Transversity measurement at hermes

Delia Hasch
on behalf of the HERMES collaboration

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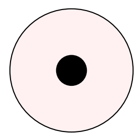
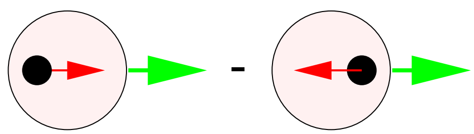
- how to measure transversity in sidis
- target-spin + beam-spin azimuthal asymmetries
- outlook

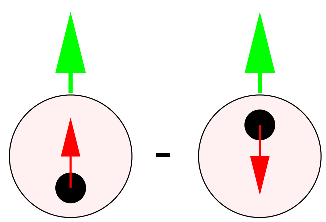
$$\Phi^{\rm LO}_{\rm corr}(x) \;=\; \frac{1}{2}\left[\, f_1(x) + S_{\rm L}\, g_1(x)\gamma_5 + h_1(x)\,\gamma_5 \not{S}_T \,\right] \not{n}_+$$

f_1 = 

spin averaged (O.K.)

g_{1L} = 

helicity difference (O.K.)

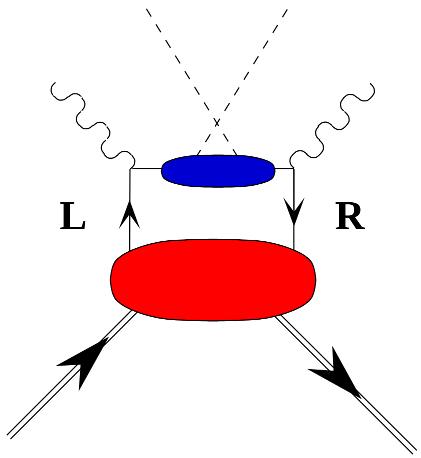
h_1 = 

helicity flip (→WANTED←)

transverse spin state =
off-diagonal state in the helicity basis:

$$\begin{pmatrix} f_1 + g_1 & 0 & 0 & 2\,h_1 \\ 0 & f_1 - g_1 & 0 & 0 \\ 0 & 0 & f_1 - g_1 & 0 \\ 2\,h_1 & 0 & 0 & f_1 + g_1 \end{pmatrix}$$

how to measure in SIDIS

$h_1 = \frac{1}{2}$ 

→ **chiral odd**

→ observed only in combination with another chiral odd structure:

$$\sigma^{\mathrm{lH}\to\mathrm{lhX}} = \sum_{\mathrm{q}} f^{\mathrm{H}\to\mathrm{q}} \otimes \sigma^{\mathrm{lq}\to\mathrm{lq}} \otimes D^{\mathrm{q}\to\mathrm{h}}$$

⇓ chiral-odd DF ⇓ chiral-odd FF

→ interference fragmentation: $ep^{\uparrow} \to e'\pi\pi X$

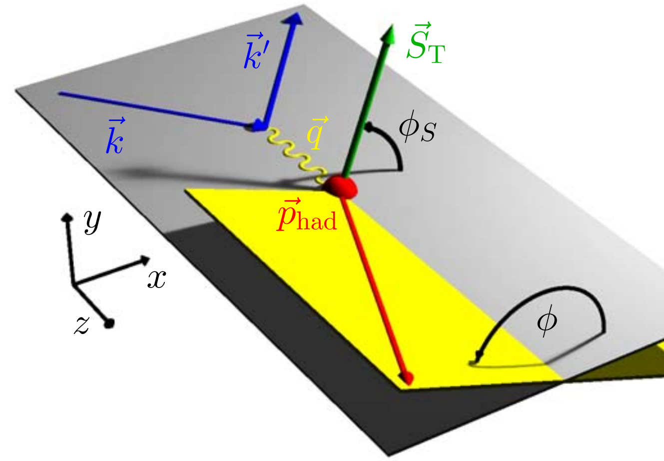
→ final state polarisation:
spin-1/2 (Λ) fragmentation: $ep^{\uparrow} \to e'\Lambda^{\uparrow} X$

→ Collins effect: $ep^{\uparrow} \to e'\pi X$

$$A_{\mathrm{T}} = \langle \sin\phi \rangle_{\mathrm{UT}} \propto h_1(x) \otimes H_1^{\perp}(z, k_T)$$

... azimuthal asymmetries

DIS+SIDIS cross section



$$d\sigma = d\sigma^0_{UU} + \frac{1}{Q}\cos\phi\, d\sigma^1_{UU} + \lambda\frac{1}{Q}\sin\phi\, d\sigma^2_{LU}$$

$f_1 \otimes D_1$ ↙

$$+S_L[\sin 2\phi\, d\sigma^3_{UL} + \frac{1}{Q}\sin\phi\, d\sigma^4_{UL}] + \lambda S_L[\, d\sigma^5_{LL} + \frac{1}{Q}\cos\phi\, d\sigma^6_{LL}]$$

$h^\perp_{1L}\otimes H^\perp_1$ ↙ $g_{1L}\otimes D_1$ ↙

$$+S_T[\sin(\phi+\phi_S)\, d\sigma^7_{UT} + \sin(\phi-\phi_S)\, d\sigma^8_{UT} + \sin(3\phi-\phi_S)\, d\sigma^9_{UT} + \frac{1}{Q}\sin(2\phi-\phi_S)\, d\sigma^10_U$$

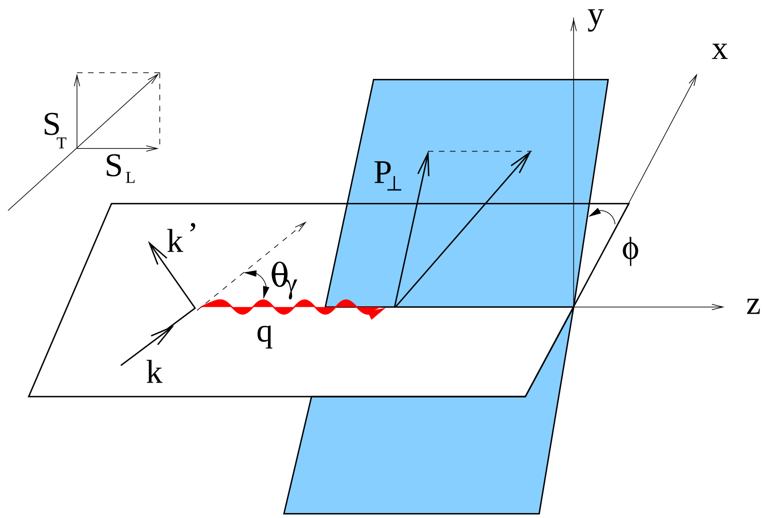
$h_1\otimes H^\perp_1$ ↙ $f^\perp_{1T}\otimes D_1$ ↙ $h^\perp_{1T}\otimes H^\perp_1$ ↙

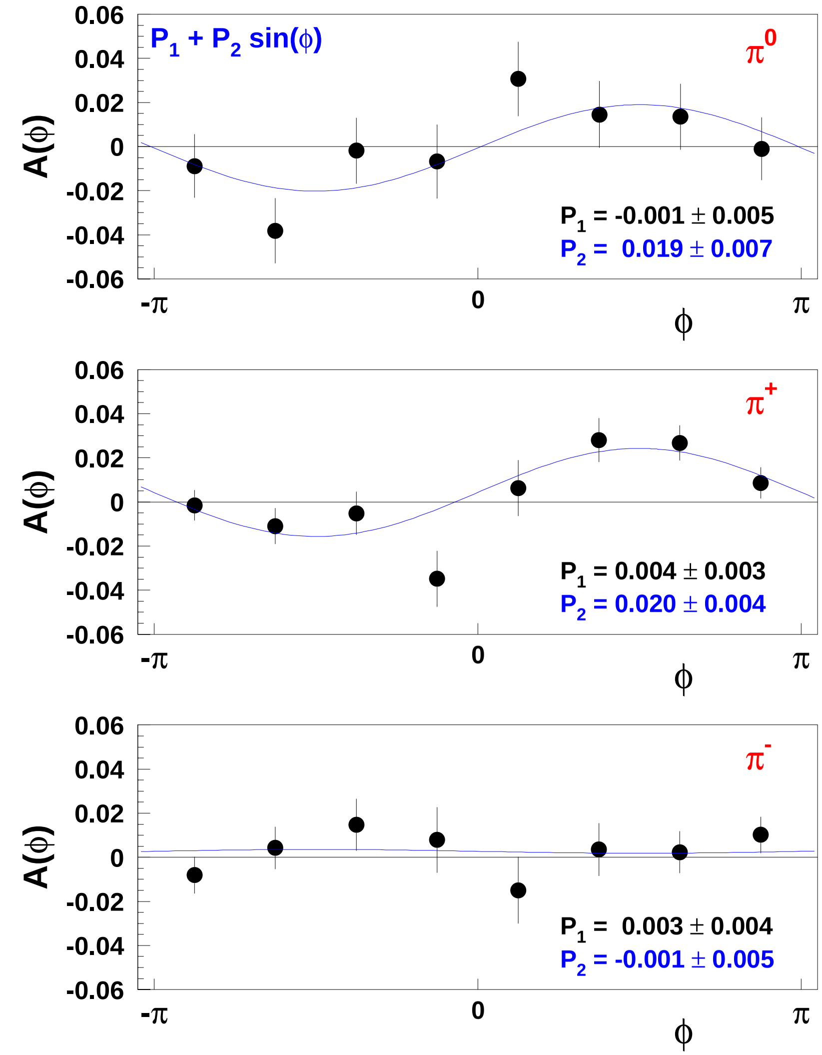
$$+\lambda S_T[\cos(\phi-\phi_S)\, d\sigma^{11}_{LT} + \frac{1}{Q}\cos(2\phi-\phi_S)\, d\sigma^{12}_{LT}]$$

$g_{1T}\otimes D_1$ ↙

[Mulders and Tangermann, NP B461 (1996) 197]

target single-spin azimuthal asymmetry





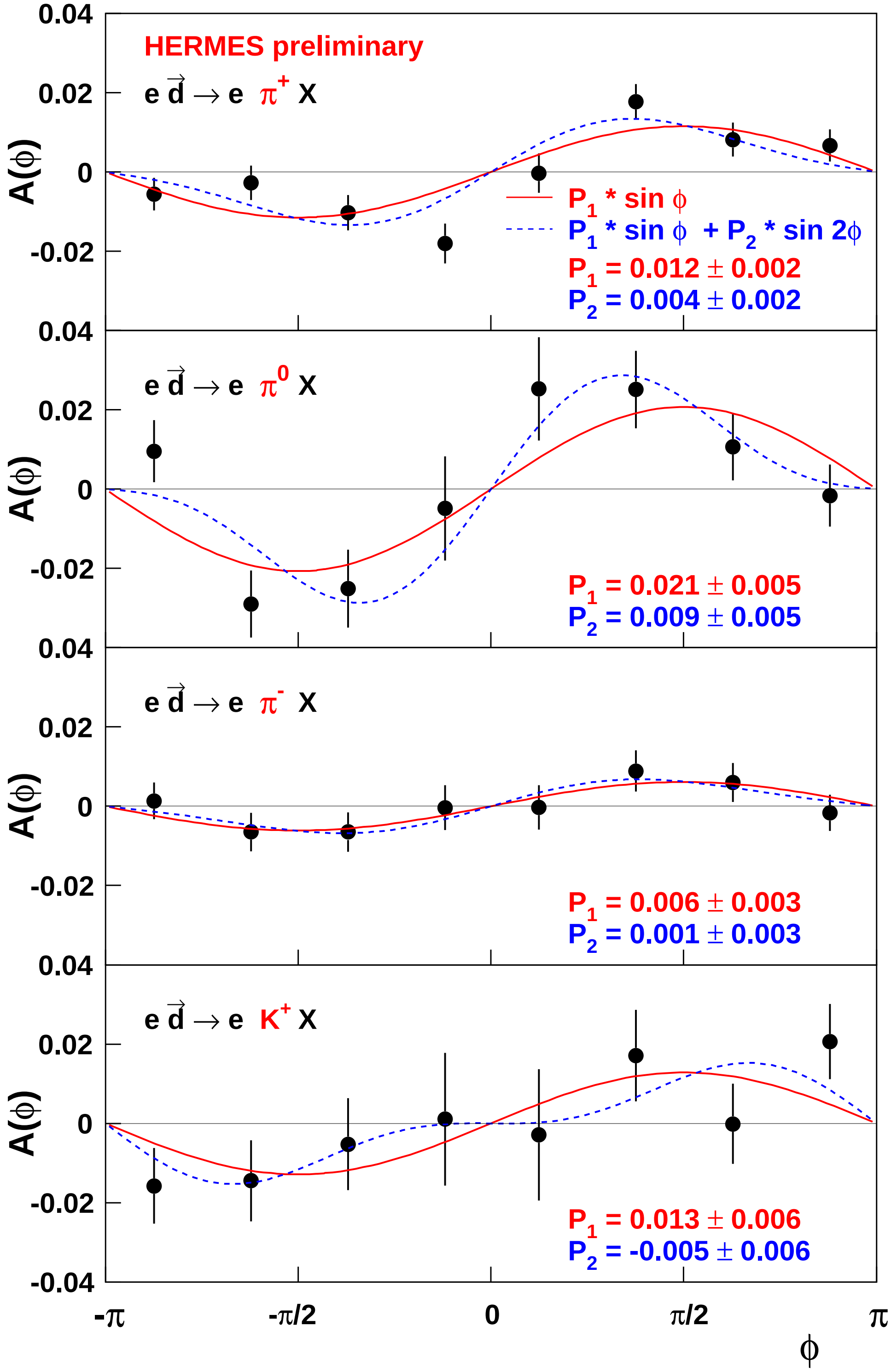
$$S_{\rm T} = \mid S \mid \sin\theta_\gamma \simeq \mid S \mid \frac{2Mx}{Q^2}\sqrt{1-y} \sim 0.15$$

$$A(\phi)_{\rm UL} = \frac{1}{\langle P \rangle} \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$

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

target SSA

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



A_{UL} interpretation

longitudinal polarised target has 2 components:

$S_{\mathrm{L}}/S \approx 1$ and $S_{\mathrm{T}}/S \approx 1/Q$

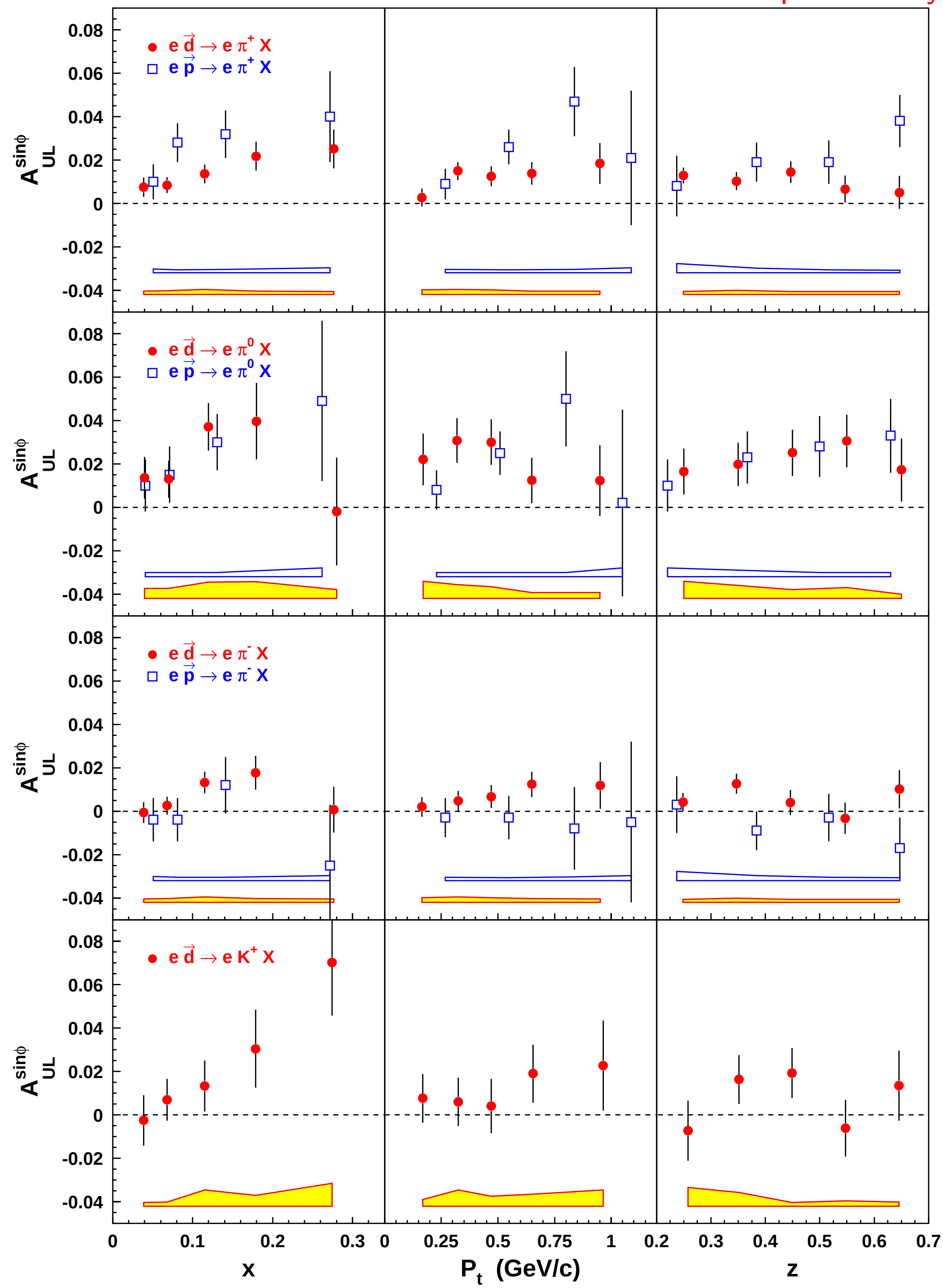
$$\langle \frac{P_{\mathrm{T}}}{z M_{\mathrm{h}}} \sin\phi \rangle_{\mathrm{UL}} \propto \Big[S_{\mathrm{T}} \sum_{a,\bar{a}} \big(e_a^2 x\, h_1^a(x)\; H_1^{\perp a}(z) \big)$$

$$+ \frac{1}{Q} S_{\mathrm{L}} \sum_{a,\bar{a}} \big(e_a^2 x\, h_{\mathrm{L}}^a(x)\; H_1^{\perp a}(z) \big) \frac{2(2-y)}{\sqrt{1-y}} + \cdots \Big]$$

$$\langle \frac{P_{\mathrm{T}}}{z M_{\mathrm{h}}} \sin 2\phi \rangle_{\mathrm{UL}} \propto S_{\mathrm{L}} \sum_{a,\bar{a}} \big(e_a^2 x\, h_{1\mathrm{L}}^{\perp a}(x)\; H_1^{\perp a}(z) \big)$$

$A_{UL}^{\sin\phi}$

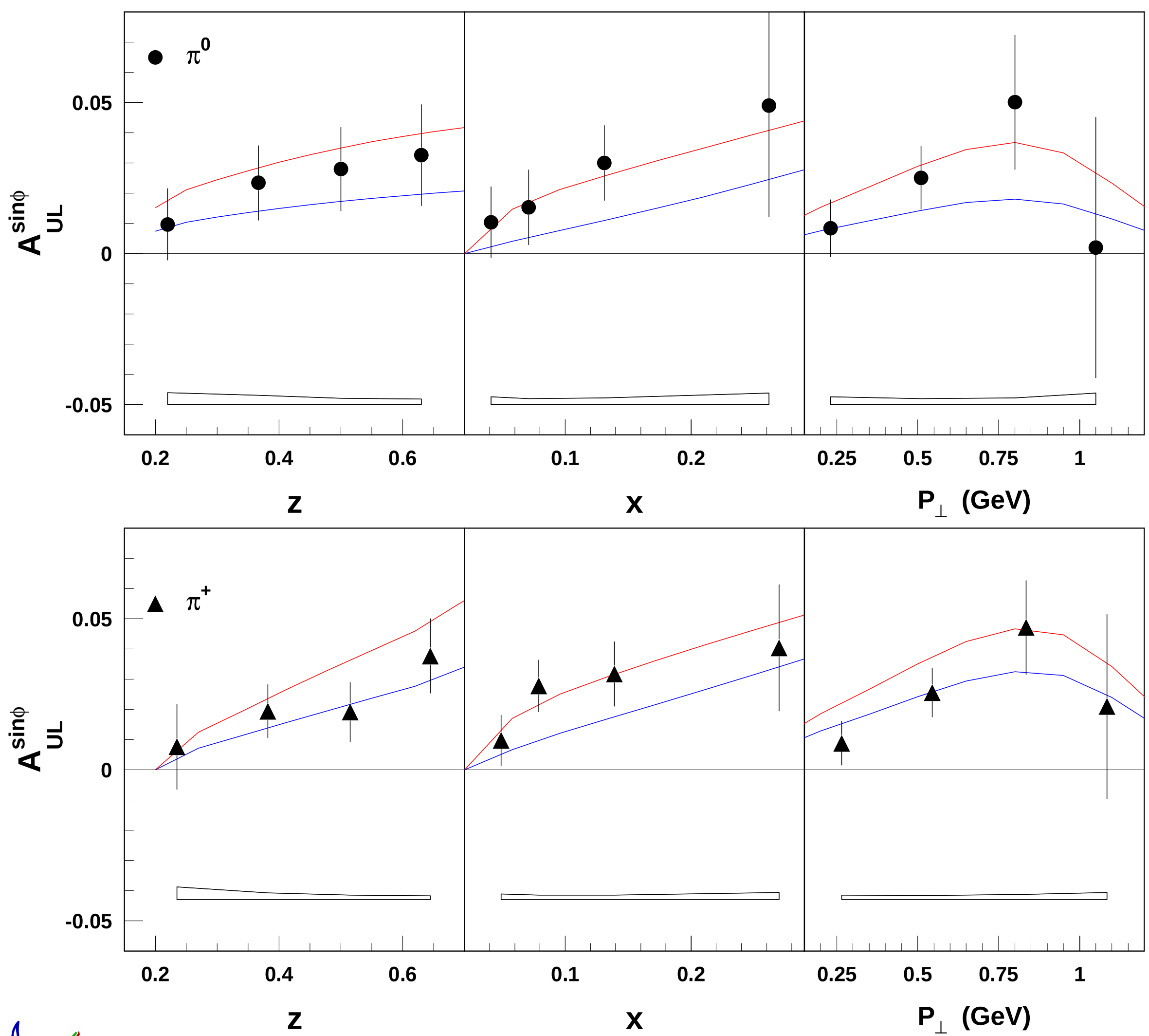
deuteron data is preliminary



model calculations for $A_{\rm UL}^{\sin\phi}$

[Oganessyan et al., hep-ph/9808368, PLB 483 (2000) 69]

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



approximation:

$$h_{\rm L}(x) = h_1(x) - \frac{\rm d}{{\rm d}x} h_{1\rm L}^{\perp(1)}(x) \approx h_1(x)$$

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

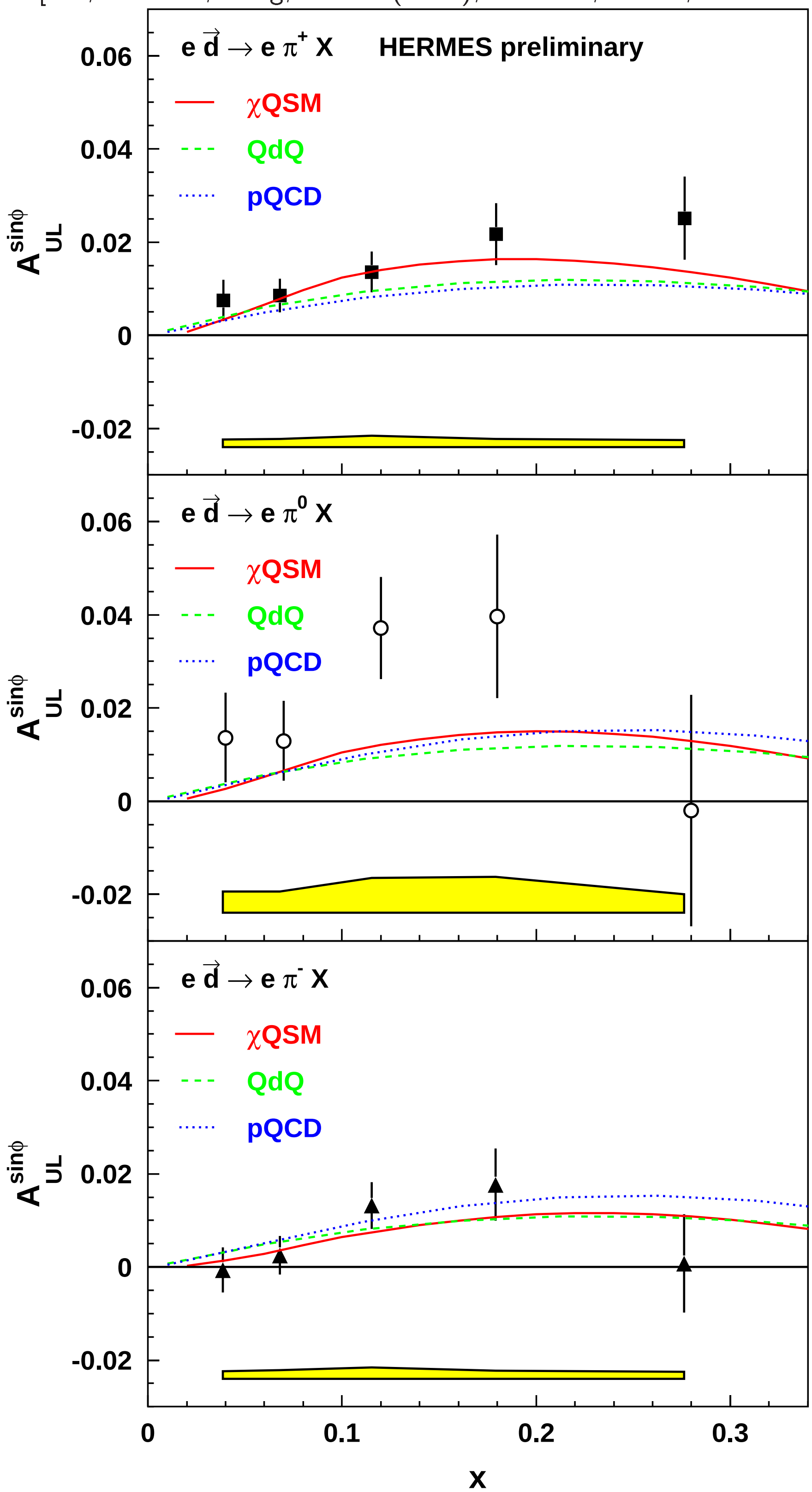
lower limit: $h_1 = g_1$
non-relativistic limit

'Collins guess' for $H_1^\perp$:

$$A_{\rm C}(z, k_T) = \frac{|\,k_T\,|}{M_h} \frac{H_1^\perp(z, k_T^2)}{D_1(z, k_T^2)} = \eta \frac{M_{\rm C}\,|\,k_T\,|}{M_{\rm C}^2 + k_T^2}$$

model calculations for $A_{\mathrm{UL}}^{\sin\phi}$

[Ma, Schmidt, Yang, PRD63(2001); Efremov, Goeke, Schweitzer, EPC24(2002)]



approximation:

$h_1(x)$:

$$h_{\mathrm{L}}^{a}(x) = 2x\int_x^1 \mathrm{d}x' \frac{h_1^a(x')}{x'^2} + \tilde{h}_{\mathrm{L}}^{a}$$

$$\tilde{h}_{\mathrm{L}} \simeq 0$$

$H_1^{\perp}$:

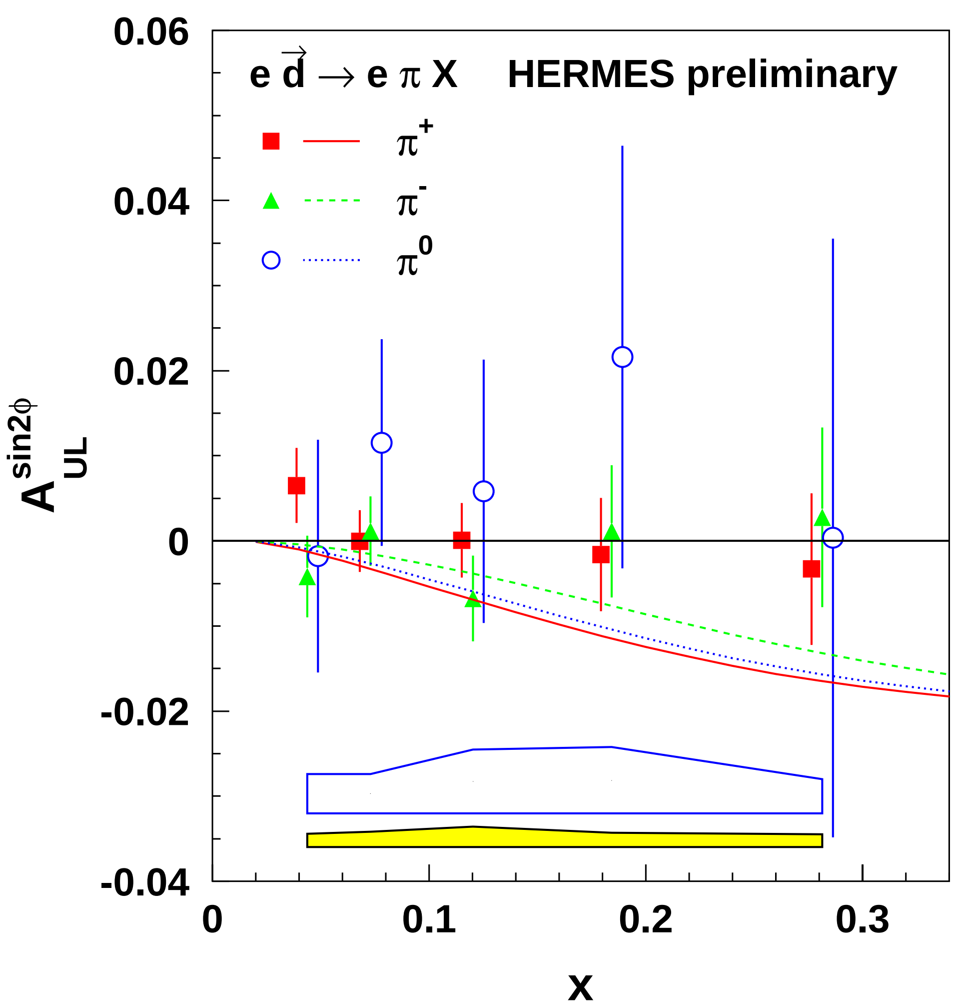
χQCD:

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

QdQ, pQCD:

'Collins guess'

model calculations for $A_{UL}^{\sin 2\phi}$



[Efremov, Goeke, Schweitzer, EPC24, 407 (2002)]

chiral quark-soliton model:

$h_1(x)$:

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

$$\tilde{h}_L^a \simeq 0$$

$H_1^\perp$:

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

remarks on model calculations

$\sin\phi$ moments from proton + deuteron targets well described by various model calculations based on Collins effect $\sim h_1 \otimes H_1^{\perp}$

BUT

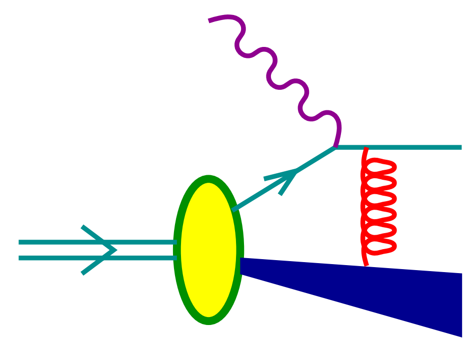
$\Rightarrow$ @ longitudinally polarised target: $S_{\rm T}$ w.r.t. $\gamma^* \propto 1/Q$

$A_{\rm UL}^{\sin\phi} \sim$ twist-3: $h_{\rm L} H_1^{\perp(1)}$ contribution $\approx 75\%$ $\leftarrow$ opposite sign

while $h_1 H_1^{\perp(1)}$ contribution $\approx 25\%$ $\swarrow$ [K. Oganessyan], [Efremov, Goeke, Schweitze

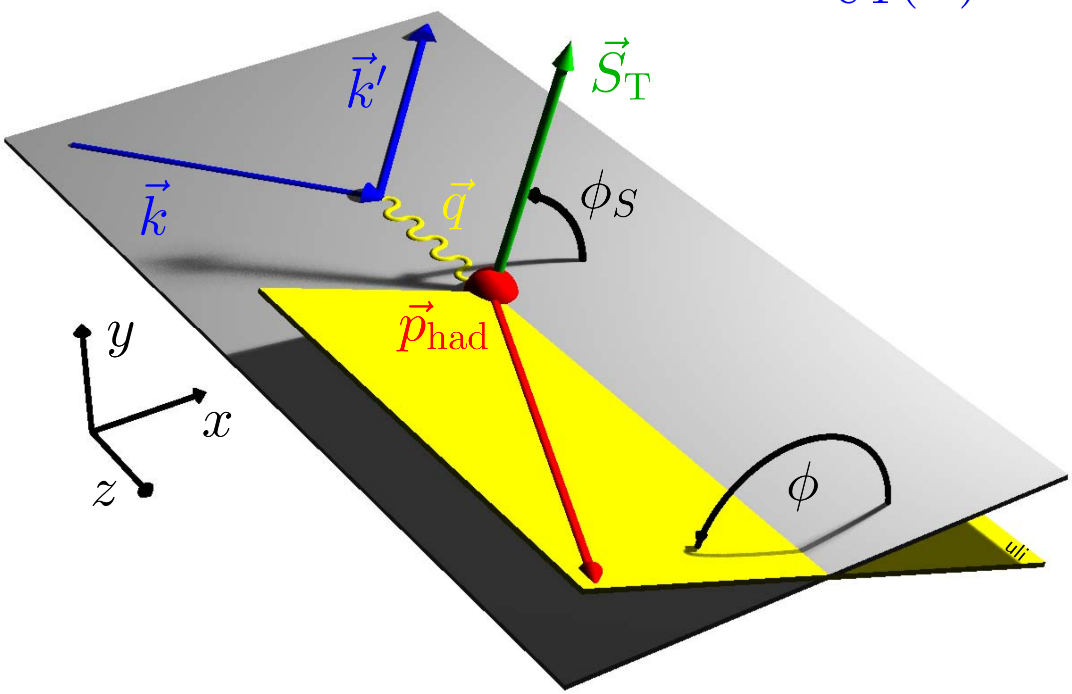
$\Rightarrow$ SSA from final state interaction (gluon exchange)

$\equiv$ Sivers effect $\sim f_{1T}^{\perp} \otimes D_1$



$\cdots$ Collins + Sivers effect show different dependence on z

transversely polarised target



$$A_{UT}(\Phi) = \frac{1}{\langle P_t \rangle} \cdot \frac{N+(\Phi) - N^-(\Phi)}{N^+(\Phi) + N^-(\Phi)}$$

$$\Phi = \phi + \phi_S$$

$\cdots$ [Collins type]

$$\Phi = \phi - \phi_S$$

$\cdots$ [Sivers type]

∘ ∘ ∘ HERMES measurements in 2002++

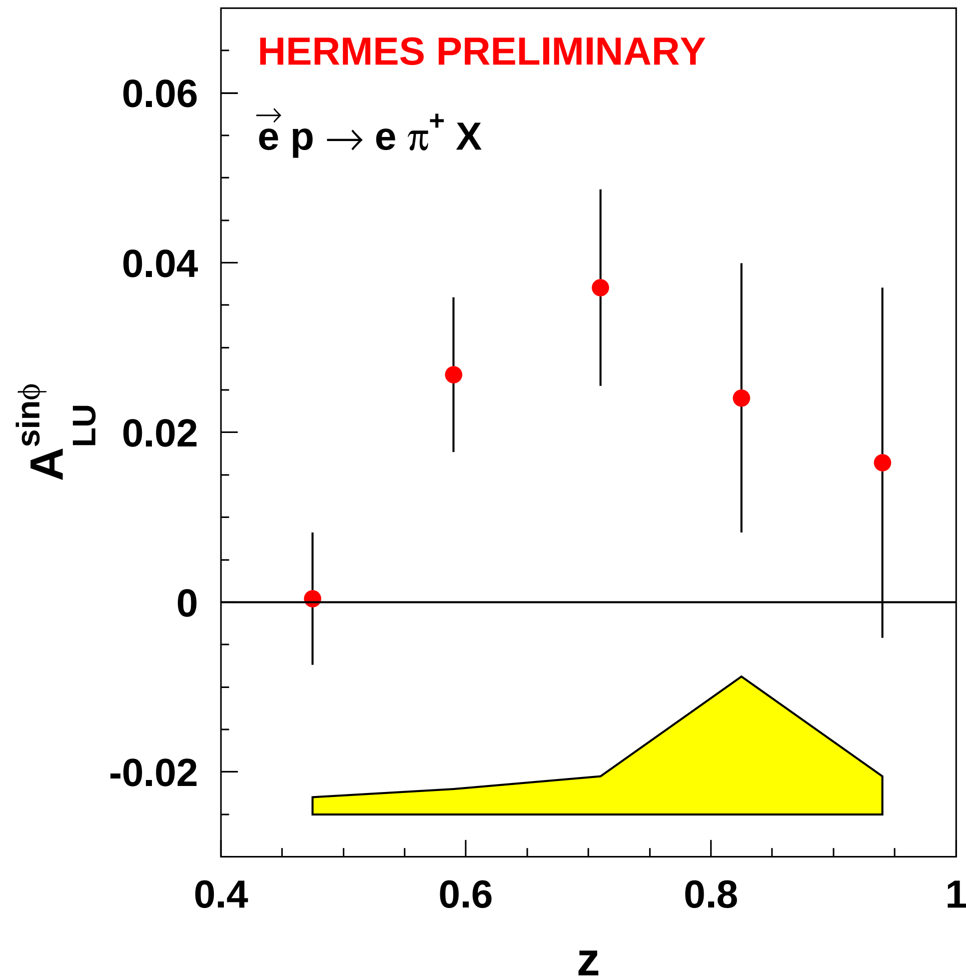
$A_{\mathrm{LU}}^{\sin\phi}$

$$A_{\mathrm{LU}}^{\sin\phi} = \frac{\sum_{i=1}^{N^+} \sin(\phi_i^+) - \sum_{i=1}^{N^-} \sin(\phi_i^-)}{\frac{1}{2}[N^+ + N^-]}$$

$$\propto \frac{\sum_{a,\bar{a}} \left(e_a^2 x \, e^a(x) \; H_1^{\perp a}(z) \right)}{\sum_{a,\bar{a}} \left(e_a^2 x \, f^a(x) \; D_1^a(z) \right)}$$

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

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



summary & **outlook**

single-target + single-beam spin azimuthal asymmetries measured in $\pi(K)$ electroproduction with longitudinally polarised target and beam

$A_{\mathrm{UL}}^{\sin\phi}$ well described by model calculations based on **Collins effect**

$\Rightarrow$ non-ambiguous measurement of **transversity** will be possible with transversely polarised target:

$\longrightarrow$ **HERMES run-II 2002**++

mapping transversity:

sidis:	$ep^{\uparrow} \rightarrow \pi X$	Hermes, Compass, JLab
annihilation:	$e^{+}e^{-} \rightarrow \pi\pi X$	Delphi, Belle
inclusive pion:	$p^{\uparrow}p \rightarrow \pi X$	E704, RHIC
Drell Yan:	$p^{\uparrow}p^{\uparrow} \rightarrow llX$	RHIC (after lumi upgrade)