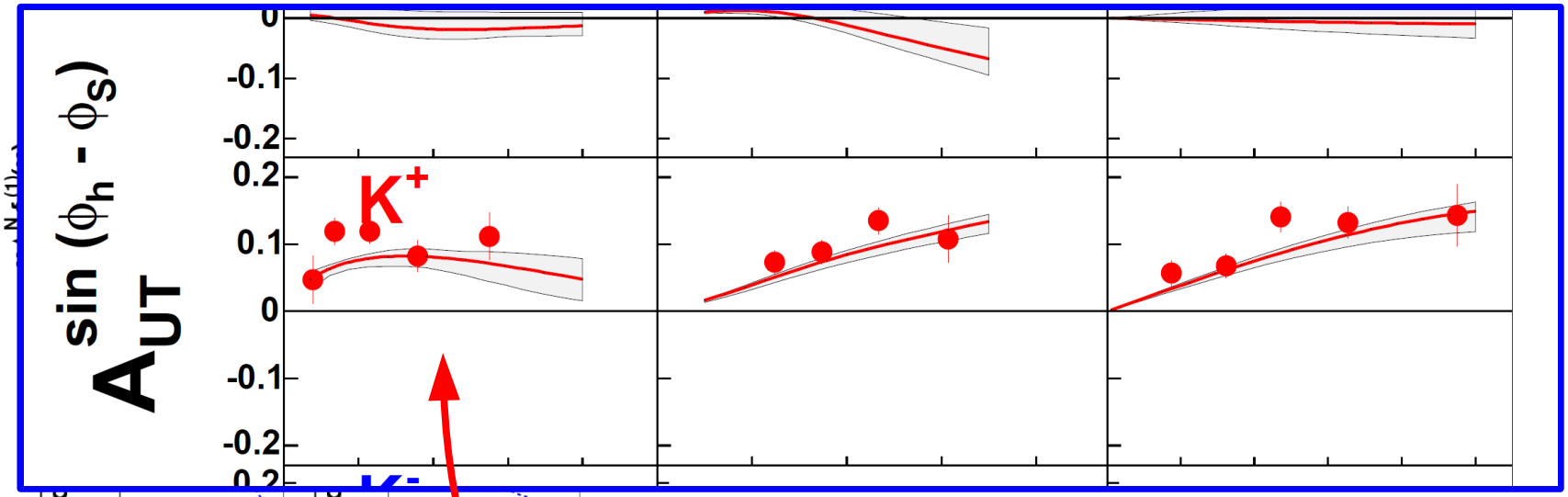
- $\Delta^N f_{\bar{s}/p^\uparrow} > 0 \quad \Rightarrow f_{1T}^{\perp \bar{s}} < 0$

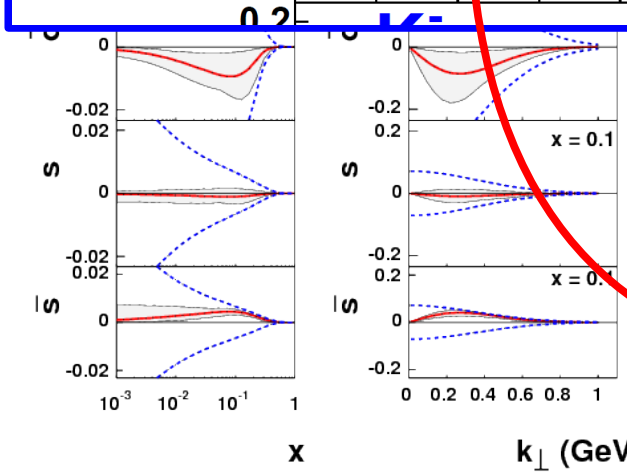
$\chi^2/d.o.f = 1$		
$N_u = 0.35^{+0.078}_{-0.079}$ $N_{\bar{u}} = 0.037^{+0.22}_{-0.24}$ $\alpha_u = 0.73^{+0.72}_{-0.58}$ $\beta = 3.5^{+4.9}_{-2.9}$	$N_d = -0.9^{+0.43}_{-0.098}$ $N_{\bar{d}} = -0.4^{+0.33}_{-0.44}$ $\alpha_d = 1.1^{+0.82}_{-0.65}$ $M_1^2 = 0.34^{+0.3}_{-0.16}$ GeV^2	$N_s = -0.24^{+0.62}_{-0.5}$ $N_{\bar{s}} = 1^{+0}_{-0.0001}$ $\alpha_{sea} = 0.79^{+0.56}_{-0.47}$

➔ $\Delta^N f_q^{(1)}(x) \equiv \int d^2\boldsymbol{k}_\perp \frac{k_\perp}{4m_p} \Delta^N f_{q/p^\uparrow}(x, k_\perp) = -f_{1T}^{\perp(1)q}(x)$

Extracted Sivers Functions

Anselmino et al.





✔Sea quarks

- $\Delta^N f_{\bar{s}/p^\uparrow} > 0$ ⇨ $f_{1T}^{\perp \bar{s}} < 0$

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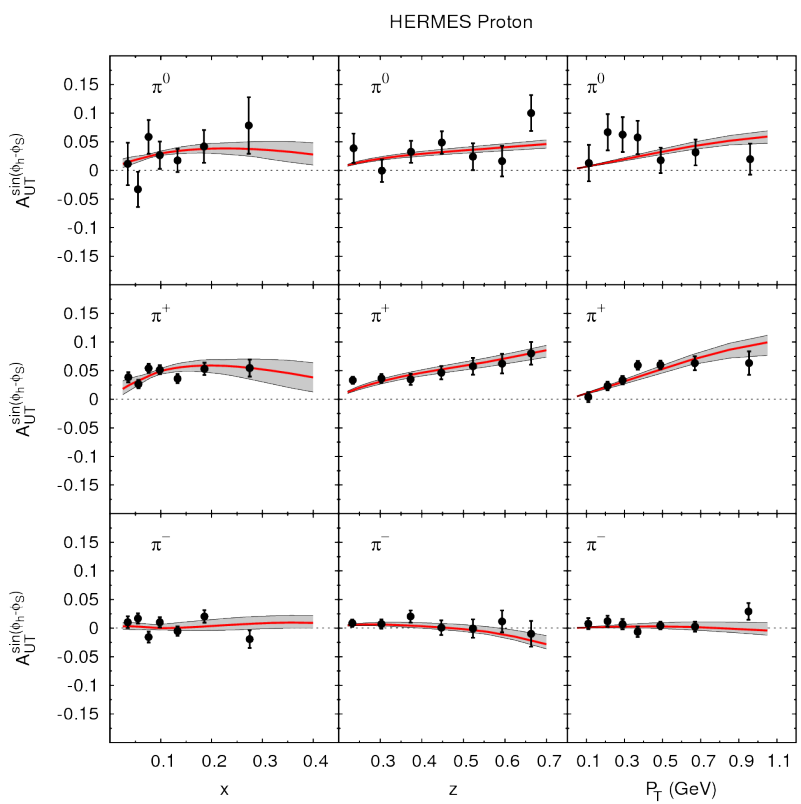
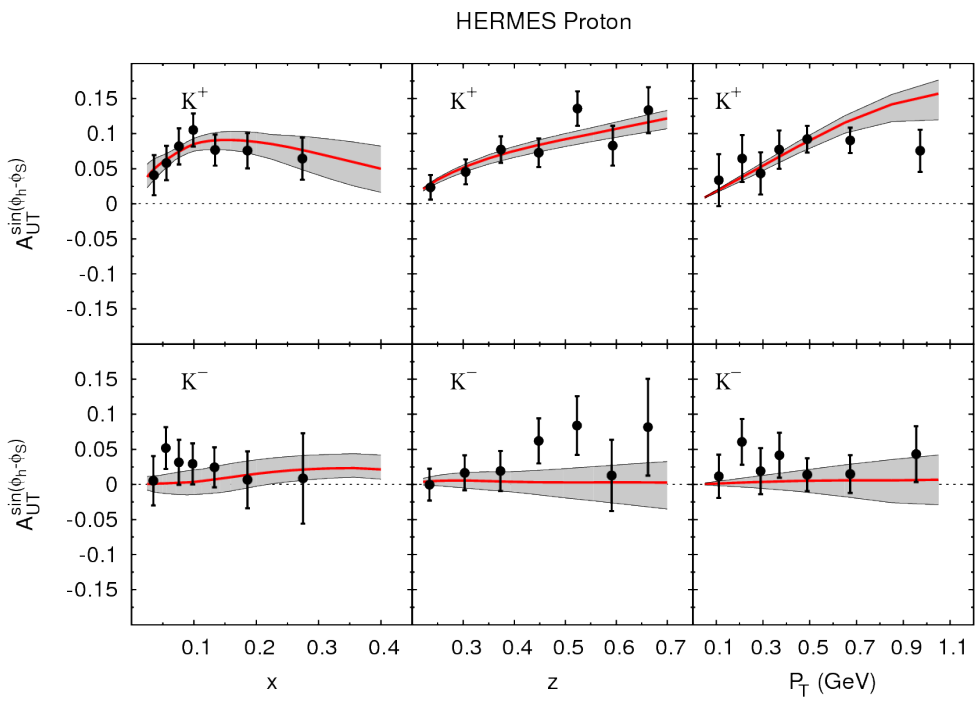
New HERMES and COMPASS DATA!

New data-old fit

HERMES Proton Target-2009





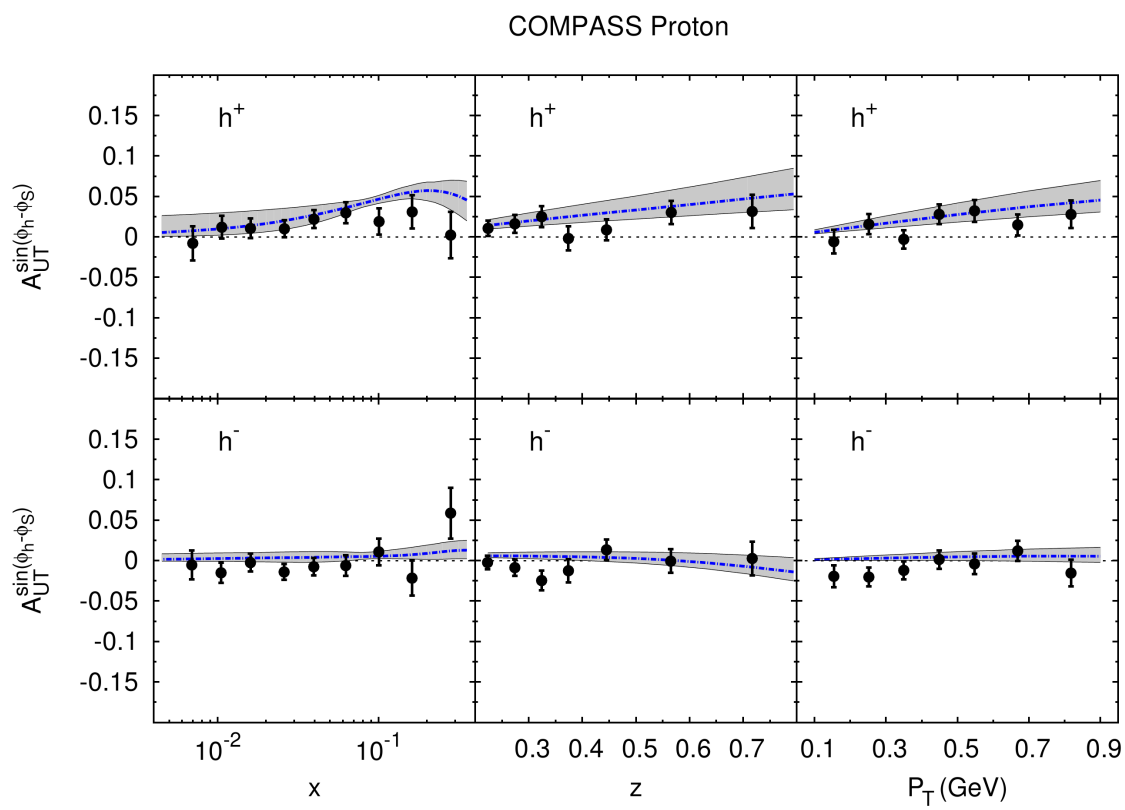
- A. Airapetian et al., Phys. Rev. Lett. 103 (2009) 152002

χ^2/dof=.96

New data-old fit

COMPASS Proton Target

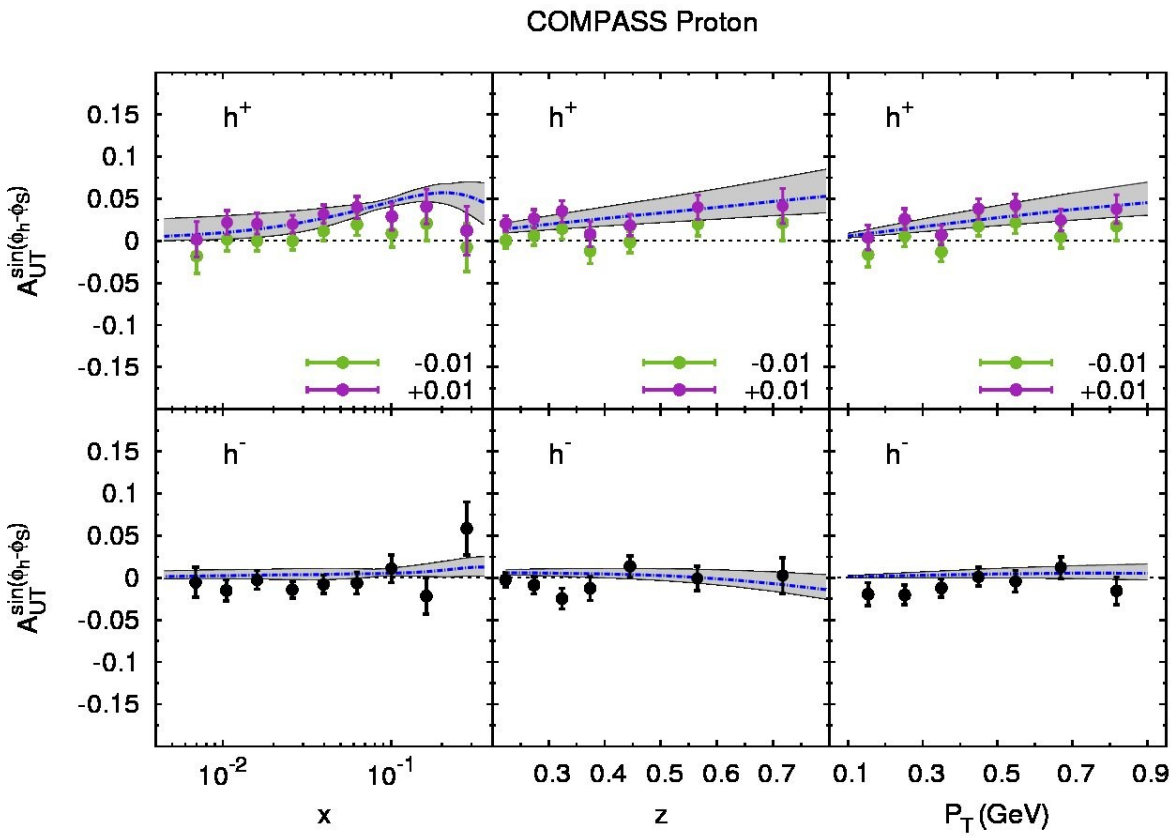
arXiv:1005.5609



Statistical and systematic errors added in quadrature, no scale error

New data-old fit

COMPASS Proton Target



Statistical and systematic errors added in quadrature + scale error

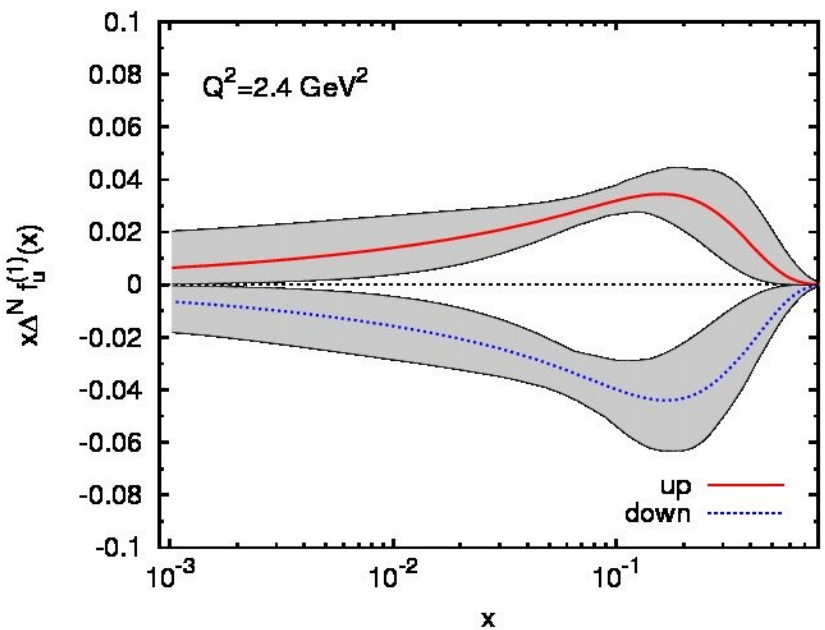
New data-new fit!

- Smaller K^+ asymmetries from HERMES
  - Do we need sea quarks?

- u and d flavours only (7 parameters)
- HERMES DATA(2009) π^+ π^- π^0 K^+ K^-
- COMPASS DATA Deuteron π^+ π^- π^0 K^+ K^-

New data-new fit!

FIT u & d only



	$\chi^2_{dof} = 1.06$	
$N_u = 0.4$ $N_d = -0.97$	$\alpha_u = 0.35$ $\alpha_d = 0.44$ $M_1^2 = 0.19\ \mathrm{GeV}^2$	$\beta_u = 0.26$ $\beta_d = 0.90$

✔ $\Delta^N f_{q/p^\uparrow}(x, k_\perp) = 2\,\mathcal{N}_q(x)\,h(k_\perp)\,f_{q/p}(x, k_\perp)$

✔ $\mathcal{N}_q(x) = N_q\, x^{\alpha_q}(1-x)^{\beta_q}\,\dfrac{(\alpha_q+\beta_q)^{(\alpha_q+\beta_q)}}{\alpha_q^{\alpha_q}\,\beta_q^{\beta_q}}$

✔ $h(k_\perp) = \sqrt{2e}\,\dfrac{k_\perp}{M_1}\,e^{-k_\perp^2/M_1^2}$

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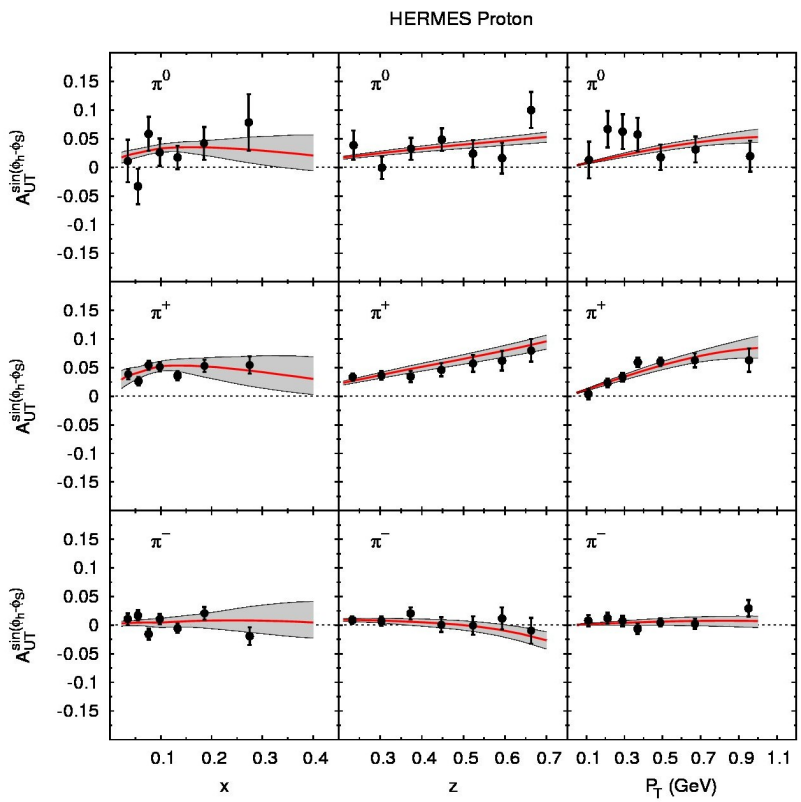

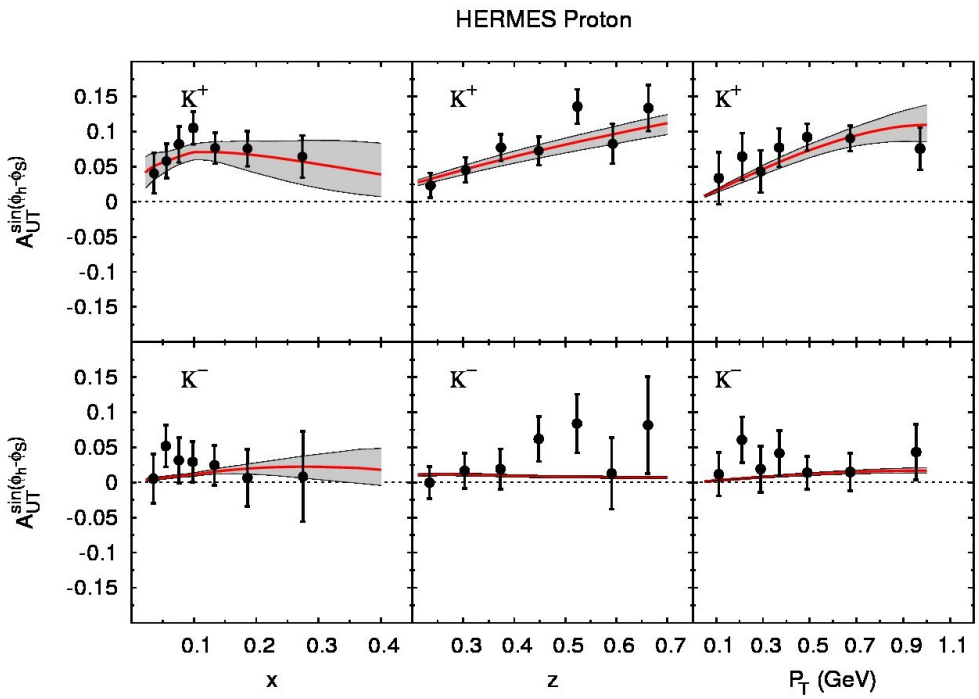

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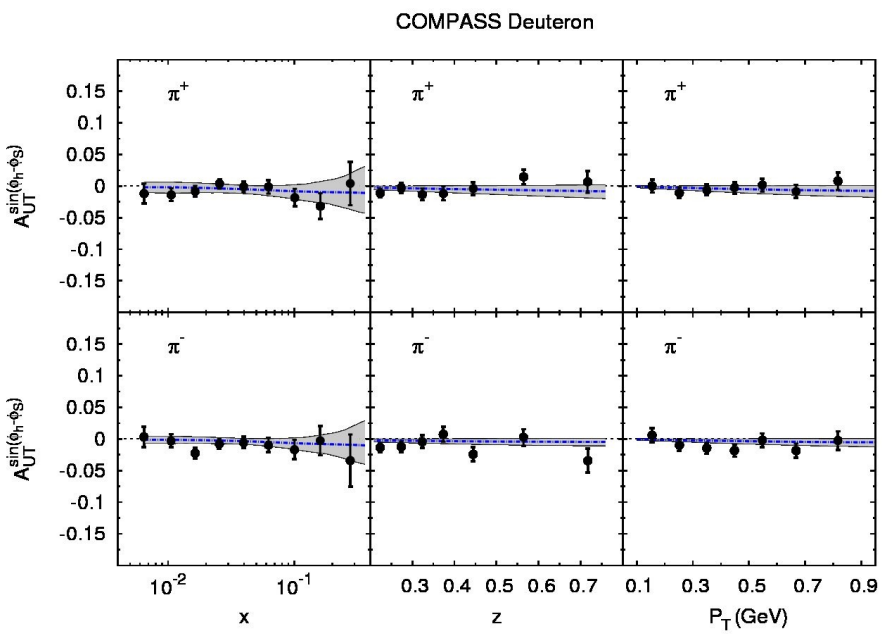

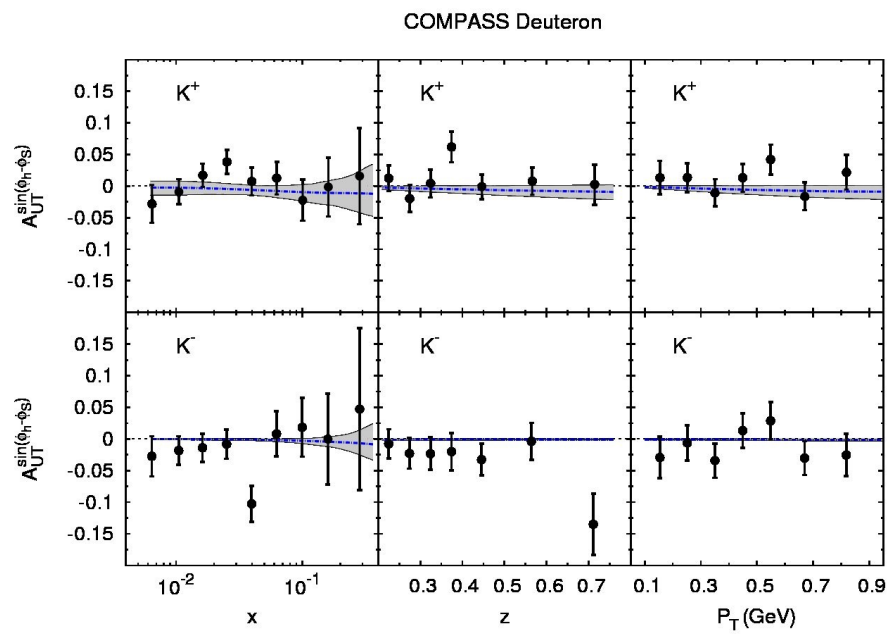

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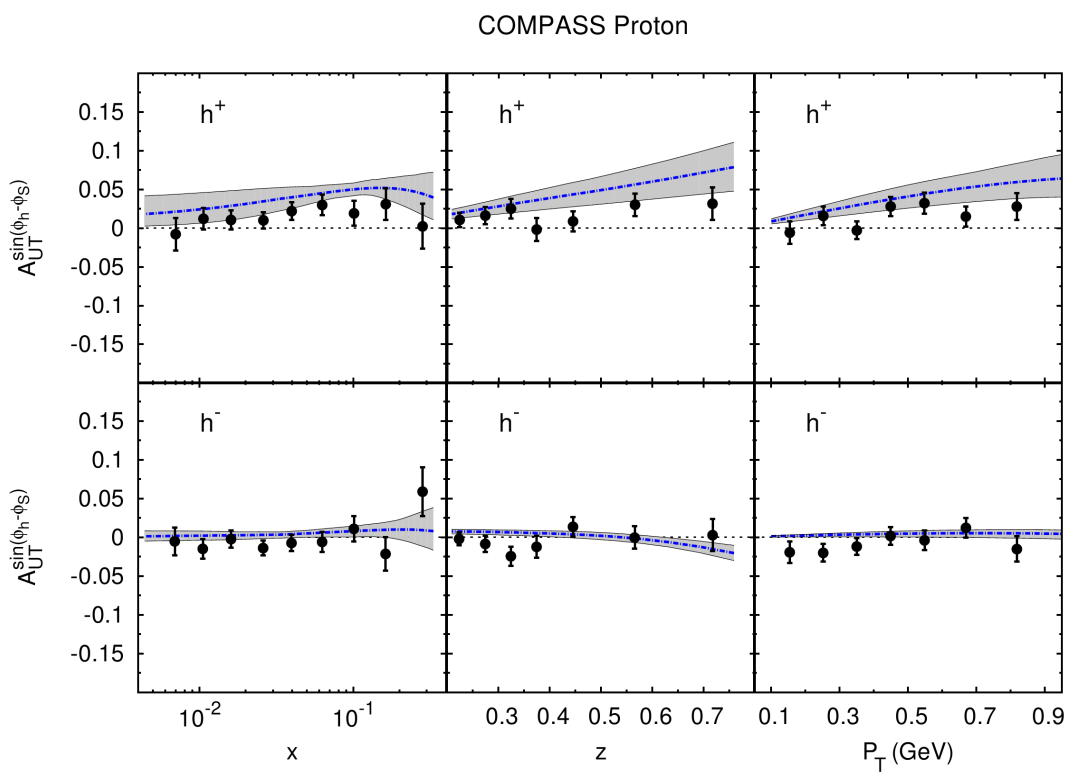
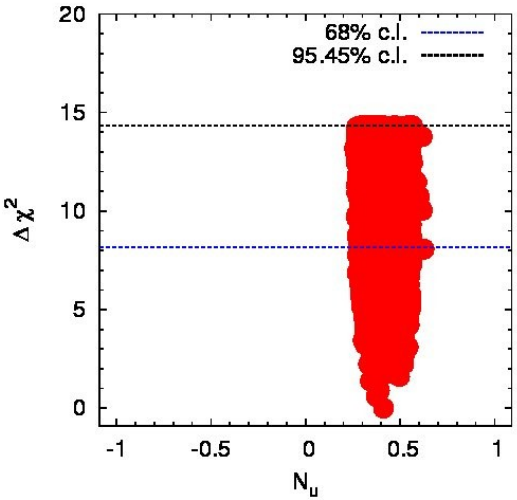
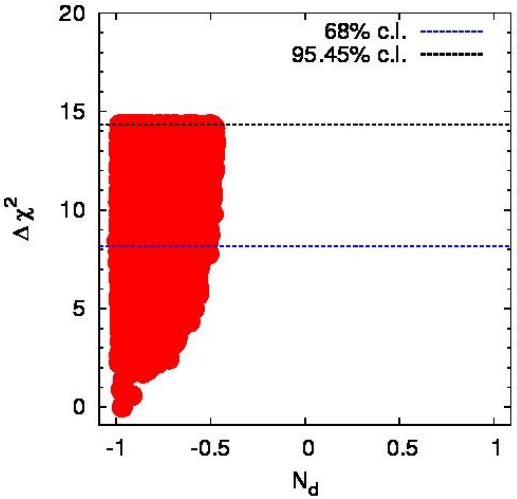


New data-new fit!

FIT I

A look to the parameters





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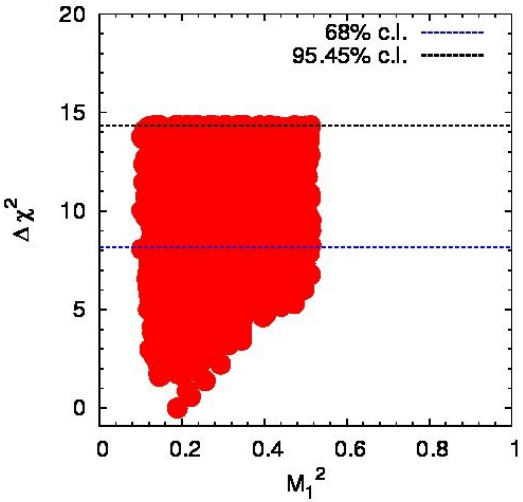

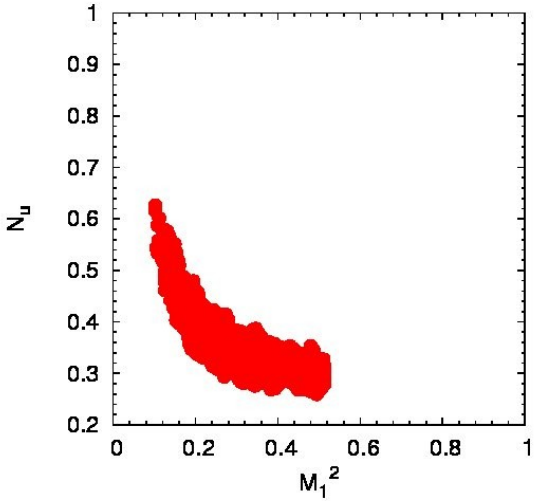

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New data-new fit!

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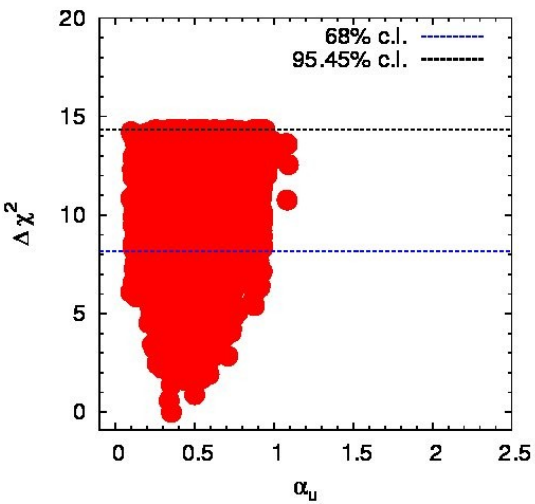

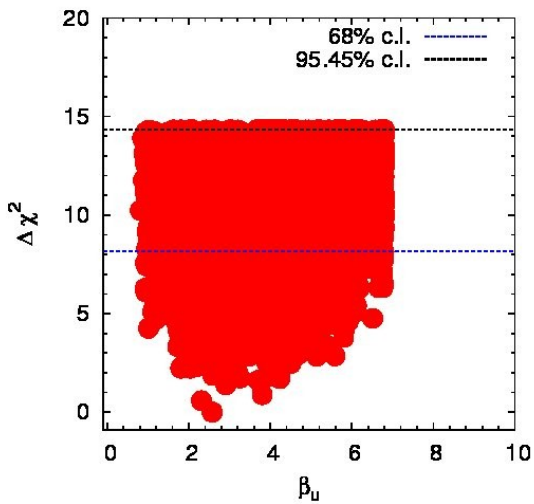

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New data-new fit!

FIT I

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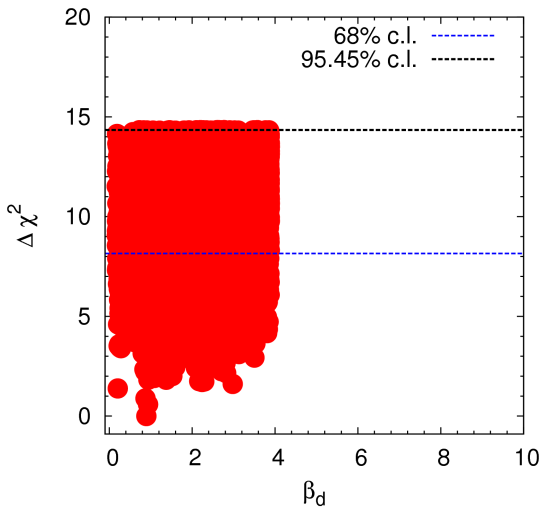

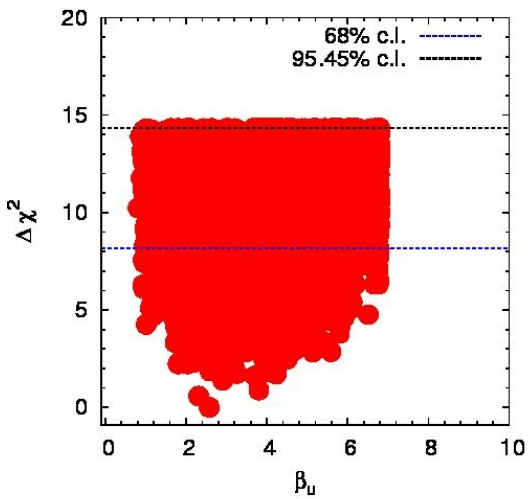

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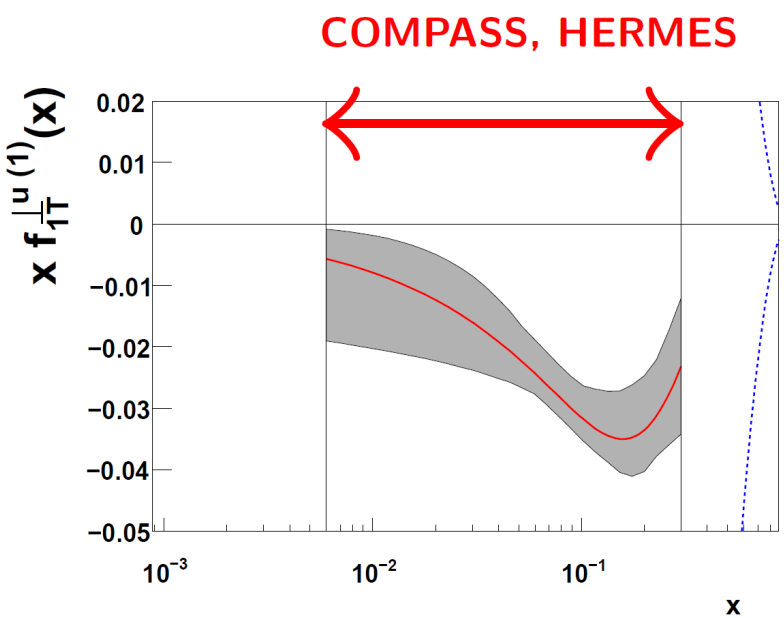
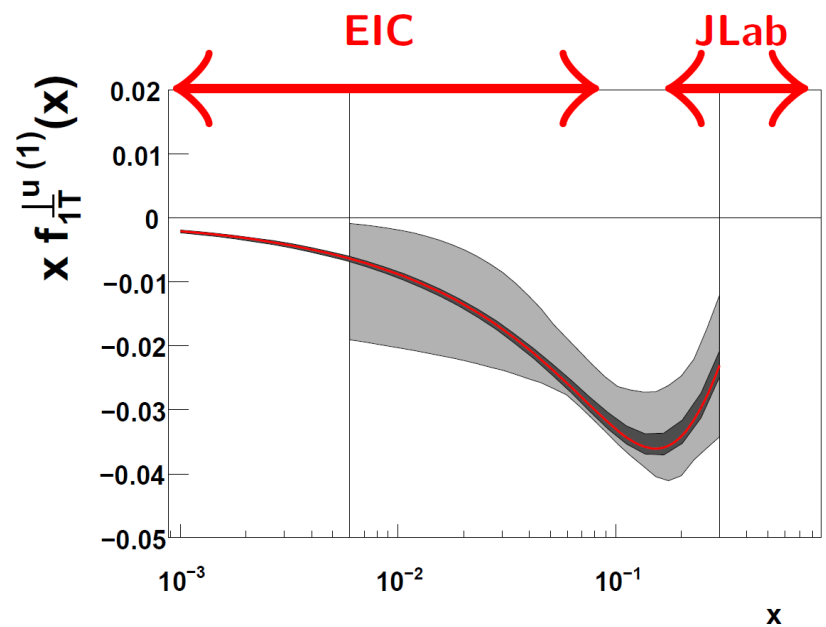
Conclusions I

- The old fit still describes well new HERMES and COMPASS data
- A large anti-strange contribution is no more required
- The "sizes" of the Sivers functions are well constrained in the available kinematical regions
- The behavior of the Sivers functions is not constrained by data in the full x range : JLAB, EIC

Conclusions II



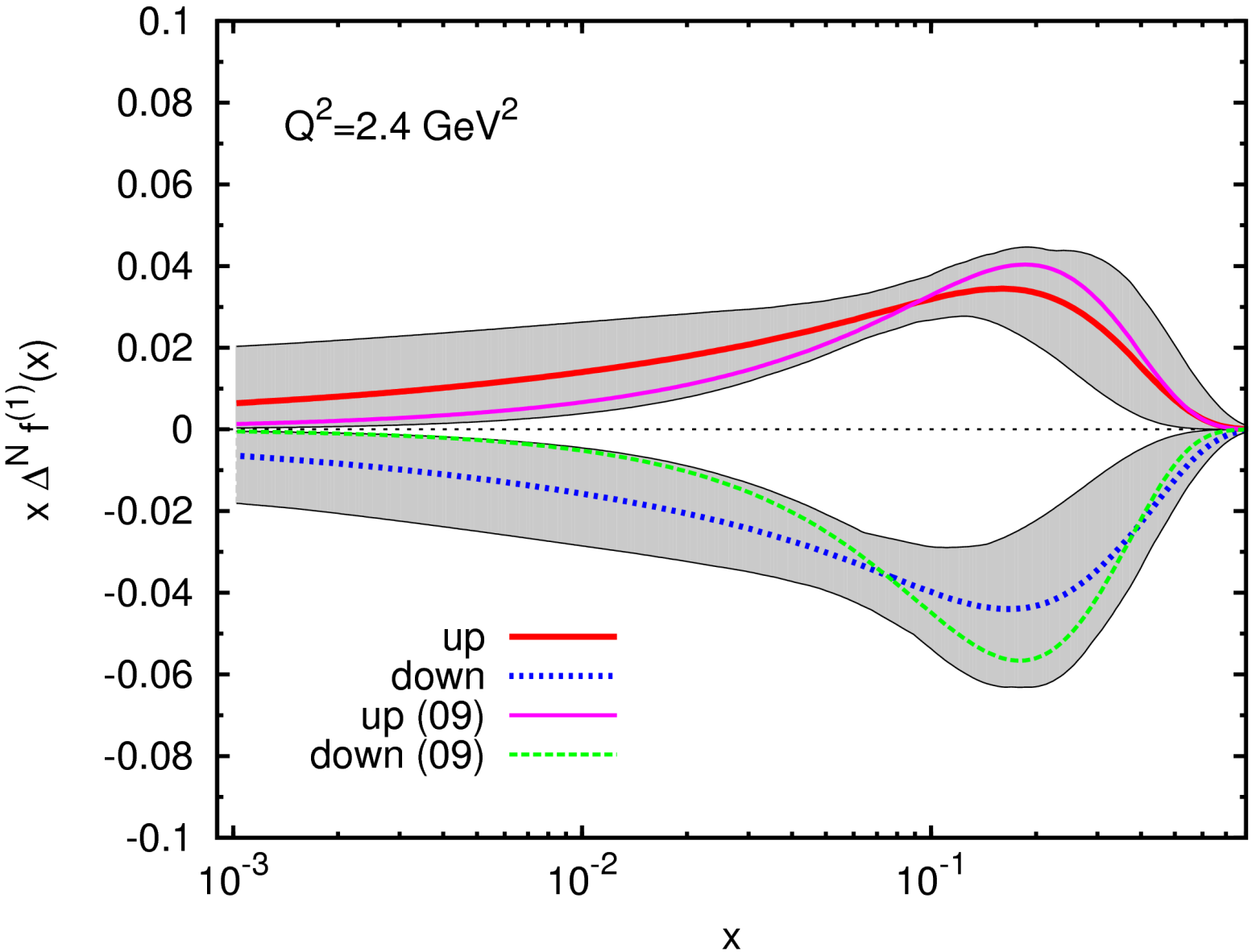


Courtesy of A. Prokudin

Open questions

- The role of sea quarks is important for small x
  Any extrapolation of the Sivers functions
  in this region is delicate.
- For instance our parametrization does not allow a sign change

- Evolution of Sivers function?


Q^2=2.4 GeV^2
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
$x\,\Delta^N f^{(1)}(x)$
10^{-3}
10^{-2}
10^{-1}
x
up
down
up (09)
down (09)

Polarized SIDIS:

Extraction of the Sivers Function

- Gaussian smearing for both unpolarized PDF and FF

$$f_{q/p}(x, k_\perp) = f_q(x) \frac{1}{\pi \langle k_\perp^2 \rangle} e^{-k_\perp^2 / \langle k_\perp^2 \rangle}$$

GRV98 set

[*] $\langle k_\perp^2 \rangle = 0.25 \ (\mathrm{GeV}/c)^2$

$$D_q^h(z, p_\perp) = D_q^h(z) \frac{1}{\pi \langle p_\perp^2 \rangle} e^{-p_\perp^2 / \langle p_\perp^2 \rangle}$$

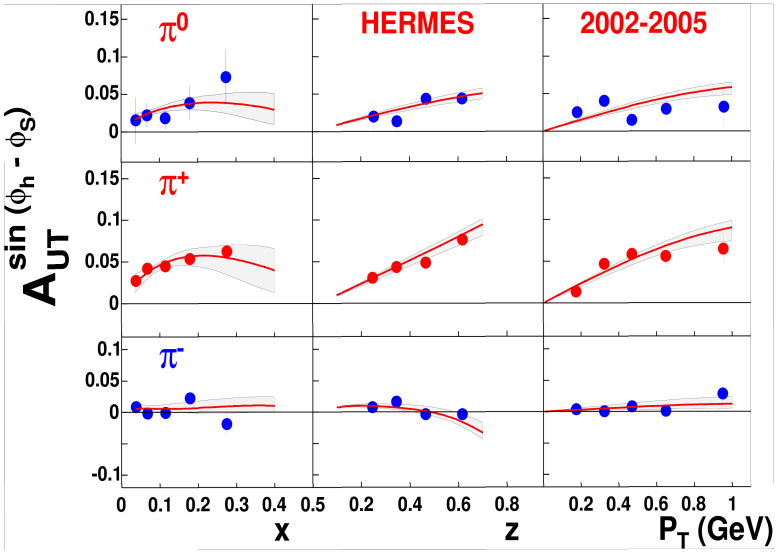
DSS set

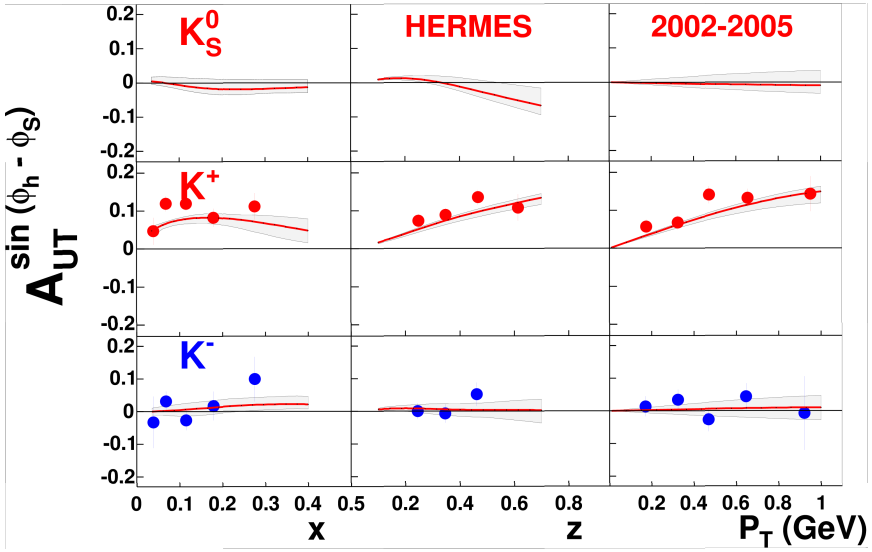
[*] $\langle p_\perp^2 \rangle = 0.20 \ (\mathrm{GeV}/c)^2$

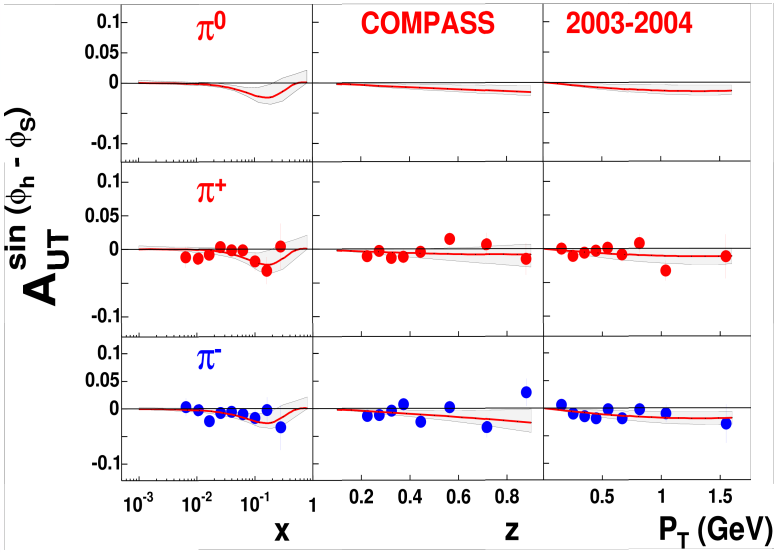
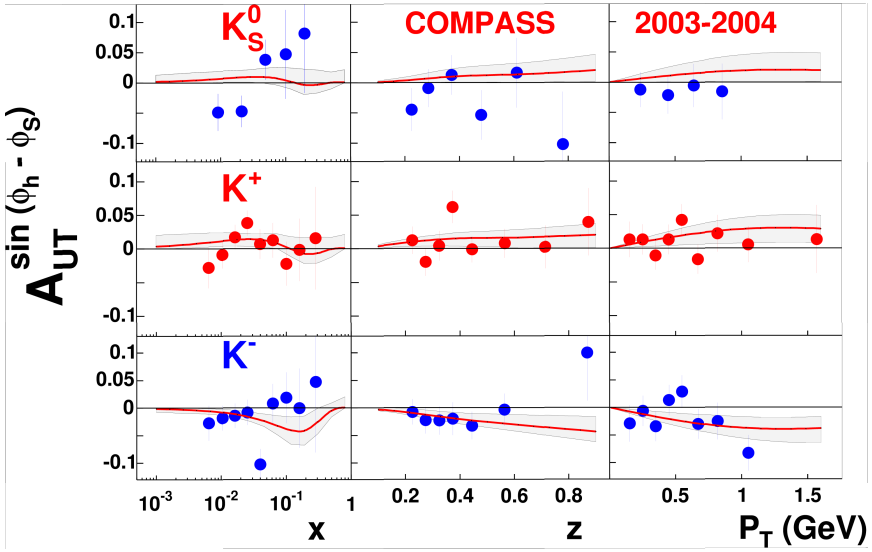
[*]Anselmino et. Phys. ReV D71, 074006 (2005)

Extracted Sivers Functions

HERMES Proton Target





Extracted Sivers Functions

COMPASS Deuteron Target