Longitudinal single-spin asymmetries for pions and kaons obtained at

Christian Schill
on behalf of the HERMES Collaboration

DIS 2003 conference
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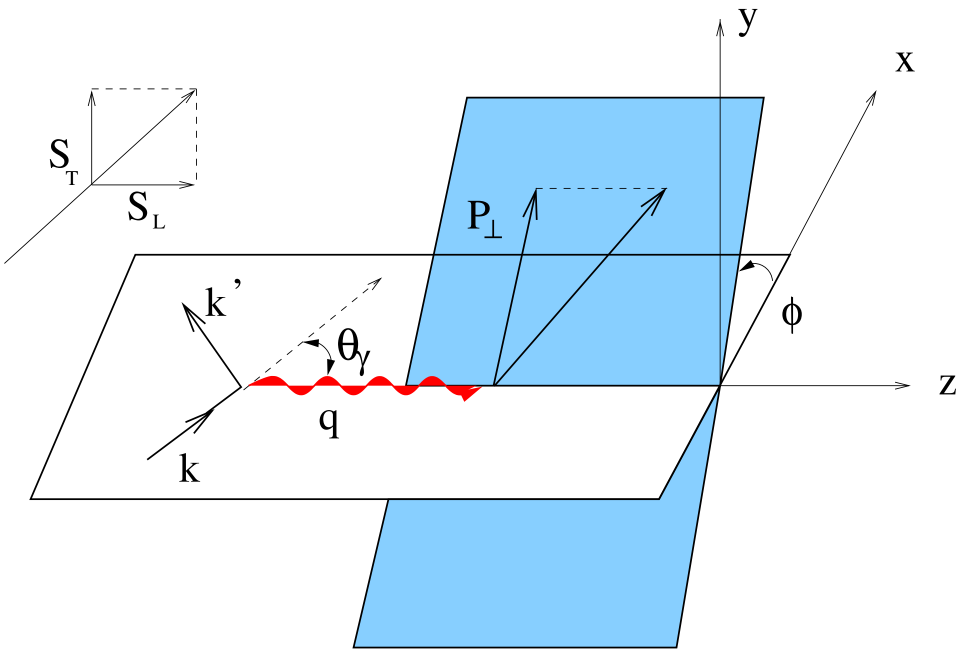
- Single-Spin Asymmetries
- Measurements of Target and Beam Spin Azimuthal Asymmetries at HERMES
- Comparison with Phenomenological Models

Single Target-Spin Asymmetry

- Longitudinally polarized hydrogen or deuteron target
- Unpolarized electron beam (polarization averaged)

$$\boxed{e\vec{p}\,(\vec{d}) \longrightarrow e'\,X\,h}$$



$$S_T = |S|\sin\theta_\gamma \simeq |S|\frac{2Mx}{Q}\sqrt{1-y} \approx 0.15 \cdot |S|$$

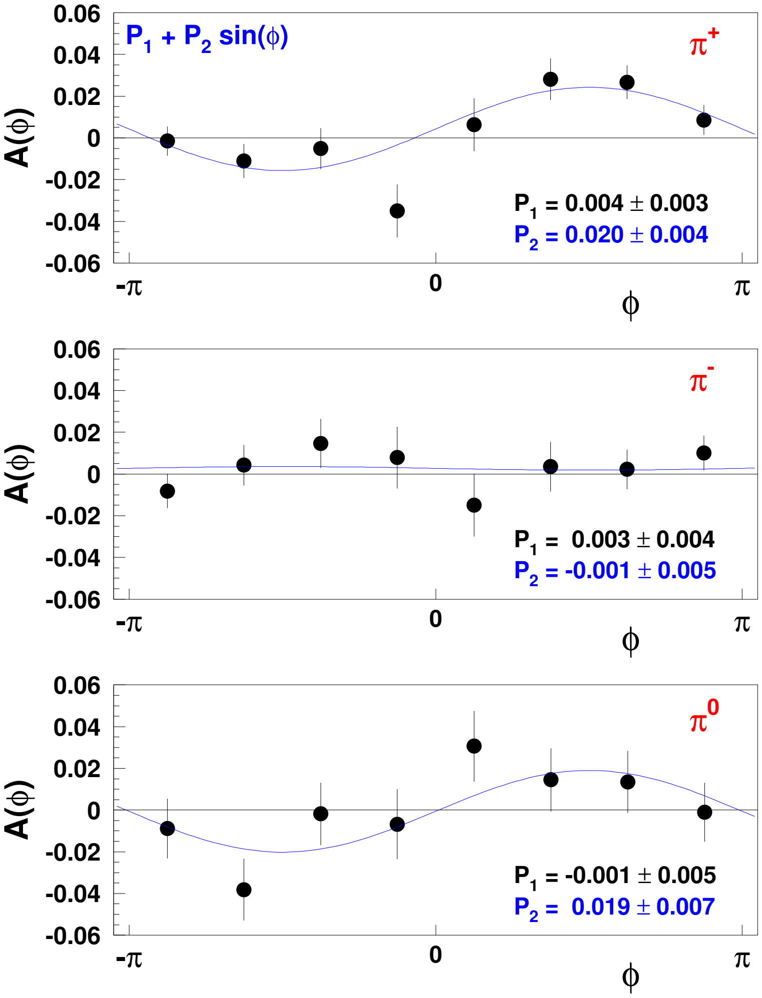
Azimuthal asymmetry:

$$\boxed{A(\phi)_{\mathrm{UL}} = \frac{1}{|S|}\frac{N^{\leftarrow}(\phi) - N^{\rightarrow}(\phi)}{N^{\leftarrow}(\phi) + N^{\rightarrow}(\phi)}}$$

Target SSA $A_{\mathrm{UL}}(\phi)$

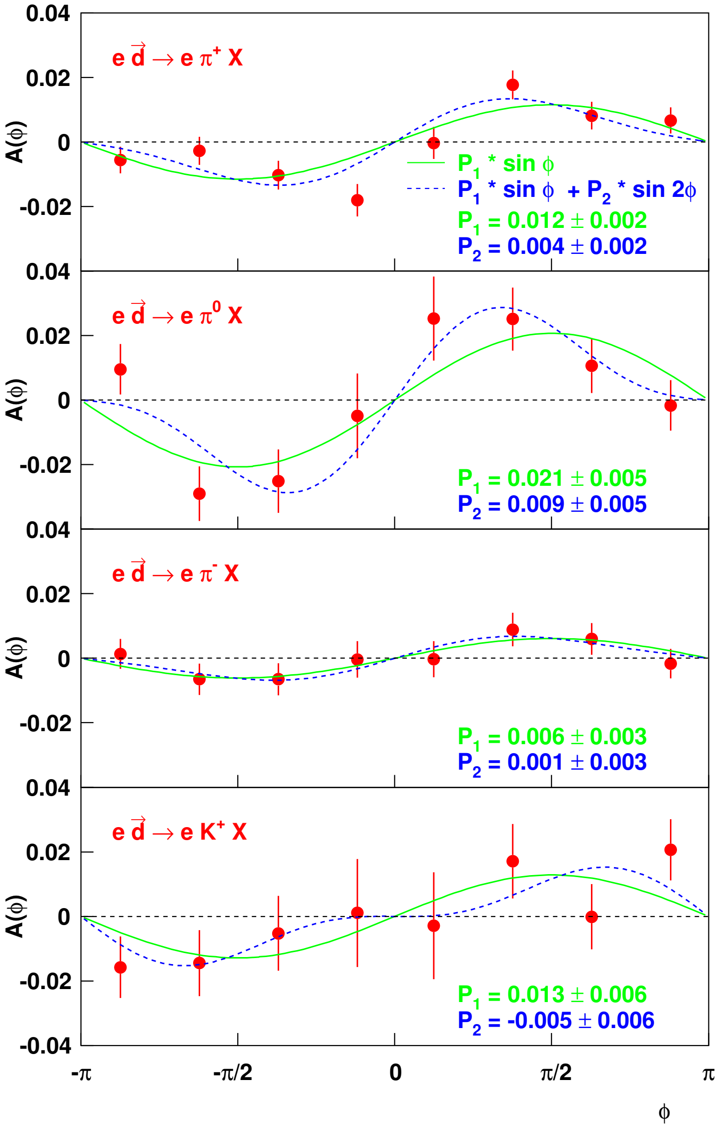
Proton:

HERMES, PRL 84,4047 (2000); PRD 64, 97101 (2001)



Deuteron:

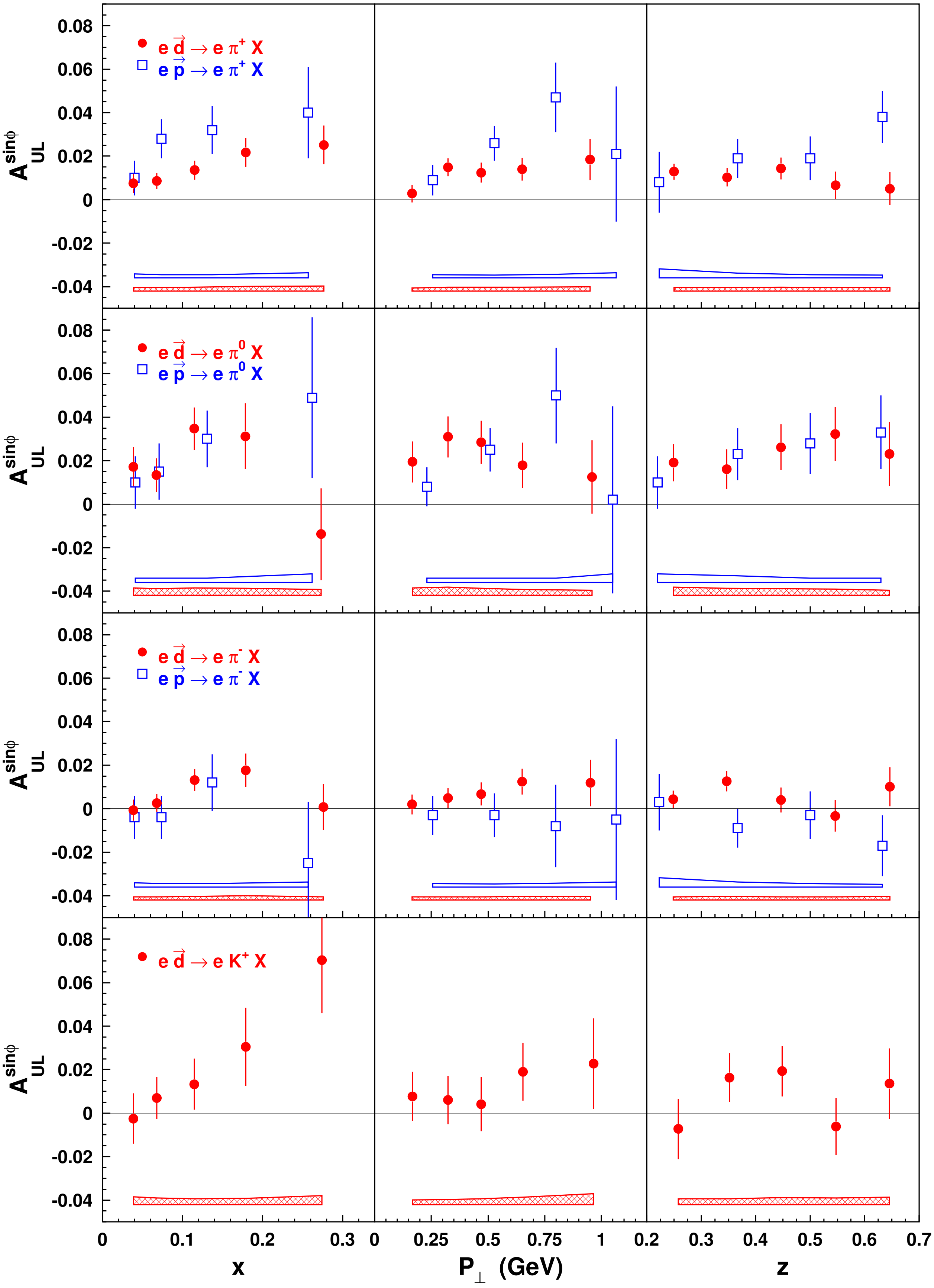
hep-ex/0212037, PLB in press (2003)



$$\langle x \rangle = 0.09,\ \langle y \rangle = 0.57,\ \langle z \rangle = 0.48,\ \langle P_\perp \rangle = 0.44\ \mathrm{GeV},$$
$$\langle Q^2 \rangle = 2.4\ \mathrm{GeV}^2$$

Kinematic Dependences of $A_{UL}^{\sin\phi}$

HERMES, hep-ex/0212037, PLB (2003) in press.



$0.2 < z < 0.7$

A_{UL} Interpretation

Longitudinal polarized target has 2 components:

$\boxed{S_L/S \approx 1}$ and $\boxed{S_T/S \approx 1/Q}$ (kinematics)

$$\langle \sin\phi \rangle_{\mathrm{UL}} \propto S_T \sum_{a,\bar{a}} e_a^2\, h_1^a(x)\, H_1^{\perp a}(z)$$

$$+ \frac{1}{Q} S_L \sum_{a,\bar{a}} e_a^2 \left[\tilde{h}_L^a(x)\, H_1^{\perp a}(z) \oplus h_{1L}^{\perp a}(x) H_1^{\perp a}(z) \oplus h_{1L}^{\perp a}(x) \tilde{H}(z) \right]$$

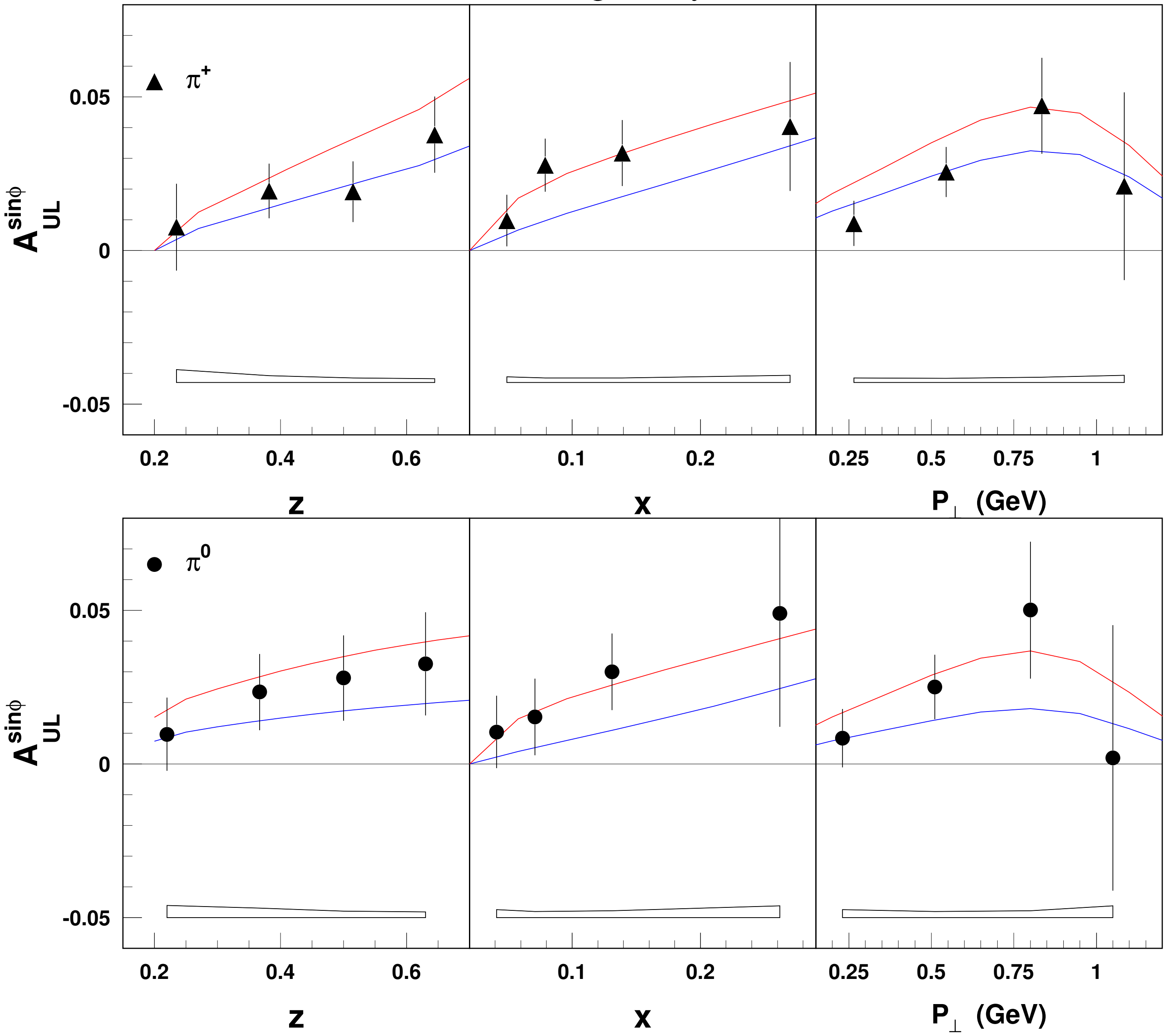
$$\langle \sin 2\phi \rangle_{\mathrm{UL}} \propto S_L \sum_{a,\bar{a}} e_a^2\, h_{1L}^{\perp a(x)}\, H_1^{\perp a}(z)$$

The longitudinal part of $\langle \sin\phi \rangle_{\mathrm{UL}}$ has sub-leading order and involves interaction-dependent twist-3 distribution and fragmentation functions like $\tilde{h}_L(x)$ and $\tilde{H}(z)$

Model Calculations for $A_{\mathrm{UL}}^{\sin\phi}$

$$e\vec{p} \to e\pi X$$

[Oganessyan *et al.*, PLB 483 (2000) 69]



Assumption:

$$h_{1L}^{\perp}(x) \approx 0,\ \tilde{h}_L(x) = h_1(x) - \frac{\mathrm{d}}{\mathrm{dx}} h_{1L}^{\perp}(x) \approx h_1(x)$$

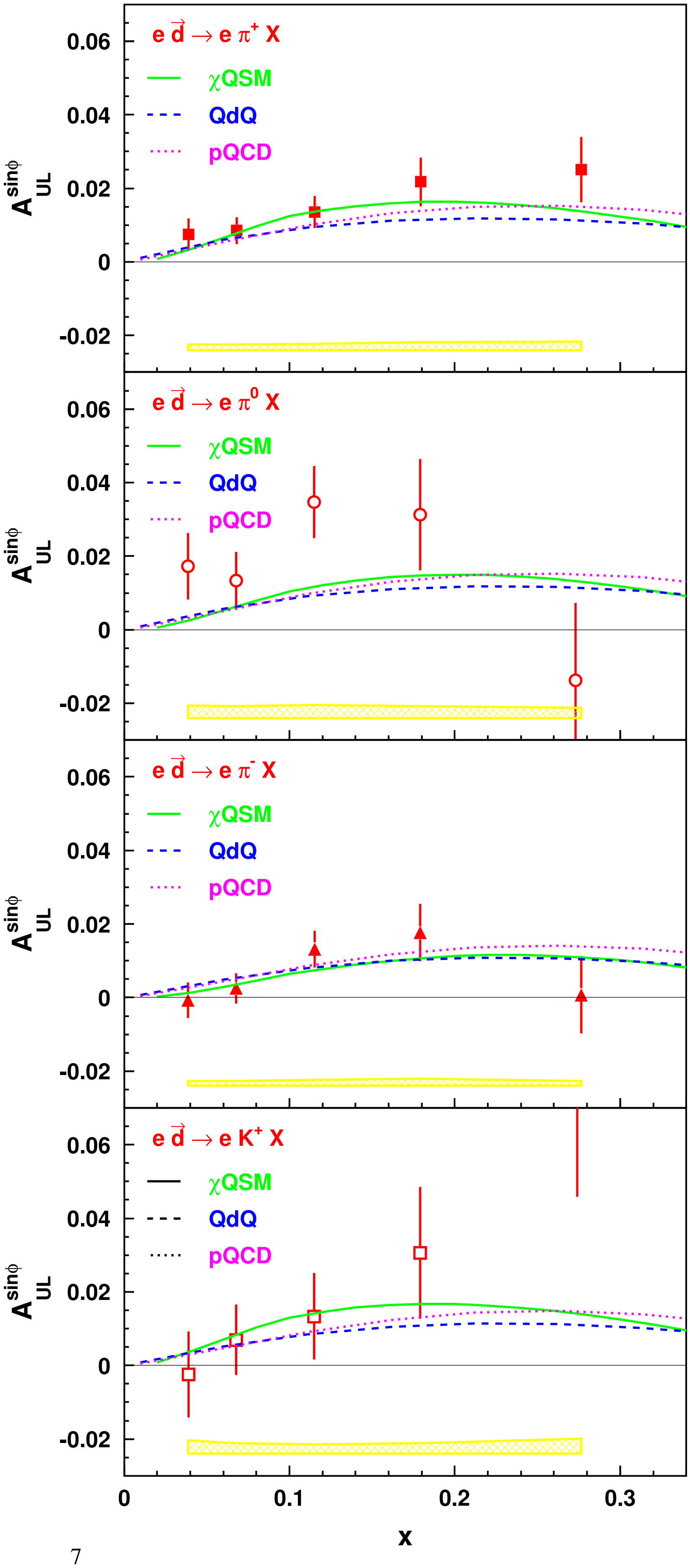
upper limit: $h_1 = (f_1 + g_1)/2$ Soffer inequality

lower limit: $h_1 = g_1$ non-relativistic limit

'Collins guess' for $H_1^{\perp} = \eta \dfrac{M_C |k_T|}{M_C^2 + k_T^2}$

Model Calculations for $A_{UL}^{\sin\phi}$

[Ma *et al.*, PRD66 (2002) 94001, Efremov *et al.*, PLB 544 (2002) 389]



h_1 calculated in: χQSM, QdQ, pQCD models.

Assumptions for twist-3:

$\boxed{h_1(x):}$

$\tilde{h}_L \simeq 0$

$$h_{1L}^{a}(x) = 2x\int_0^1 dx' \frac{h_1^a(x')}{x'^2} + \tilde{h}_L^a(x)$$

$\boxed{H_1^{\perp}(z):}$

χ QCD:

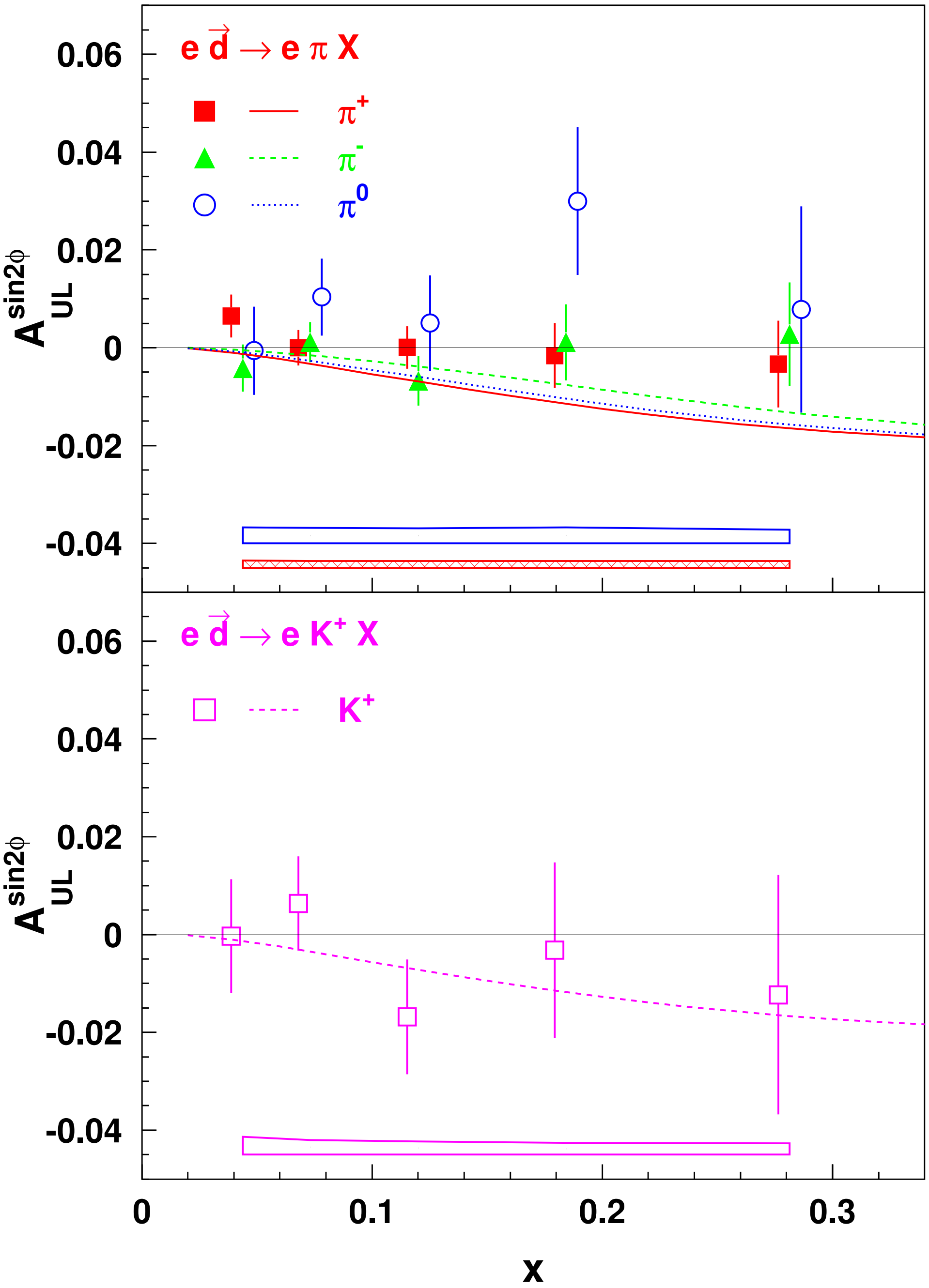
$$\left|\frac{\langle H_1^{\perp}\rangle}{\langle D_1\rangle}\right| = (12.5 \pm 1.4)\%$$

QdQ, pQCD:

'Collins guess'

Model Calculations for $A_{\mathrm{UL}}^{\sin 2\phi}$

[Efremov *et al.*, PLB 544 (2002) 389]



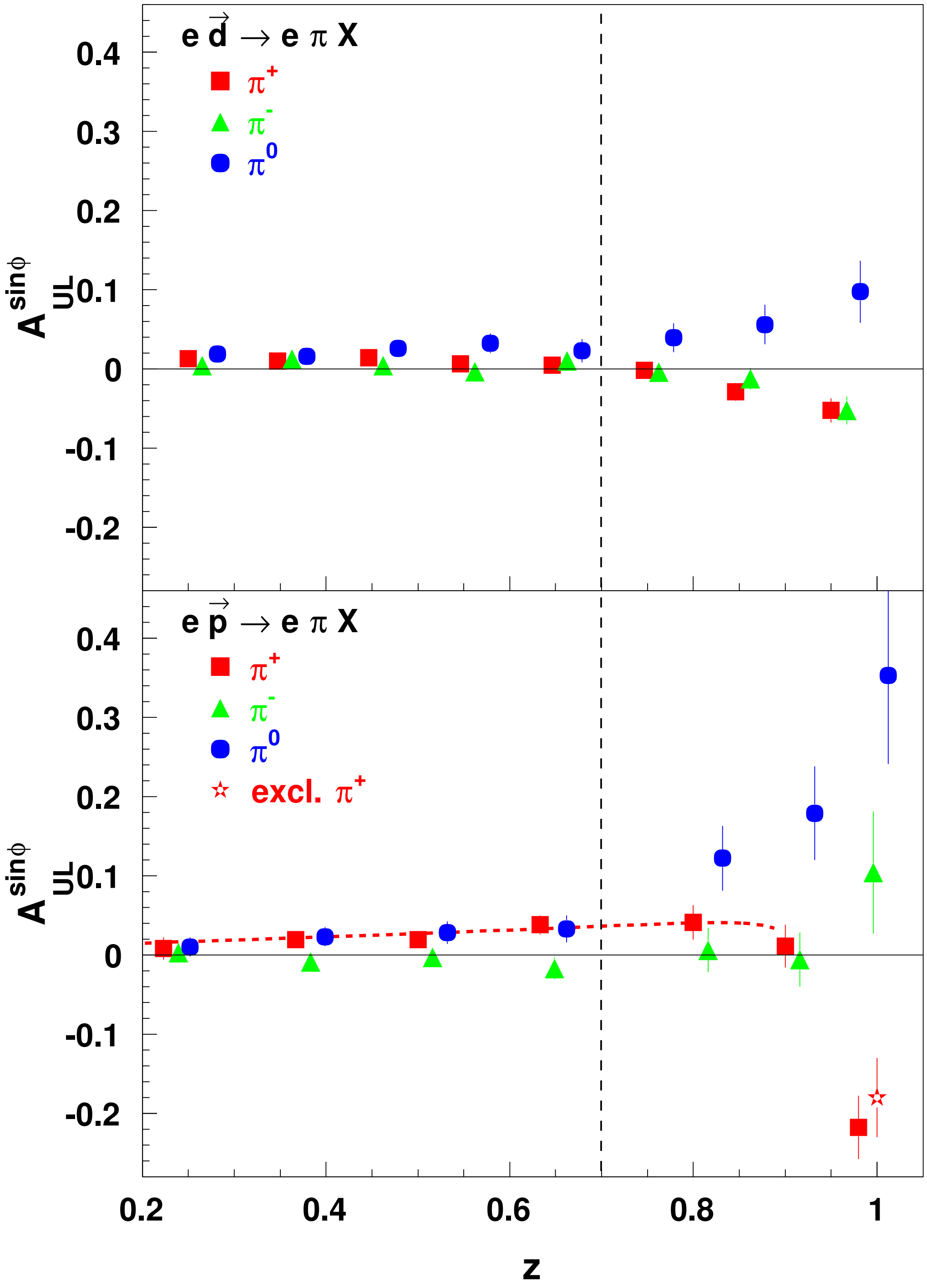
Chiral Quark-Soliton Model:

$\boxed{h_1(x):}$ $$h_{1L}^a(x) = 2x \int_0^1 dx' \frac{h_1^a(x')}{x'^2} + \tilde{h}_L^a(x), \qquad \tilde{h}_L \simeq 0$$

$\boxed{H_1^\perp(z):}$ $$\left|\frac{\langle H_1^\perp\rangle}{\langle D_1\rangle}\right| = (12.5 \pm 1.4)\%$$

z-Dependence of $A_{UL}^{\sin\phi}$

[HERMES, hep-ex/0212037, PLB in press, PLB 535 (2002) 85, curve from Bacchetta *et al.*, hep-ph/0206309]



- Model Calculation (normalized to the data): z-dependence of Collins function $H_1^\perp(z)$ at the one-loop level in a chiral-invariant model.
- Another Model by Oganessyan et al. Nucl.Phys. A689 (2001) 784 shows very similar curve.

Remarks on Model Calculations

$\sin\phi$ moments on proton and deuteron targets well described by various model calculations based on the Collins effect

BUT

S_T suppressed by $1/Q$ for a longitudinally polarised target

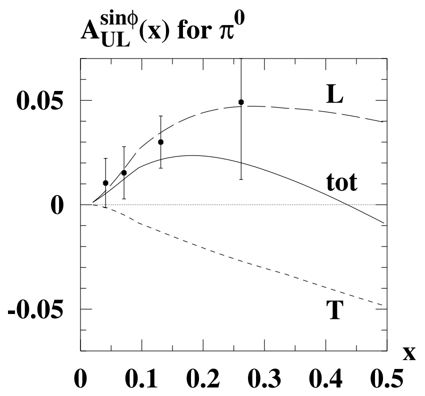
$A_{\mathrm{UL}}^{\sin\phi} \propto$ twist-3 contribution: $h_{1L}H_1^{\perp} \approx 75\%$

S_T contribution $\approx 25\%$ (x-dependent)

with opposite sign!

[K. Oganessyan]

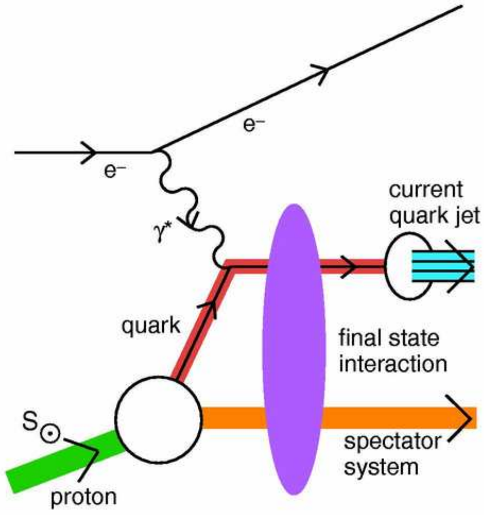
[Efremov *et al.* PLB 544, 389 (2002)]



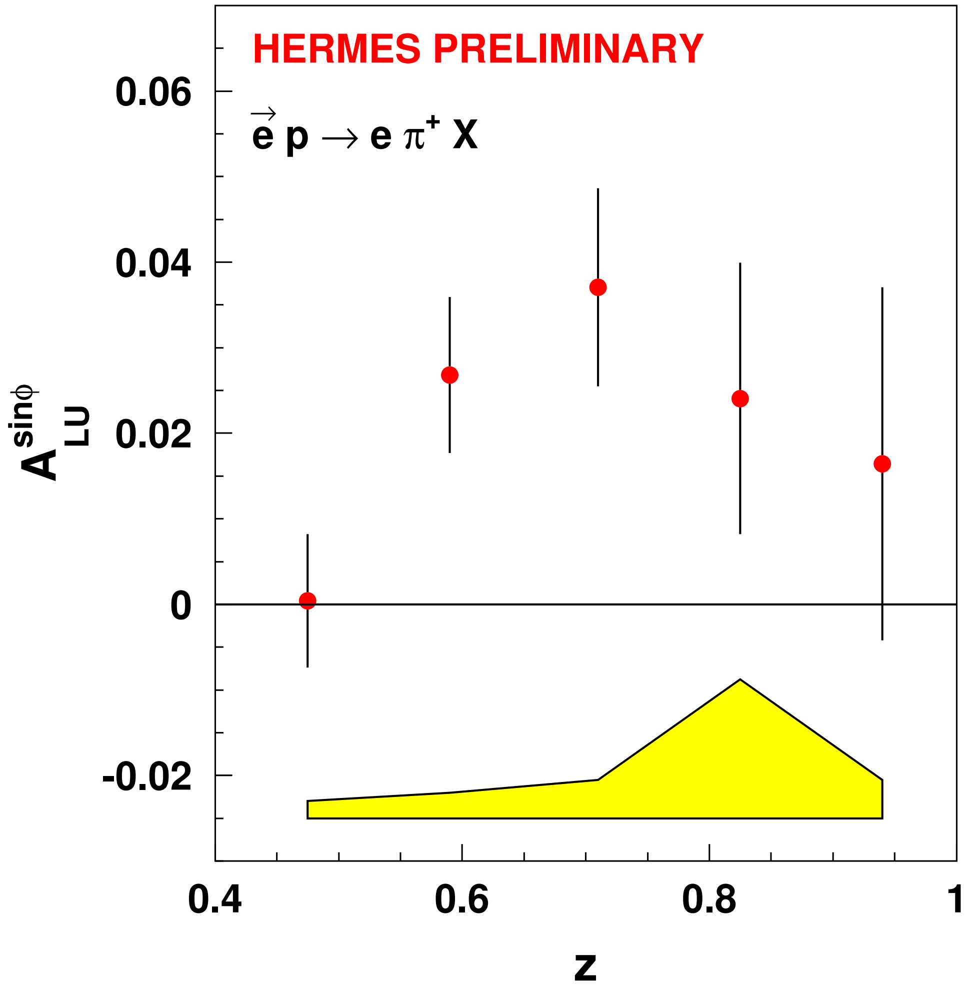
Other mechanisms:

SSA from final state interaction (Gluon exchange)

Sivers effect $\propto f_{1T}^{\perp} \times D_1$ [Brodsky *et al.*, PLB 530, 99 (2002)]



Beam Spin Asymmetry $A_{\mathrm{LU}}^{\sin\phi}$



$$\boxed{A_{LU} = \frac{1}{|P_{\mathrm{beam}}|} \frac{N^+ - N^-}{N^+ + N^-}}$$

$$A_{\mathrm{LU}}^{\sin\phi} \propto \frac{\sum_{a,\bar{a}} e_a^2\, e^a(x)\, H_1^{\perp a}(z)}{\sum_{a,\bar{a}} e_a^2\, f^a(x)\, D_1^{\perp a}(z)}$$

$e^a(x)$: twist-3 chiral odd DF

$H_1^{\perp a}(z)$: Collins FF

Summary

Single target-spin azimuthal asymmetries measured in π and K electroproduction on longitudinally polarized hydrogen and deuterium targets

- Results well described by phenomenological calculations based on different assumptions for the quark distributions and the Collins fragmentation function

- To describe the data, the longitudinal and transverse target spin component in the virtual photon frame and the effect of twist-3 distribution functions have to be considered

Single beam-spin azimuthal asymmetry for π^+ production on the proton observed

Single Spin Asymmetries are a successful tool to investigate the complete structure of the nucleon and new distribution functions