Single Spin Asymmetries at HERMES

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On behalf of HERMES collaboration

- Introduction
- SSA at other experiments
- SSA at HERMES
- Conclusions

Motivations.

HERMES: Spin structure of the nucleon

- Double Spin Asymmetries:

  Polarized Beam and Target.

  $g_1^n \; g_1^p \; \Delta q \; \cdots$

  Longitudinal quark polarization densities.

- Single Spin Asymmetry (SSA):

  Polarized Beam or Target.

  Transverse quark polarization densities,

  Chiral odd DF .

  $\Downarrow$

  Time-odd Collins FF

  $\Downarrow$

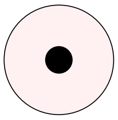
  SSA

Naive parton models, non interacting collinear parton
Parity, Angular momentum, Helicity conservation

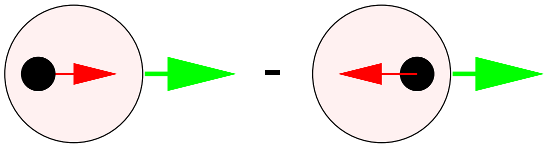
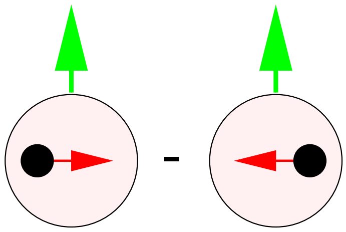
$$\Rightarrow \; \mathrm{SSA} = 0$$

SSA originates from multi-parton correlation and vanish when PQCD becomes effective.

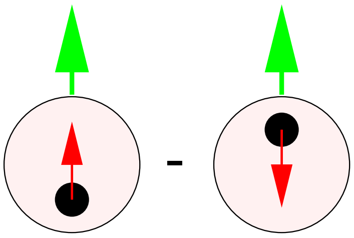
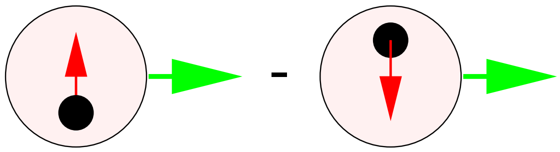
Interpretation of distribution functions.

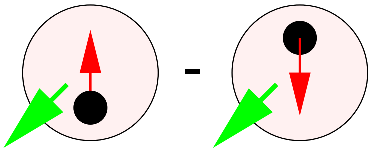
f_1 = 

Unpolarized quark in unpolarized nucleon.

g_{1L} =  g_{1T} = 

Longitudinal quark in longitudinal and transverse nucleon.

h_1 =  $h_{1L}^{\perp}$ = 

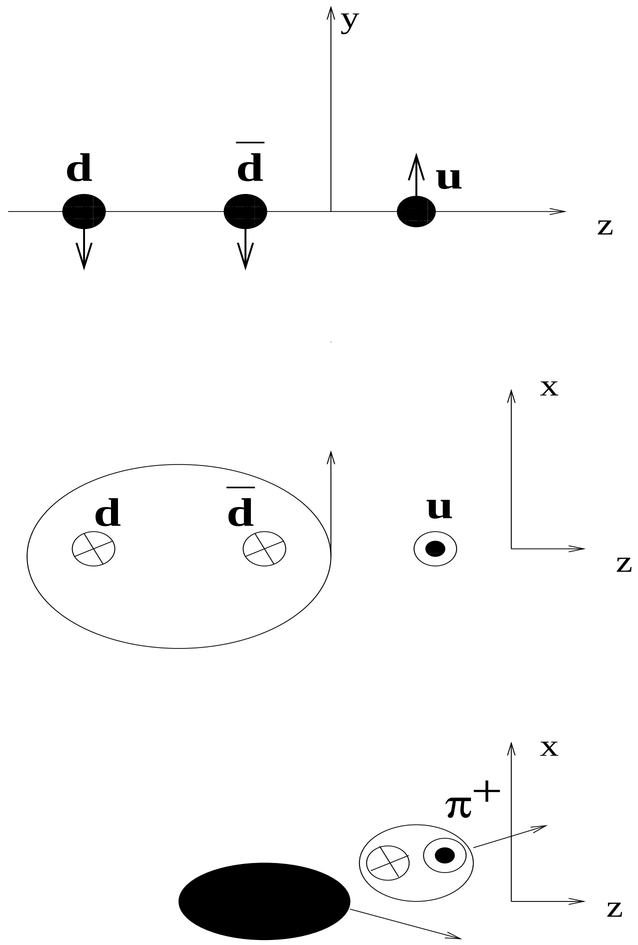
$h_{1T}^{\perp}$ = 

Transverse quark in longitudinal and transverse nucleon.

COLLINS FF

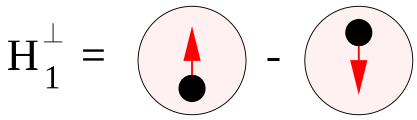
Transverse quark polarimeter

Simple interpretation by Artru (Semi classical string model). `X. Artu et al. hep-ph/9508239`



Correlation between the spin of the valance quark and the transverse momentum of the outgoing $\bar{q}$ (pion).

COLLINS FF:



$e^+ + e^- \to Z^0 \to$ **2 jets**

A. V. Efromov *et al.*, (DELPHI) hep-ph/9812522

- Transverse polarization of quarks and antiquark are highly correlated near the Z^0 peak.
- Collins FF leads to an asymmetry in the production of a hadron in one jet around the axis of a second in the opposite jet.

Result:

$$\left| \overline{\frac{H_1^\perp}{D_1}} \right| = 6.3 \pm 1.7\% \ .$$

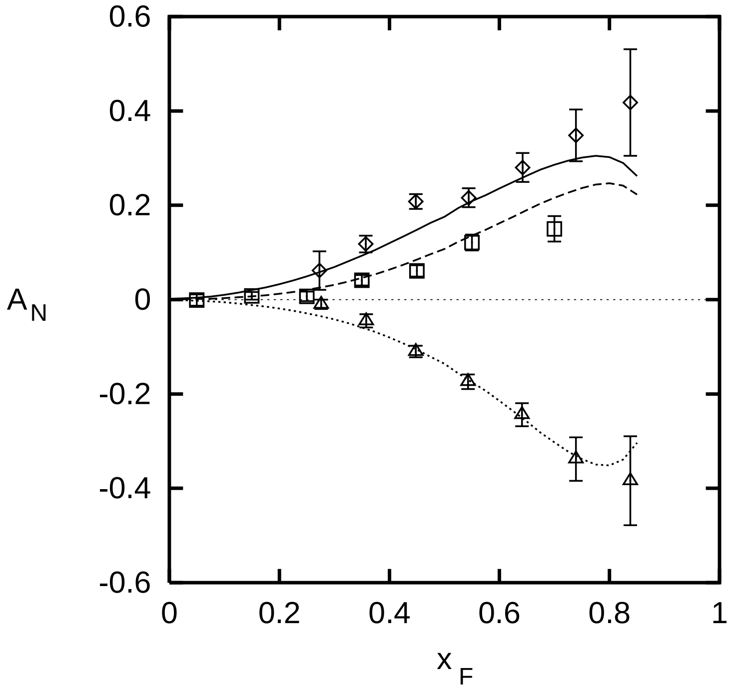
$p^{\uparrow}p$ or $\bar{p}^{\uparrow}p \to \pi^{\pm} + X$

By E704 D.L. Adams *et al. Phys. Lett.* **B264** (1991) 462; *Phys. Rev. Lett* **77** (1996) 164

$$d\sigma^{\uparrow,\downarrow} = E_\pi \, d^3\sigma^{p^{\uparrow,\downarrow}p\to\pi X}/d^3\boldsymbol{p}_\pi$$

$$A_N(x_F, p_T) = \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}} \, ,$$

$$A_N(\bar{p}^{\uparrow}p \to \pi^{\pm}) \simeq A_N(p^{\uparrow}p \to \pi^{\mp})$$



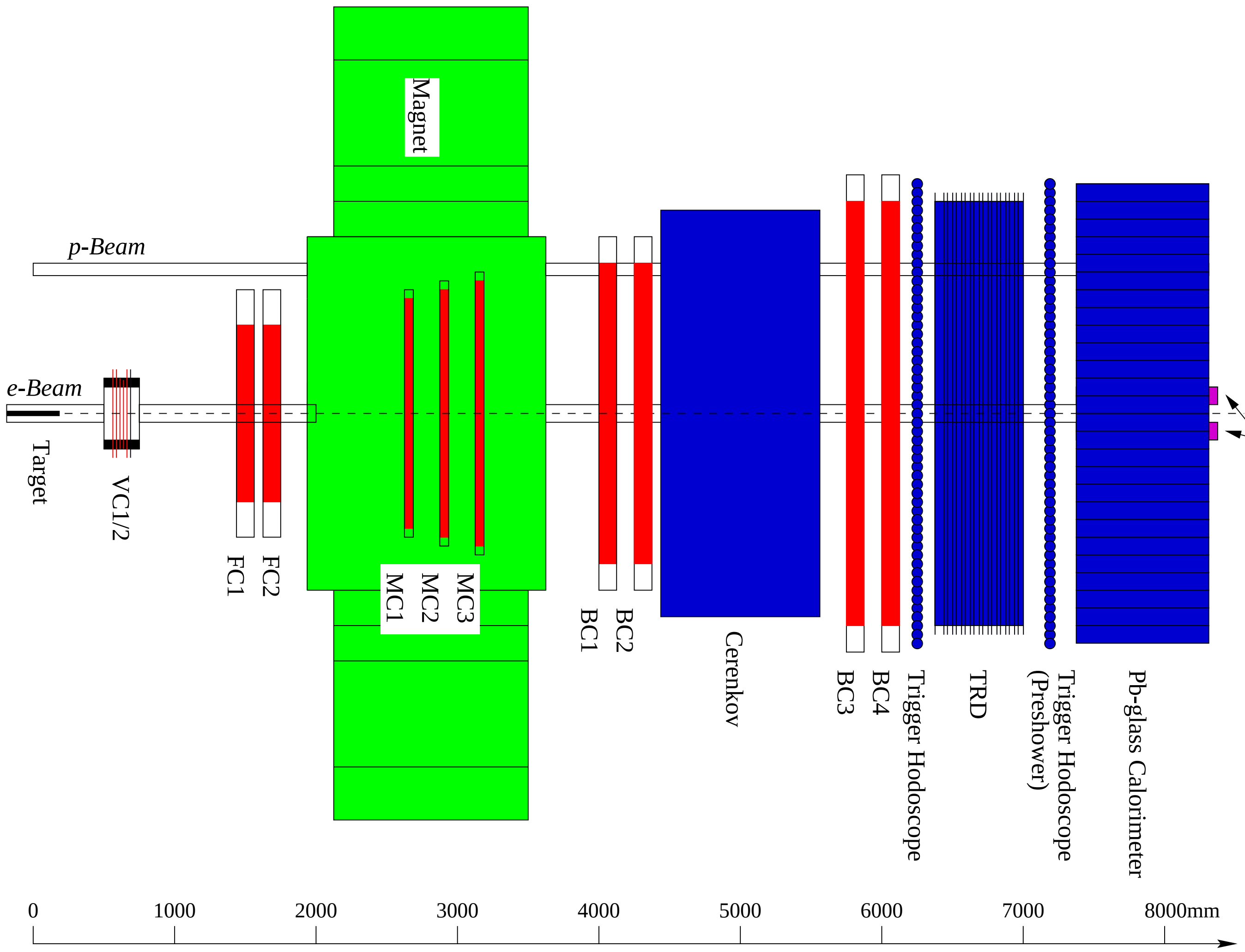
Curves from A. Anselmino et al. hep-ph/9901442

Assuming Collins FF is responsible for the effect:
M. Boglione & P.J. Mulders hep-ph/9903354

$$\left| \frac{\int_{0.1}^{1} dz_h H_1^{\perp fav}(z_h)}{\int_{0.1}^{1} dz_h D_1^{u/\pi^+}(z_h)} \right| = 0.076 \text{ Agreement with Delphi.}$$

Evidence of Collins FF

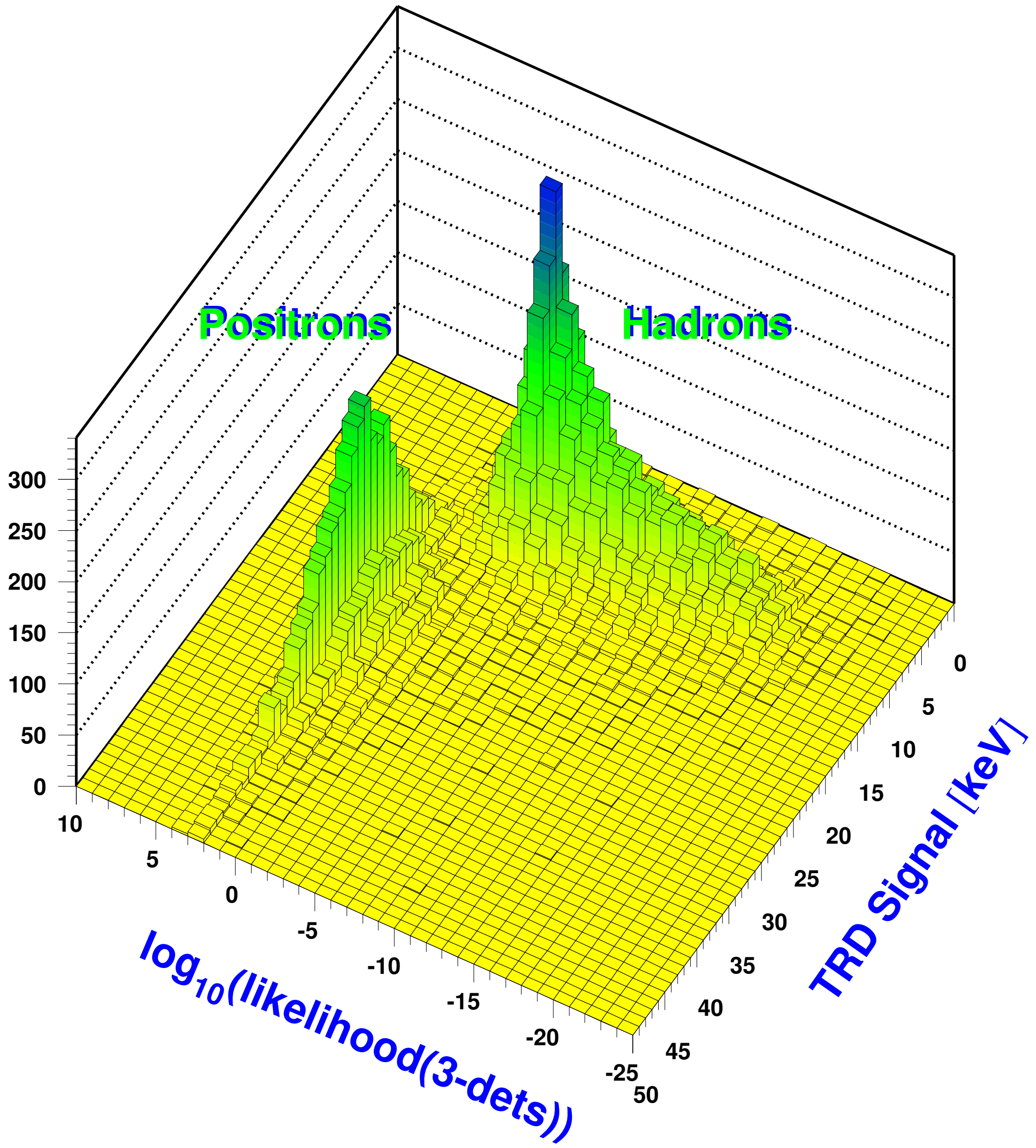
The HERMES Experiment



- Beam: 27.5 GeV Hera polarized e^+.
- Target: Internal storage cell gas target, density $(0.7 - 3) \times 10^{14}$ atoms/cm^2, $P_{\vec{H}} \approx 86\%$
- kinematic: $0.02 < x < 0.8$ for $Q^2 > 1$ and $W^2 > 4$
- **Tracking**: 57 tracking planes, $\delta P/P = (0.7 - 1.3)\%$, $\delta\theta < 0.6$ mrad
- **Particle identification**: Čerenkov, TRD, Preshower, Calorimeter.

Particle Identification

- Lepton hadron separation, from Čerenkov , TRD, Preshower and Calo: e^+ contamination $< 1\%$

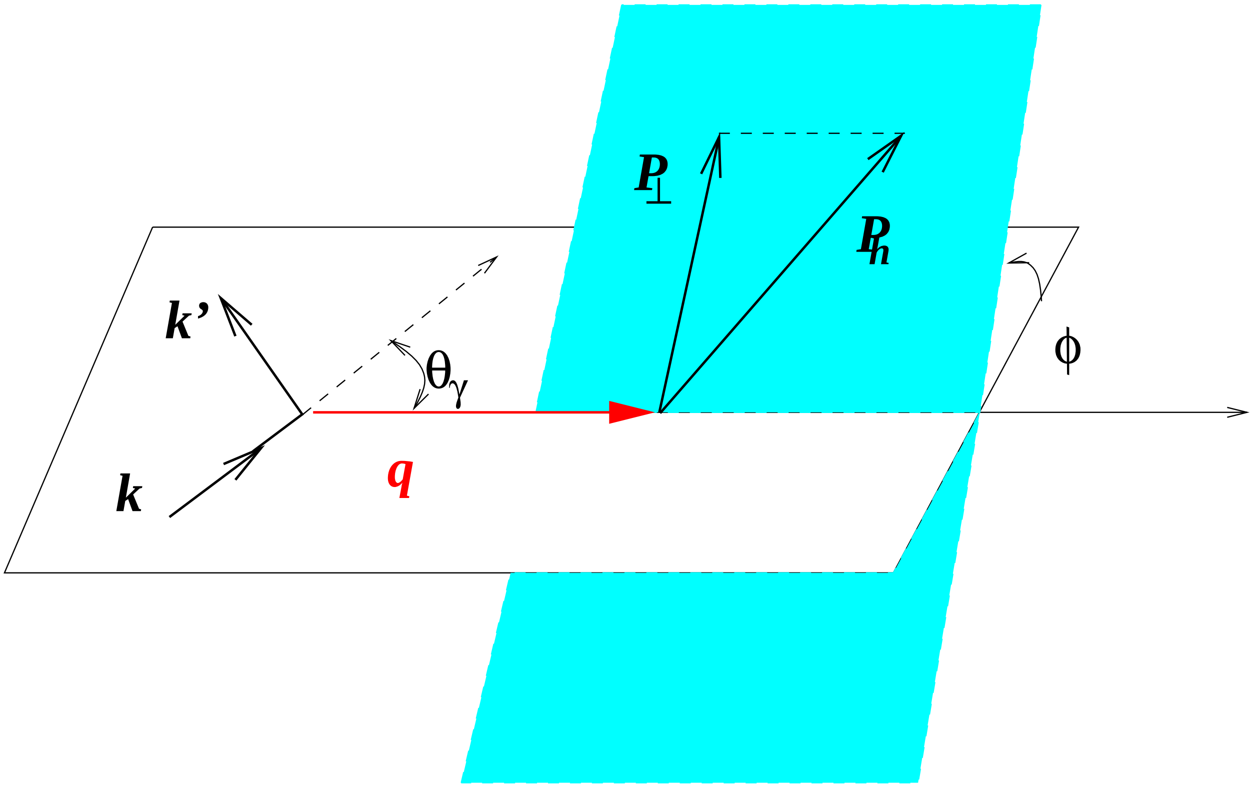


- $\pi^{\pm}$ identification: Čerenkov threshold detector

$$4.5GeV < P_{\pi}^{\pm} < 13.5GeV$$

- DIS kinematic cuts:
  $Q^2 > 1,\ W > 2,\ y < 0.85,\ 0.2 < z < 0.7$
  $\sim$ 120k π^+ and $\sim$ 80k π^-

SIDIS kinematic



$x = Q^2/2P \cdot q,$
$y = P \cdot q/P \cdot k,$
$z = P \cdot P_h/P \cdot q$
$P_\perp$ (hadron transverse momentum)

Collins angle

$$\phi = \arccos\left(\frac{(q \times k) \cdot (q \times p_h)}{|q \times k||q \times p_h|}\right) \frac{p_h \cdot q \times k}{|p_h \cdot q \times k|}$$

Contributions to $\sin\phi$

- Chirality structure of DF $\otimes$ FF : even
- Time reversal structure of DF $\otimes$ FF : odd

		T-even DF		T-odd FF	
		chirality		chirality	
		even	odd	even	odd
twist 2	O	$\mathbf{f}_1$			$H_1^\perp$
	L	$\mathbf{g}_{1L}$	$h_{1L}^\perp$		
	T	g_{1T}	$\mathbf{h}_1$ $h_{1T}^\perp$	$D_{1T}^\perp$	
twist 3	O	$f^\perp$	$\mathbf{e}$		$\mathbf{H}$
	L	$g_L^\perp$	$\mathbf{h}_L$	$D_L^\perp$	E_L
	T	$\mathbf{g}_T$ $g_T^\perp$	h_T $h_T^\perp$	$\mathbf{D_T}$	E_T

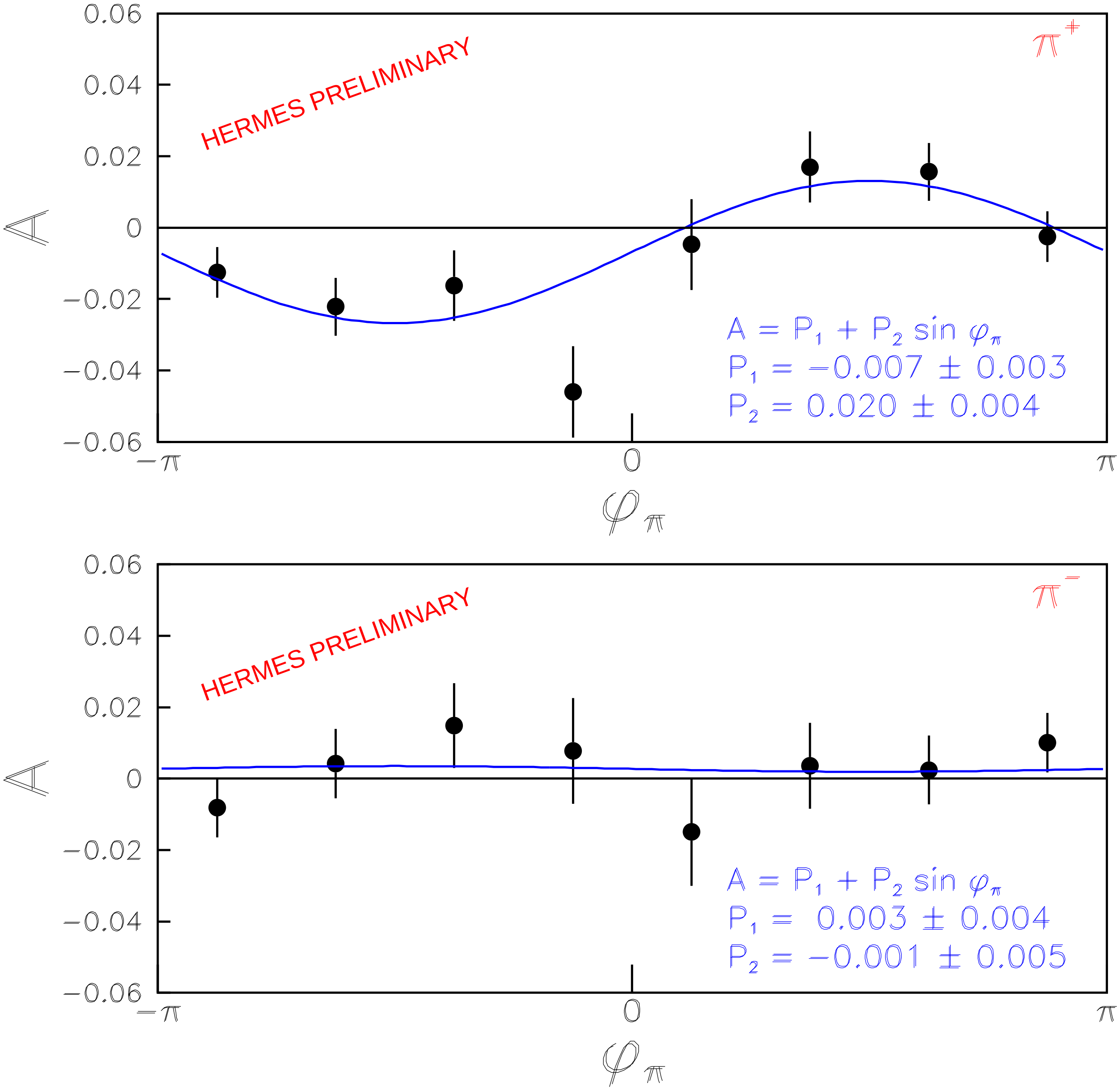
$$
\begin{aligned}
< \sin\phi >_{UL} \quad &\propto \quad S_L \sum_{a,\bar{a}} e_a^2 x h_L^a(x) H_1^{\perp a}(z) \\
&+ \quad S_T \sum_{a,\bar{a}} e_a^2 x h_1^a(x) H_1^{\perp a}(z)
\end{aligned}
$$

HERMES: Longitudinally polarized target:

$S_T << S_L$

Cross section Asymmetry

Asymmetry in the cross section $A(\phi) = \frac{1}{P_H} \frac{N^+ - N^-}{N^+ + N^-}$.



Azimuthally Weighted Asymmetries

$$\mathcal{A}_{UL}^{\sin\phi} = \frac{\frac{L^+}{L_P^+}\int_0^{2\pi}\sin\phi\,\mathrm{d}N_+ \;-\; \frac{L^-}{L_P^-}\int_0^{2\pi}\sin\phi\,\mathrm{d}N_-}{\frac{1}{2}[\int_0^{2\pi}\mathrm{d}N_+ \;+\; \int_0^{2\pi}\mathrm{d}N_-]}$$
$$= 2 < \sin\phi >$$

- $\pm$ target spin state
- $L^{\pm}$ dead-time corrected luminosities
- $L_P^{\pm}$ luminosities wighted by the target polarization

$$\pi^+ \quad \mathcal{A}_{UL}^{sin\phi} = 0.022 \pm 0.005(stat) \pm 0.003(syst)$$
$$\pi^- \quad \mathcal{A}_{UL}^{sin\phi} = -0.005 \pm 0.008(stat) \pm 0.004(syst)$$

$$\pi^+ \quad \mathcal{A}_{UL}^{sin\phi} \propto \frac{4}{9}h_L^u \mathbf{H_1^{\perp u\to\pi^+}} + \frac{1}{9}h_L^d H_1^{\perp d\to\pi^+}$$
$$\pi^- \quad \mathcal{A}_{UL}^{sin\phi} \propto \frac{4}{9}h_L^u H_1^{\perp u\to\pi^-} + \frac{1}{9}h_L^d \mathbf{H_1^{\perp d\to\pi^-}}$$

SSA @ HERMES:

A very reliable measurement!

No significant instrumental effect!

- Target $\uparrow\downarrow \quad \Rightarrow \quad < sin\phi >^{\uparrow} \approx - < sin\phi >^{\downarrow}$
- Cross check with **unpolarized** data: $< sin\phi >^{0} \approx 0$

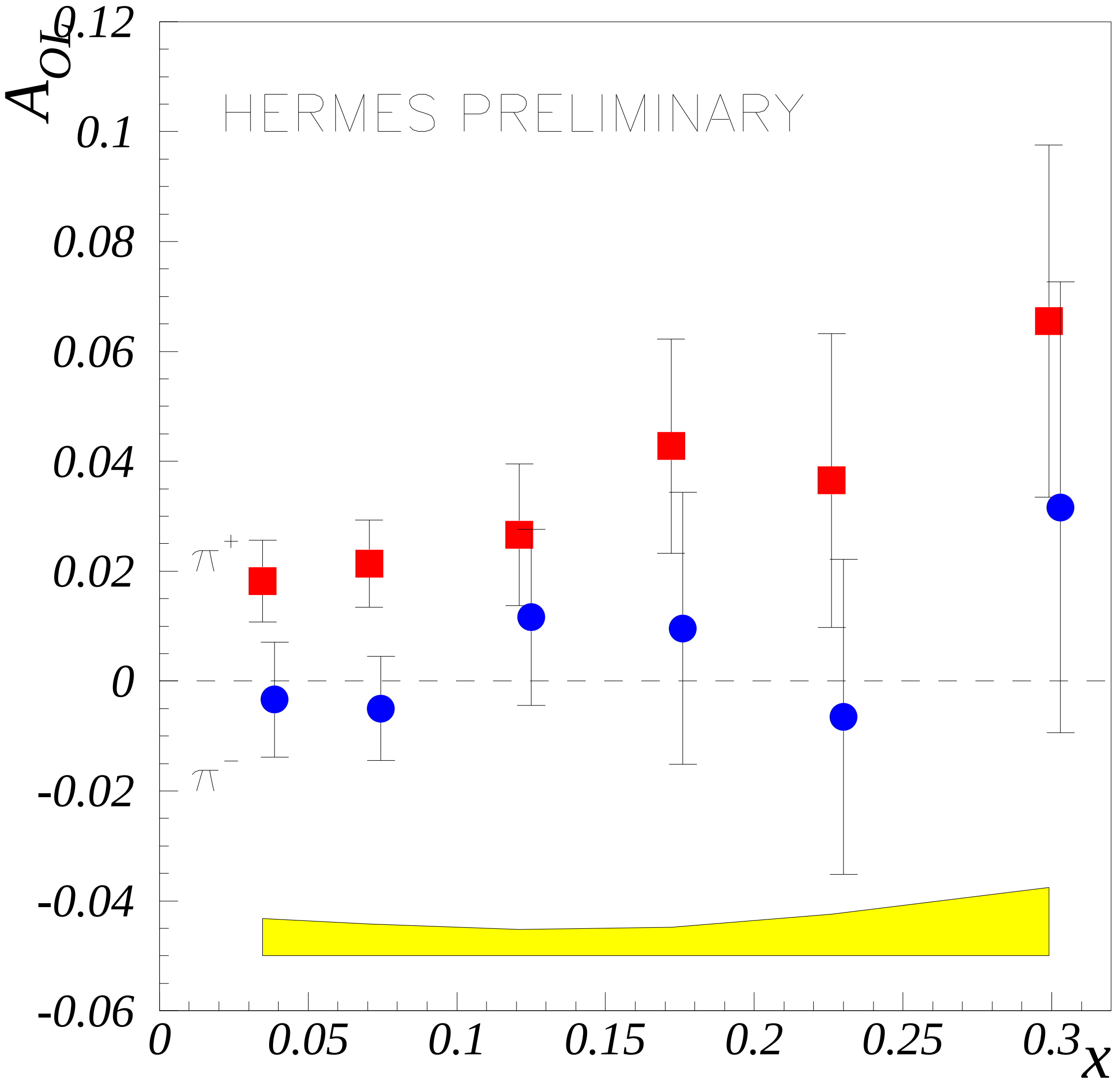
Small acceptance corrections!

Cross section	$\otimes$	Acceptance(ϕ, x)	$\propto$	Yield
$\Downarrow$Twist-2		$\Downarrow$ Geometry		
$sin2\phi$		$cos\phi$	$\propto$	$\sin\,\phi$
$\Downarrow$Data/th		$\Downarrow$ MC		
$< 1\%$		$< \lvert 0.3 \rvert$	$<$	0.003 (15%)

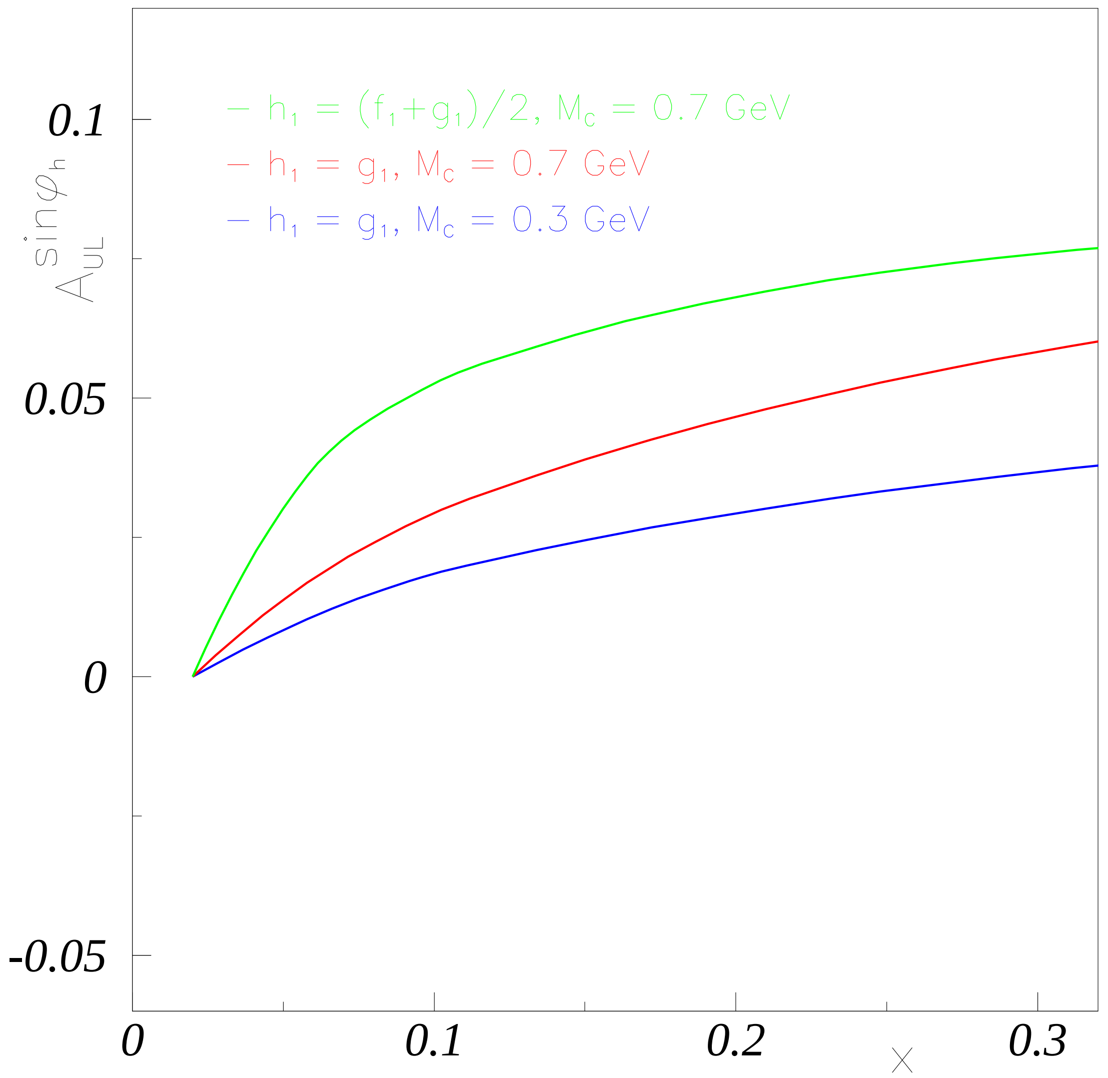
Main contributions to systematic errors:

- Acceptance dominates @ small and high x
- Target polarization: 5% rel.,
- e^{+} (π^{+}) contamination: 0.002 (0.0015) abs.,

SSA $\mathcal{A}_{UL}$: x dependence



SSA $\mathcal{A}_{UL}$, x dependence: THEORY



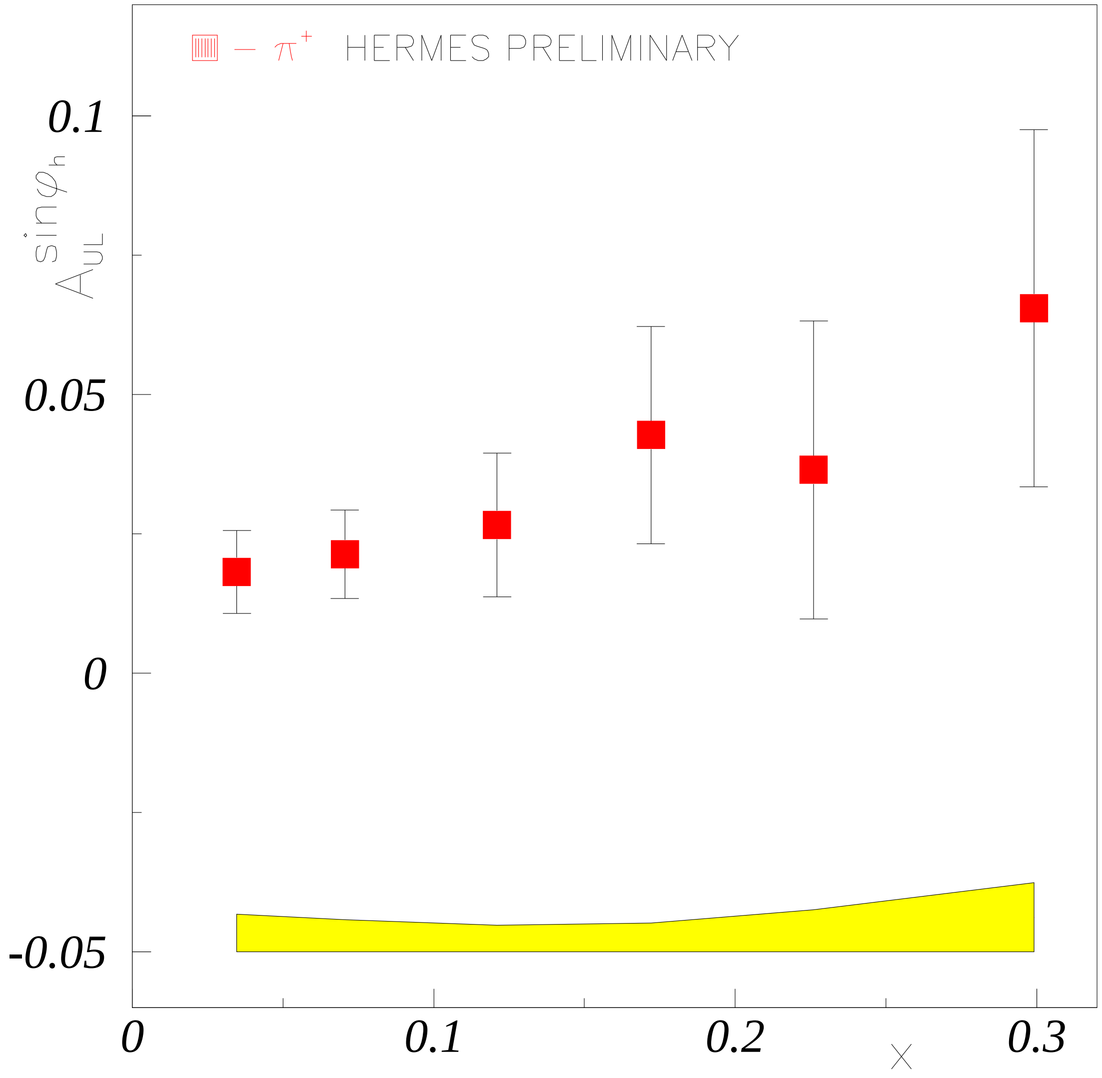
Curves: `A.M. Kotzinian` *et al.* `hep-ph/9908466`
Assuming:

$$h_{1L}^{\perp}(x) \sim h_L(x) \approx h_1(x) \approx g_1(x)$$

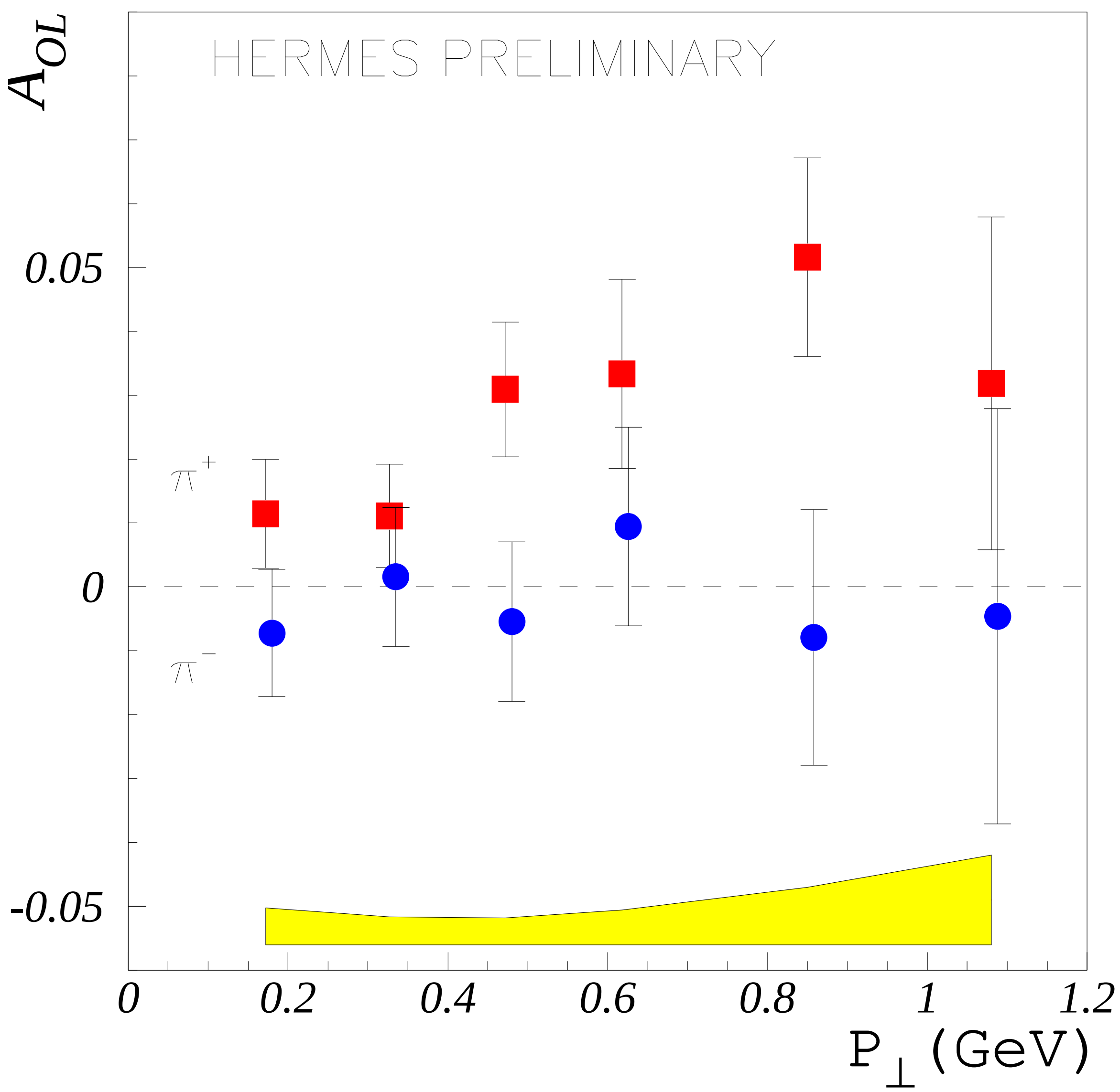
$$\Rightarrow \frac{\sigma_{UL}}{\sigma_{OO}} \propto x \frac{g_1(x)}{f_1(x)}$$

.

SSA $\mathcal{A}_{UL}$, x dependence: π^+



SSA $\mathcal{A}_{UL}$: $P_\perp$ dependence



SUMMARY

- First observation of a single-spin azimuthal asymmetry for semi-inclusive pion production in DIS.
-

$$\begin{aligned} \pi^{+} \quad \mathcal{A}_{UL}^{sin\phi} &= \quad 0.022 \pm 0.005(stat) \pm 0.003(syst) \\ \pi^{-} \quad \mathcal{A}_{UL}^{sin\phi} &= -0.005 \pm 0.008(stat) \pm 0.004(syst) \end{aligned}$$

- π^{+} asymmetry vs x and $p_{\perp}$ in agreement with models.
- Transversely polarized target $\Rightarrow h_1$