Overview of HERMES results

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(on behalf of the HERMES Collaboration)

XVII WORKSHOP ON HIGH ENERGY SPIN PHYSICS
DSPIN – 17
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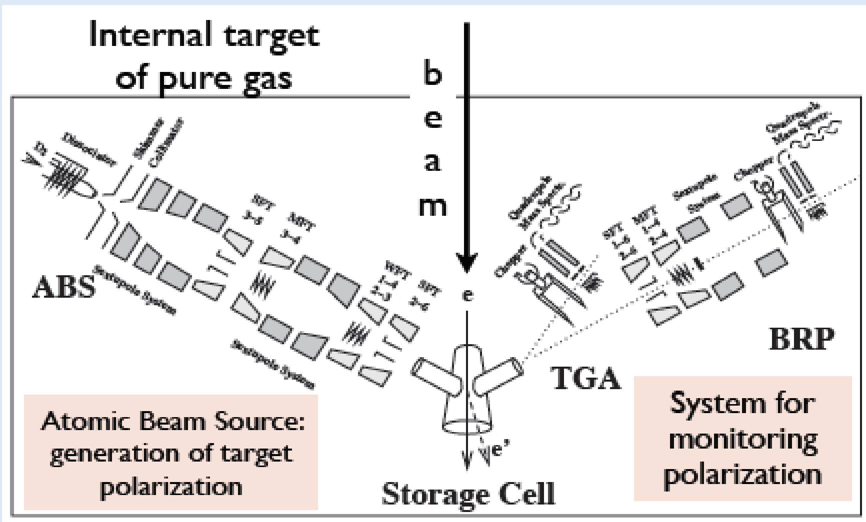
- The HERMES experiment.
- 3D picture of the nucleon:
  - A_{UT} & A_{LT}, A_{LU} in semi-inclusive DIS.
  - ω–meson production:
    - SDMEs & A_{UT} from exclusive DIS;
    - Extraction of πω transition form factor.
  - ρ^0-meson production:
    - Measurement of helicity amplitude ratios;

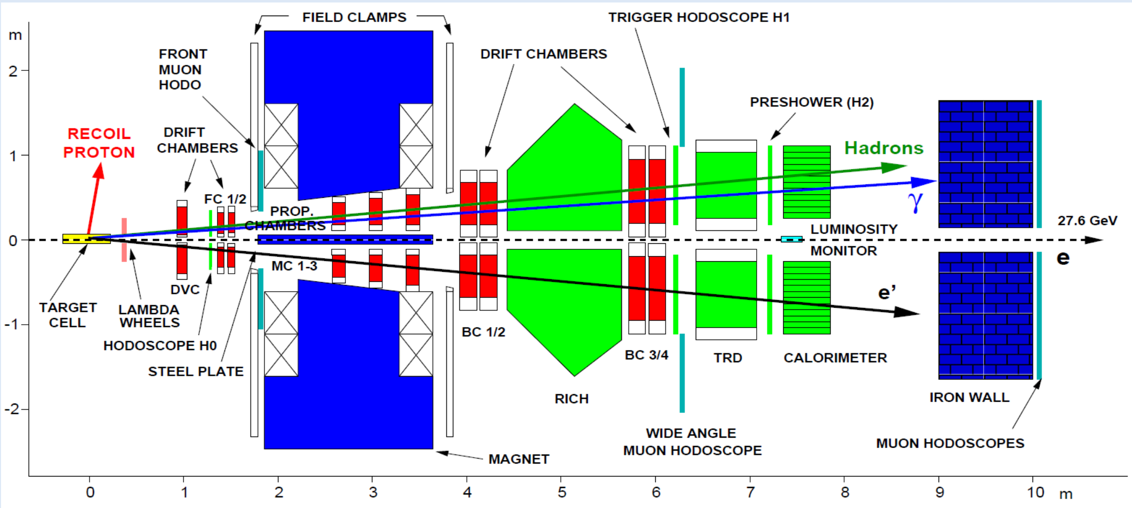
HERMES at DESY

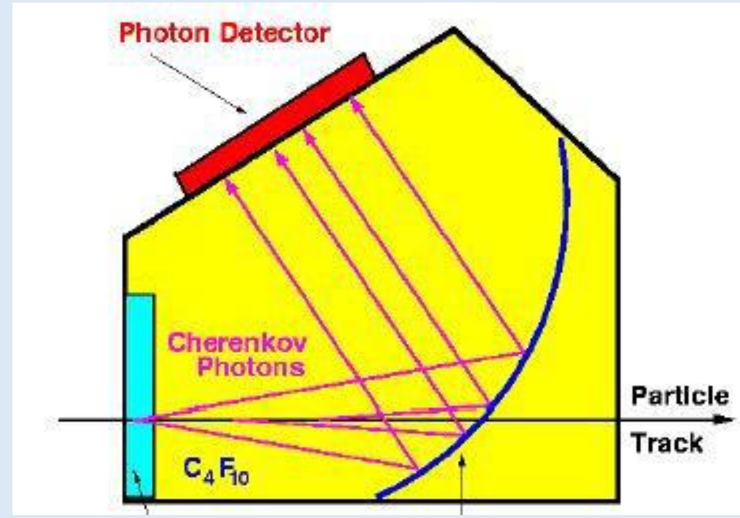
Self-polarized e^+ and e^- beams
27.6 GeV
Helicity switched every few months



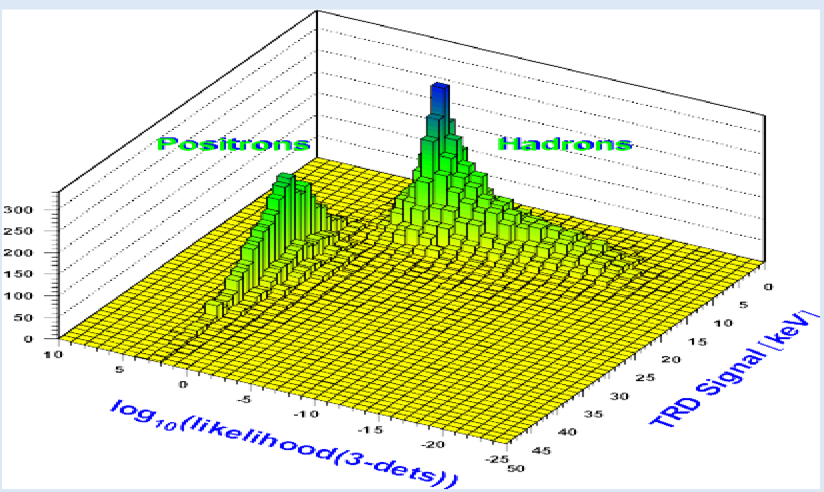
Polarized hydrogen (Long.,Trans.), deuterium (Long.)
Polarization flipped at 60-180 s time interval
Unpolarized *H,D,He,N,Ne,Kr,Xe*

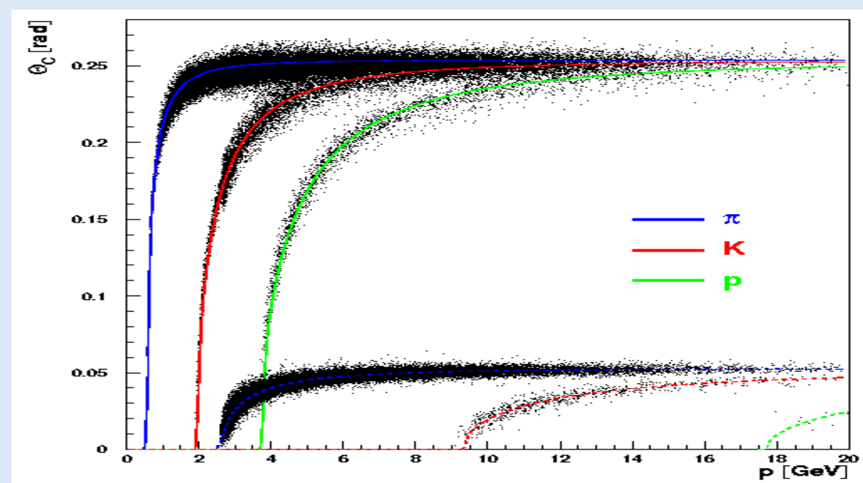
The HERMES Spectrometer





Aerogel Mirror



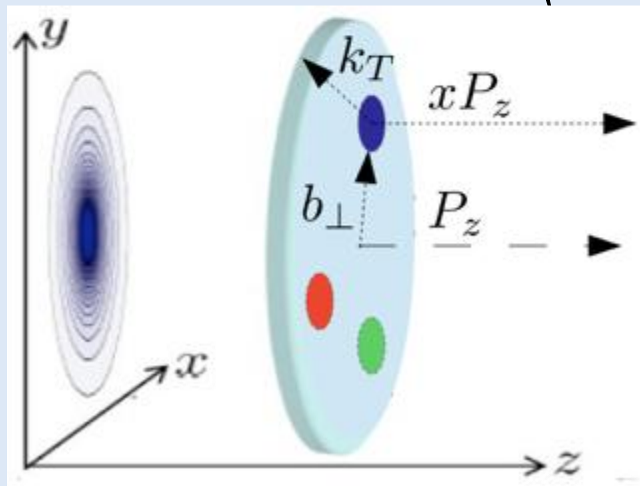


- PID: RICH, TRD, Preshower and Calorimeter; lepton-hadron > 98%
- Momentum resolution of charged particles: $\delta P/P \simeq 1.5\%$

3D picture of the nucleon

Wigner distributions $W\left(x,\vec{k}_T,\vec{b}_\perp\right)$

$\int d^2\vec{b}_\perp$



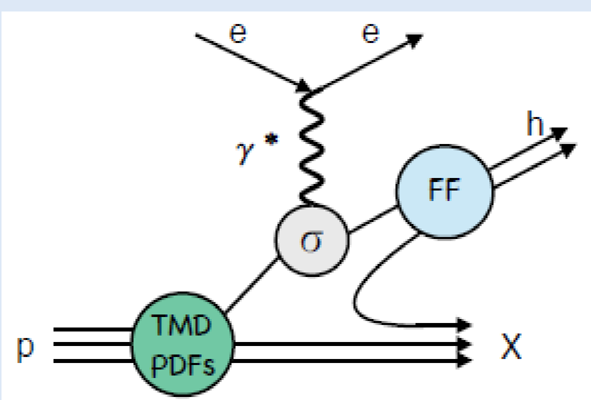
$\int d^2\vec{k}_T$

TMD PDFs: $f_p^q(x,k_T)$,…

GPDs: $H_p^q(x,\xi,t)$, …

Semi-inclusive measurements
Direct info about momentum distribution

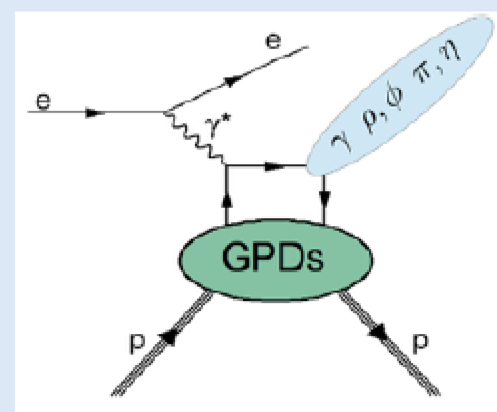
Exclusive Measurements
Direct info about spatial distribution



$\int d^2\vec{k}_T$

$\xi=0$, $t=0$

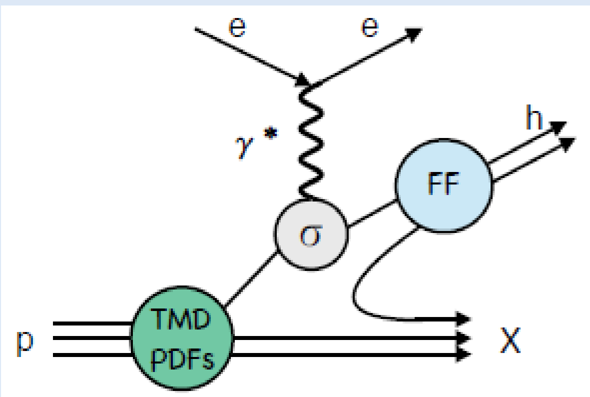
PDFs $f_p^q(x)$,…

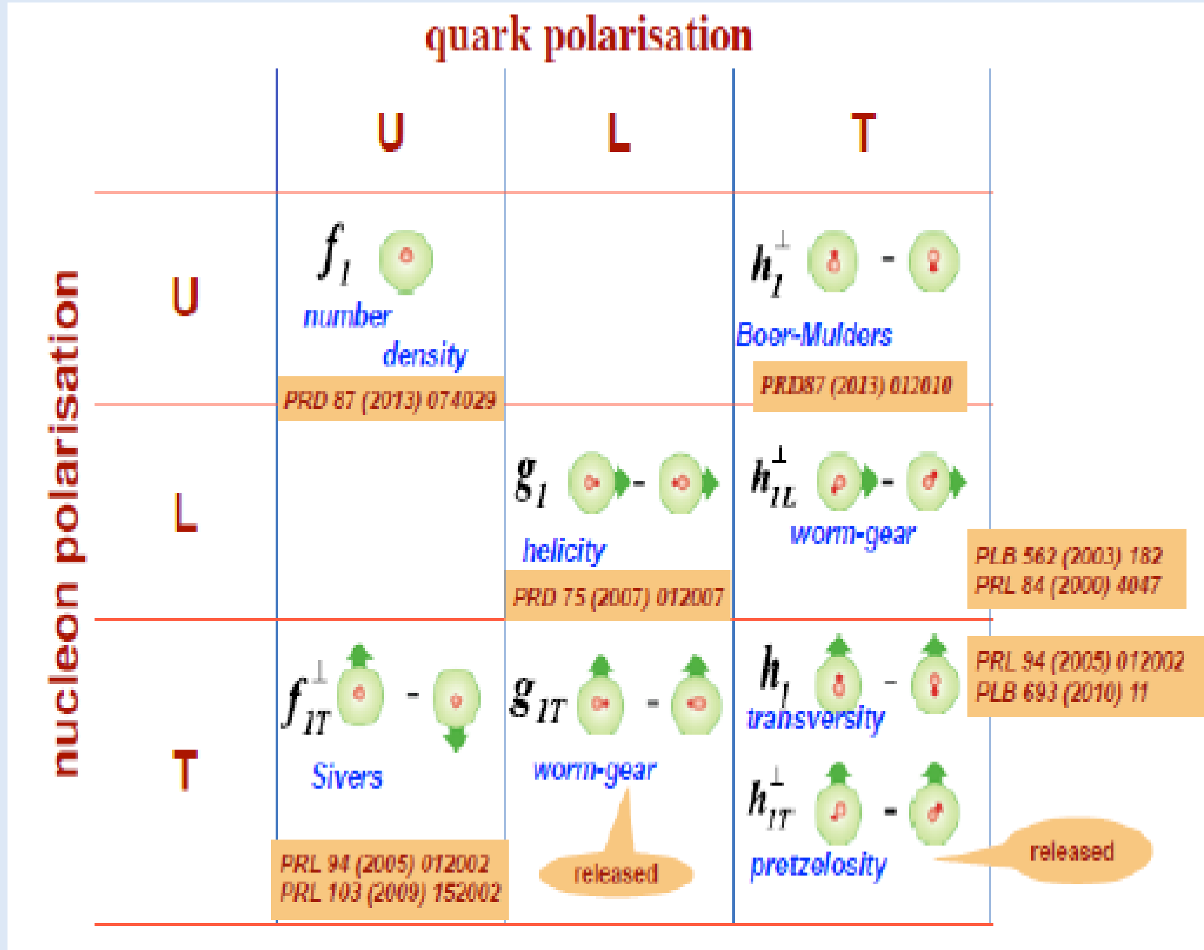


A_{UT} & A_{LT}, A_{LU} in semi-inclusive DIS

- *Unpolarized* & longitudinally polarized e^+/e^- beam
- Transversely polarized H target
- *Unpolarized* H & D targets

Semi-inclusive DIS processes (SIDIS)





SIDIS processes:

- Describe spin-orbit correlation: correlations between the hadron transverse momentum and quark or nucleon spin
- Sensitive to quark orbital angular momentum

The SIDIS cross-section

$$
\begin{aligned}
\frac{d\sigma^h}{dx\,dy\,d\phi_S\,dz\,d\phi\,d\mathbf{P}_{h\perp}^2} = & \frac{\alpha^2}{xyQ^2}\frac{y^2}{2\,(1-\epsilon)}\left(1+\frac{\gamma^2}{2x}\right) \\
\Big\{ & \Big[F_{\mathrm{UU,T}} + \epsilon F_{\mathrm{UU,L}} \\
& + \sqrt{2\epsilon\,(1+\epsilon)}\cos(\phi) F_{\mathrm{UU}}^{\cos(\phi)} + \epsilon\cos(2\phi) F_{\mathrm{UU}}^{\cos(2\phi)}\Big] \\
+ \quad \lambda_l & \Big[\sqrt{2\epsilon\,(1-\epsilon)}\sin(\phi) F_{\mathrm{LU}}^{\sin(\phi)}\Big] \\
+ S_L & \Big[\sqrt{2\epsilon\,(1+\epsilon)}\sin(\phi) F_{\mathrm{UL}}^{\sin(\phi)} + \epsilon\sin(2\phi) F_{\mathrm{UL}}^{\sin(2\phi)}\Big] \\
+ S_L\,\lambda_l & \Big[\sqrt{1-\epsilon^2} F_{\mathrm{LL}} + \sqrt{2\epsilon\,(1-\epsilon)}\cos(\phi) F_{\mathrm{LL}}^{\cos(\phi)}\Big] \\
+ S_T & \Big[\sin(\phi-\phi_S)\left(F_{\mathrm{UT,T}}^{\sin(\phi-\phi_S)} + \epsilon F_{\mathrm{UT,L}}^{\sin(\phi-\phi_S)}\right) \\
& + \epsilon\sin(\phi+\phi_S) F_{\mathrm{UT}}^{\sin(\phi+\phi_S)} + \epsilon\sin(3\phi-\phi_S) F_{\mathrm{UT}}^{\sin(3\phi-\phi_S)} \\
& + \sqrt{2\epsilon\,(1+\epsilon)}\sin(\phi_S) F_{\mathrm{UT}}^{\sin(\phi_S)} \\
& + \sqrt{2\epsilon\,(1+\epsilon)}\sin(2\phi-\phi_S) F_{\mathrm{UT}}^{\sin(2\phi-\phi_S)}\Big] \\
+ S_T\,\lambda_l & \Big[\sqrt{1-\epsilon^2}\cos(\phi-\phi_S) F_{\mathrm{LT}}^{\cos(\phi-\phi_S)} \\
& + \sqrt{2\epsilon\,(1-\epsilon)}\cos(\phi_S) F_{\mathrm{LT}}^{\cos(\phi_S)} \\
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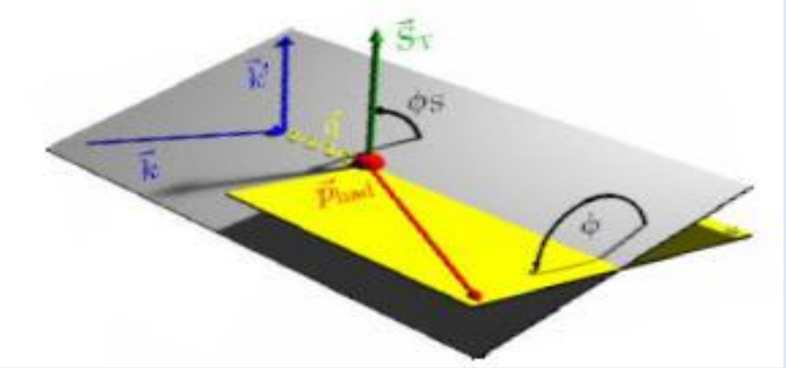
\end{aligned}
$$



$F_{XY,Z} \propto \mathrm{PDF} \otimes \mathrm{FF}$

X=beam, Y=target,

Z=γ^*polarization

TMD PDFs

		quark U	quark L	quark T
nucleon	U	f_1		$h_1^\perp$
	L		g_1	$h_{1L}^\perp$
	T	$f_{1T}^\perp$	g_{1T}	h_1, $h_{1T}^\perp$

FFs

		quark U	quark L	quark T
h	U	D_1		$H_1^\perp$

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$$

$$
\begin{aligned}
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& + \epsilon\sin(\phi+\phi_S) F_{\mathrm{UT}}^{\sin(\phi+\phi_S)} + \epsilon\sin(3\phi-\phi_S) F_{\mathrm{UT}}^{\sin(3\phi-\phi_S)} \\
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\end{aligned}
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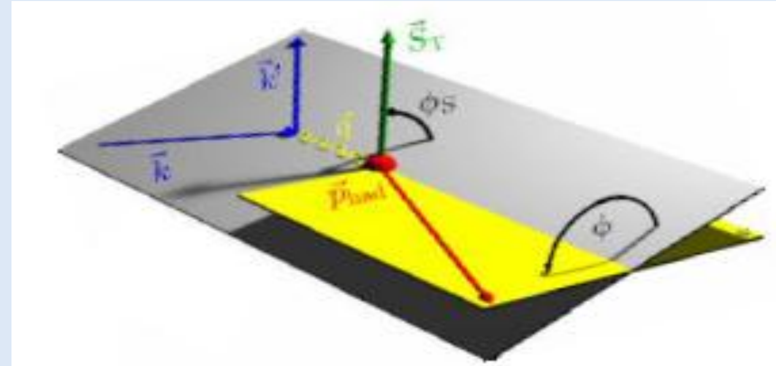

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$$+ \lambda_l \Big[\sqrt{2\epsilon(1-\epsilon)}\sin(\phi)F_{\mathrm{LU}}^{\sin(\phi)}\Big]$$

$$+ S_L \Big[\sqrt{2\epsilon(1+\epsilon)}\sin(\phi)F_{\mathrm{UL}}^{\sin(\phi)} + \epsilon\sin(2\phi)F_{\mathrm{UL}}^{\sin(2\phi)}\Big]$$

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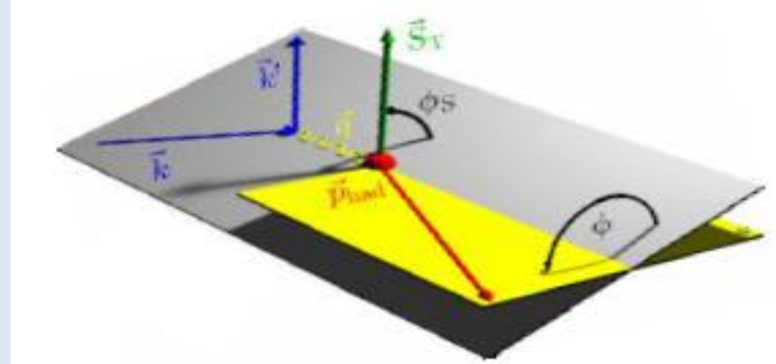
$$+ S_T\,\lambda_l \Big[\sqrt{1-\epsilon^2}\cos(\phi-\phi_S)F_{\mathrm{LT}}^{\cos(\phi-\phi_S)} + \sqrt{2\epsilon(1-\epsilon)}\cos(\phi_S)F_{\mathrm{LT}}^{\cos(\phi_S)} + \sqrt{2\epsilon(1-\epsilon)}\cos(2\phi-\phi_S)F_{\mathrm{LT}}^{\cos(2\phi-\phi_S)}\Big] \Big\}$$



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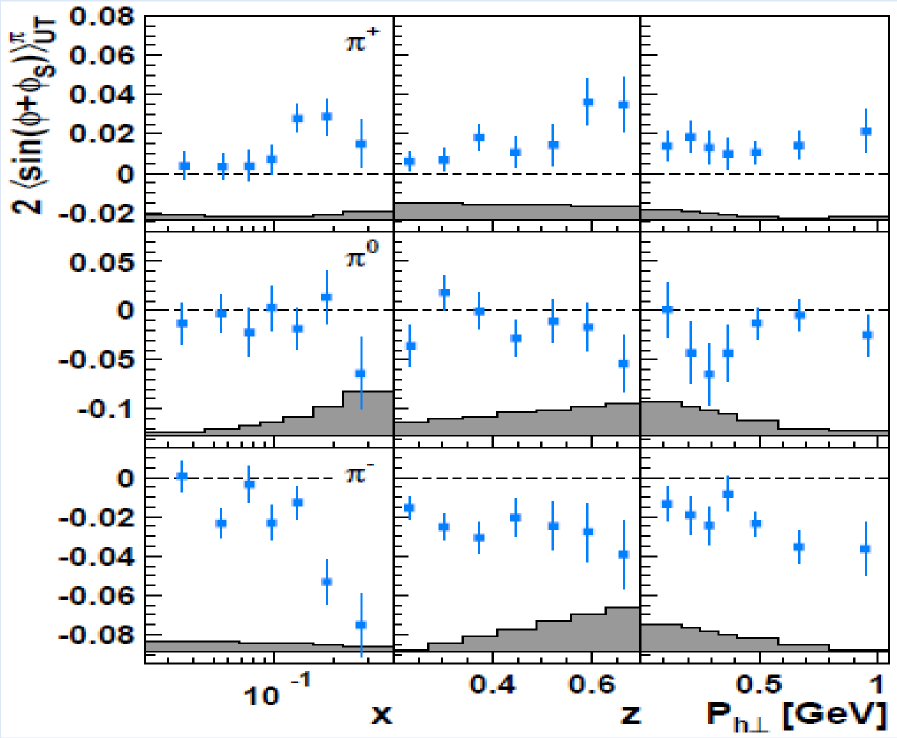
Hrachya Marukyan, 11.09.2017, DSPIN-17, Dubna, Russia

Transversely polarized quarks: Collins effect for pions

Phys. Lett. B 693 (2010) 11

$$F_{UT}^{\sin(\phi_h+\phi_S)} \propto h_1\left(x, p_T^2\right) \otimes H_1^{\perp}\left(z, k_T^2\right)$$



- Opposite in sign for charged pions
- Disfavored Collins FF large and opposite in sign to favored one

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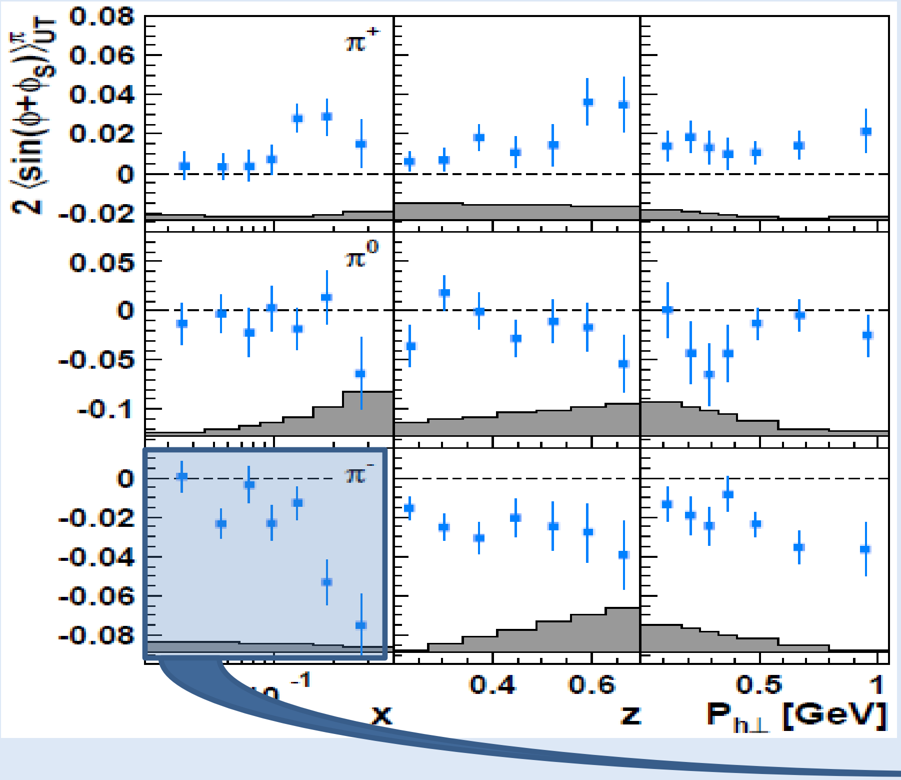
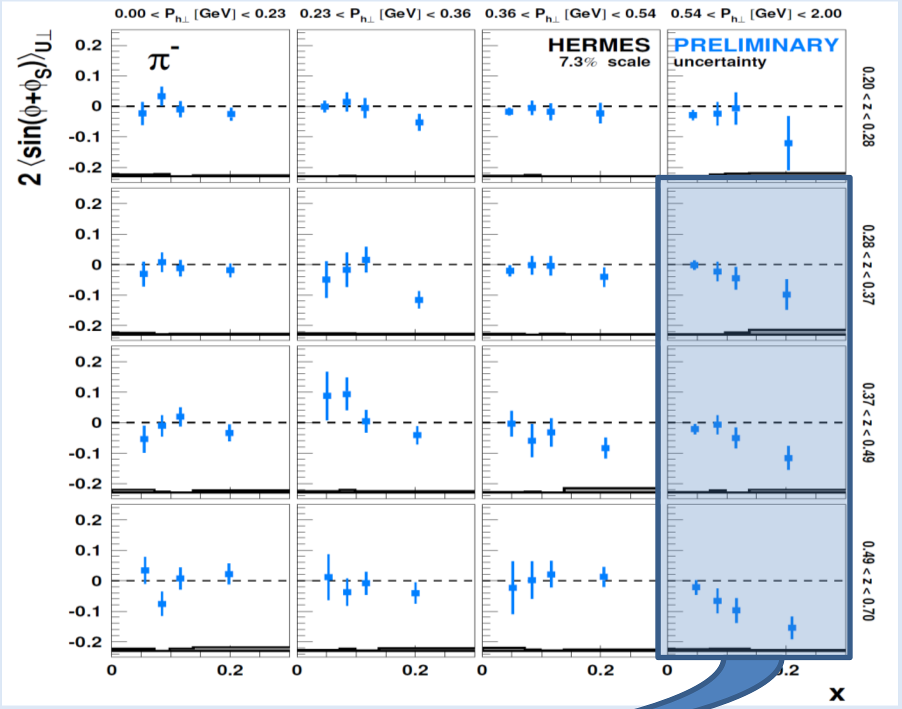


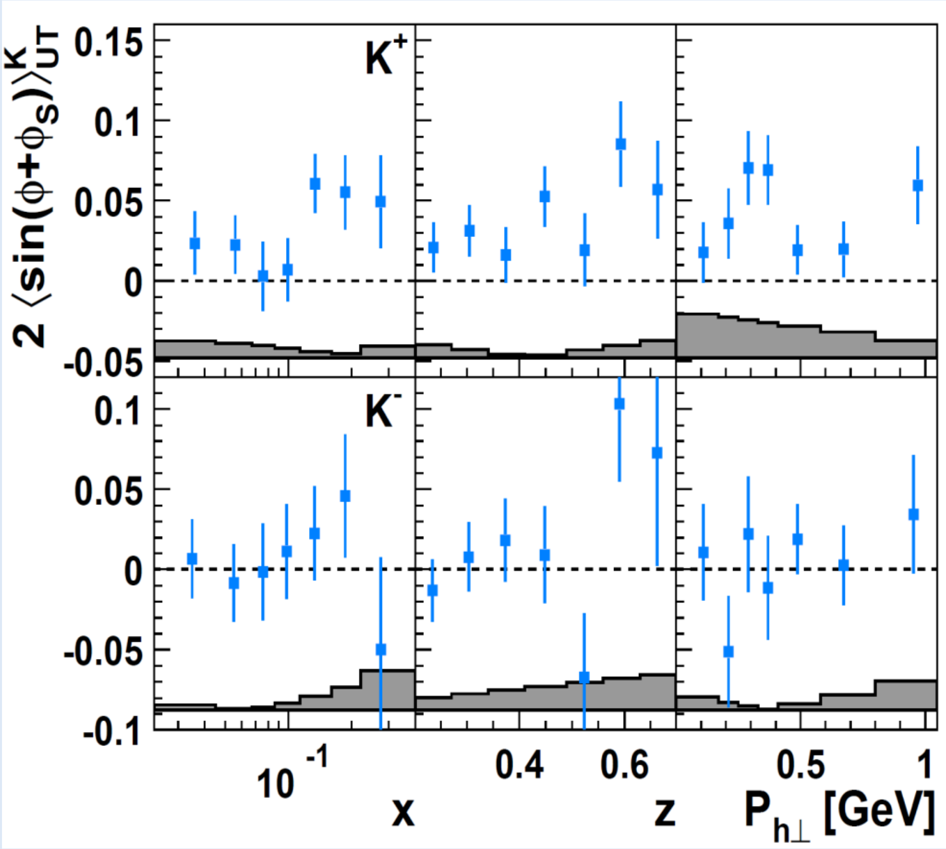


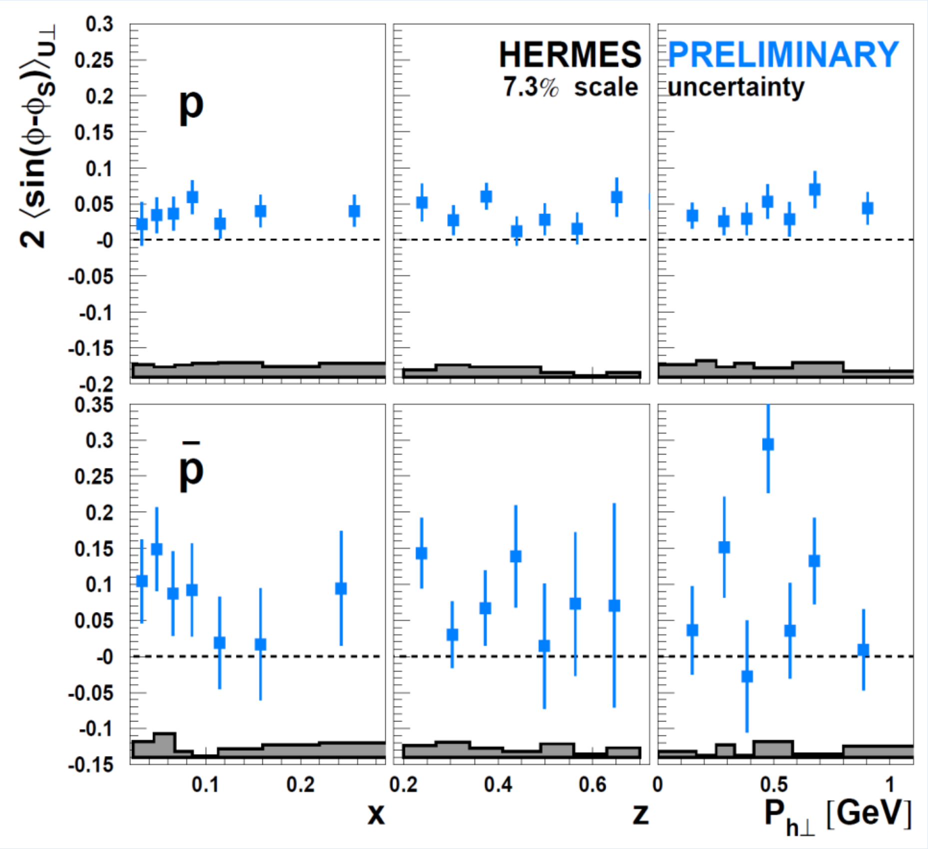
- Opposite in sign for charged pions
- Disfavored Collins FF large and opposite in sign to favored one
- 3D projections allow to constrain global fits in a more profound way
- π^- amplitudes increasing with x at large $P_{h\perp}$

Collins effect for kaons and (anti) protons

Phys. Lett. B 693 (2010) 11

$$F_{UT}^{\sin(\phi_h+\phi_S)} \propto h_1\left(x, p_T^2\right) \otimes H_1^{\perp}\left(z, k_T^2\right)$$



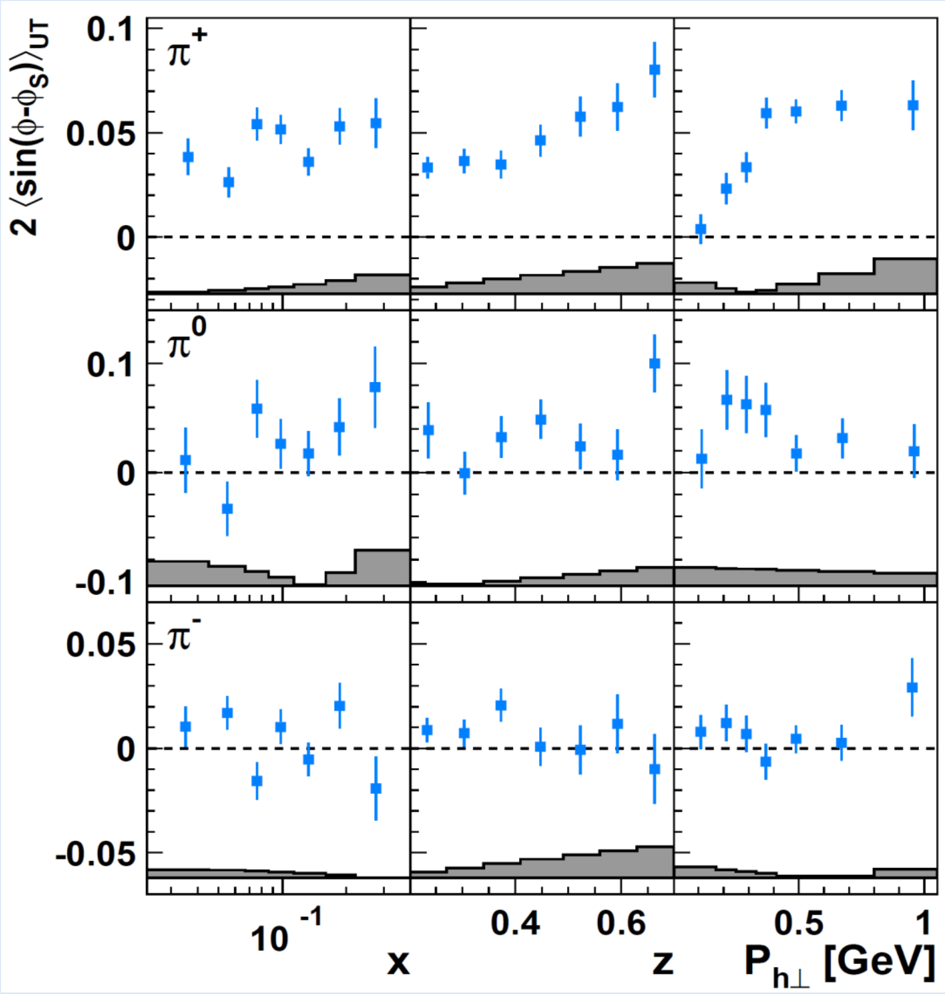


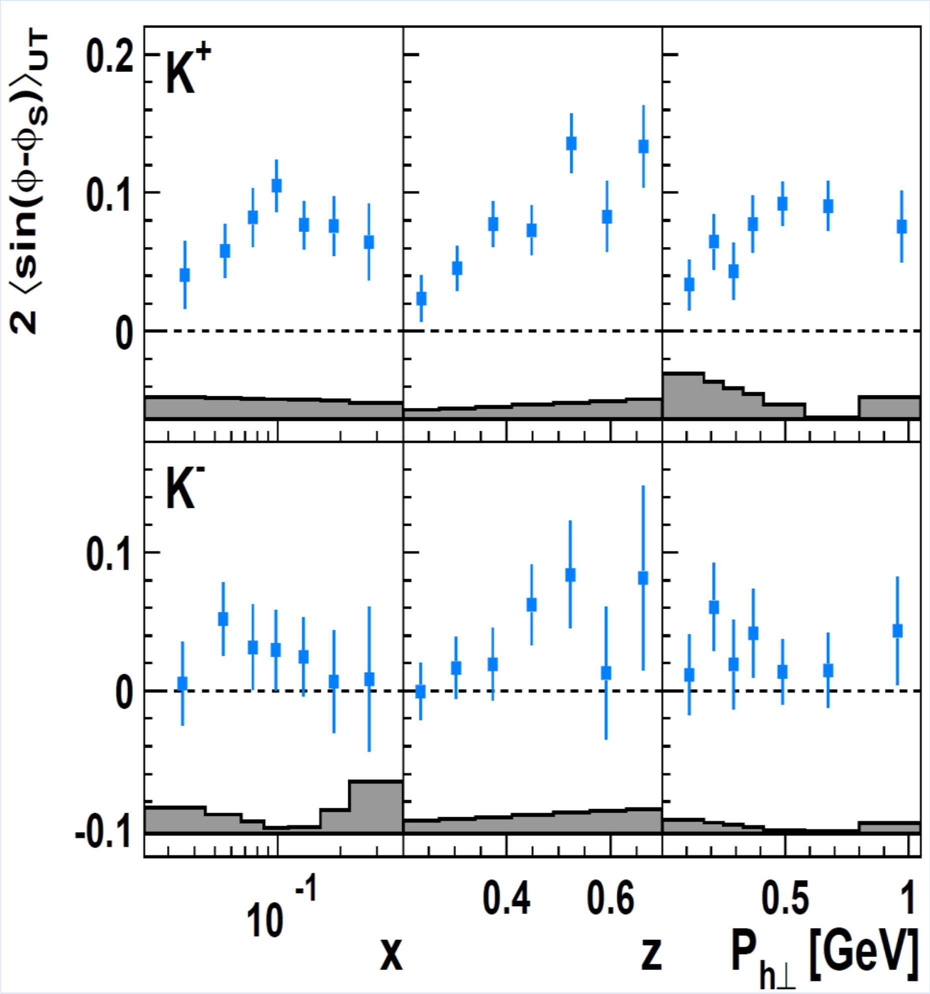
- Positive Collins SSA amplitude for positive kaons
- Consistent with zero for negative kaons and (anti)protons
- Vanishing sea-quark transversity?

Sivers amplitudes for mesons

Phys. Lett. B 693 (2010) 11

$$F_{UT}^{\sin(\phi_h-\phi_S)} \propto f_{1T}^{\perp}\left(x, p_T^2\right) \otimes D_1\left(z, k_T^2\right)$$



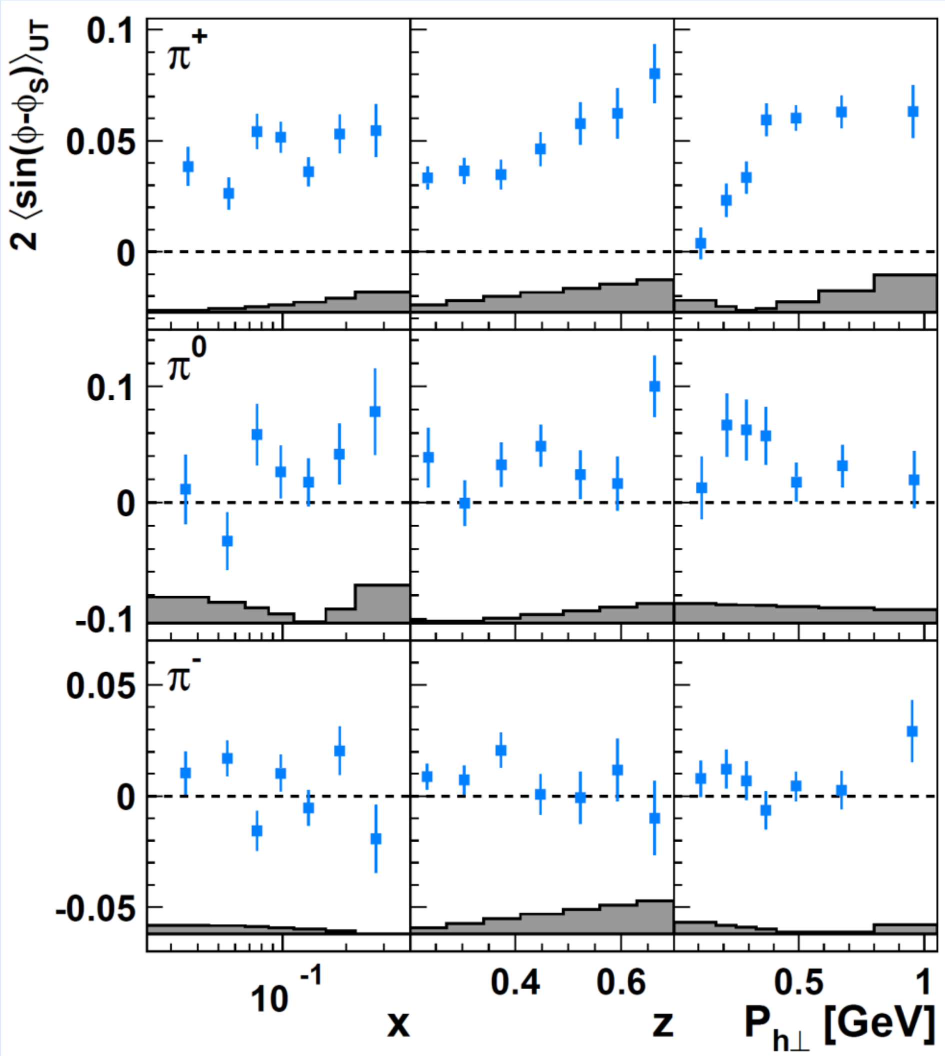


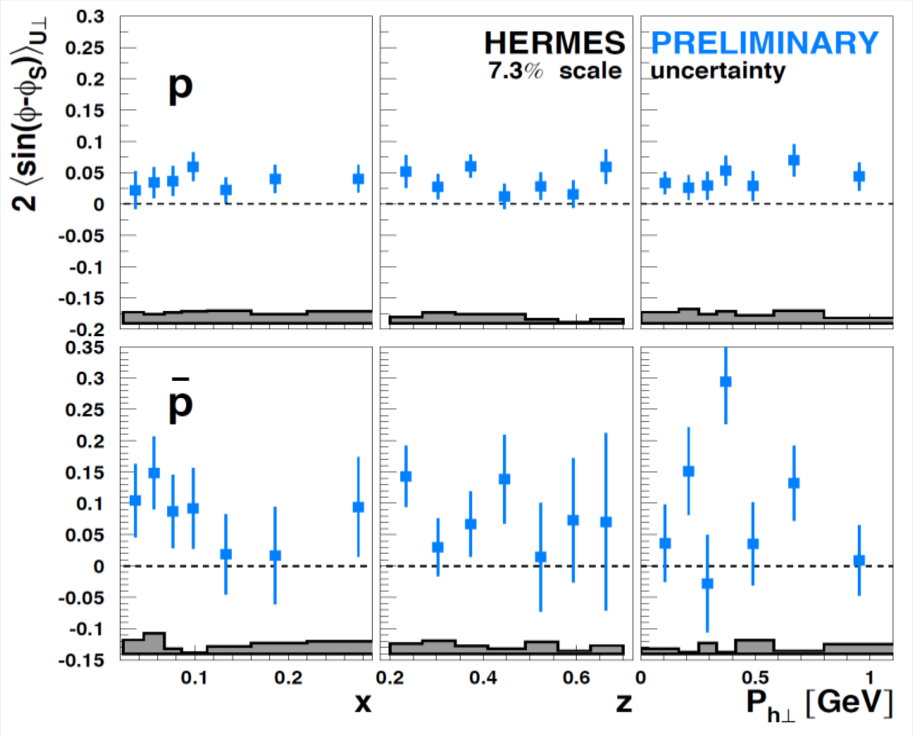
- Larger amplitudes for positive kaons vs. pions

Sivers amplitudes for baryons

Phys. Lett. B 693 (2010) 11

$$F_{UT}^{\sin(\phi_h-\phi_S)} \propto f_{1T}^{\perp}\left(x, p_T^2\right) \otimes D_1\left(z, k_T^2\right)$$

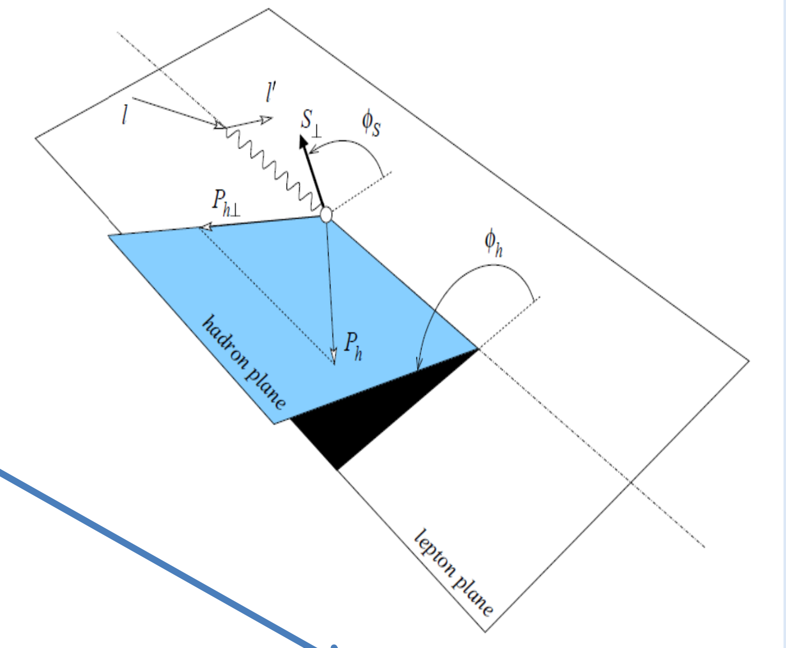




- Similar amplitudes for positive pions and protons
- u-quark dominance (and not a FF effect)?

The SIDIS cross-section: A_{LU} amplitudes

$$
\begin{aligned}
&\frac{d\sigma}{dx\,dy\,d\psi\,dz\,d\phi_h\,dP_{h\perp}^2} = \\
&\frac{\alpha^2}{xyQ^2}\,\frac{y^2}{2\,(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\Big\{F_{UU,T}+\varepsilon F_{UU,L}+\sqrt{2\,\varepsilon(1+\varepsilon)}\,\cos\phi_h\,F_{UU}^{\cos\phi_h} \\
&\quad+\varepsilon\cos(2\phi_h)\,F_{UU}^{\cos 2\phi_h}+\lambda_e\,\sqrt{2\,\varepsilon(1-\varepsilon)}\,\sin\phi_h\,F_{LU}^{\sin\phi_h} \\
&\quad+S_\parallel\Big[\sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin\phi_h\,F_{UL}^{\sin\phi_h}+\varepsilon\sin(2\phi_h)\,F_{UL}^{\sin 2\phi_h}\Big] \\
&\quad+S_\parallel\lambda_e\Big[\sqrt{1-\varepsilon^2}\,F_{LL}+\sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos\phi_h\,F_{LL}^{\cos\phi_h}\Big] \\
&\quad+|\boldsymbol{S}_\perp|\Big[\sin(\phi_h-\phi_S)\Big(F_{UT,T}^{\sin(\phi_h-\phi_S)}+\varepsilon\,F_{UT,L}^{\sin(\phi_h-\phi_S)}\Big) \\
&\qquad+\varepsilon\,\sin(\phi_h+\phi_S)\,F_{UT}^{\sin(\phi_h+\phi_S)}+\varepsilon\,\sin(3\phi_h-\phi_S)\,F_{UT}^{\sin(3\phi_h-\phi_S)} \\
&\qquad+\sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin\phi_S\,F_{UT}^{\sin\phi_S}+\sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin(2\phi_h-\phi_S)\,F_{UT}^{\sin(2\phi_h-\phi_S)}\Big] \\
&\quad+|\boldsymbol{S}_\perp|\lambda_e\Big[\sqrt{1-\varepsilon^2}\,\cos(\phi_h-\phi_S)\,F_{LT}^{\cos(\phi_h-\phi_S)}+\sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos\phi_S\,F_{LT}^{\cos\phi_S} \\
&\qquad+\sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos(2\phi_h-\phi_S)\,F_{LT}^{\cos(2\phi_h-\phi_S)}\Big]\Big\},
\end{aligned}
$$



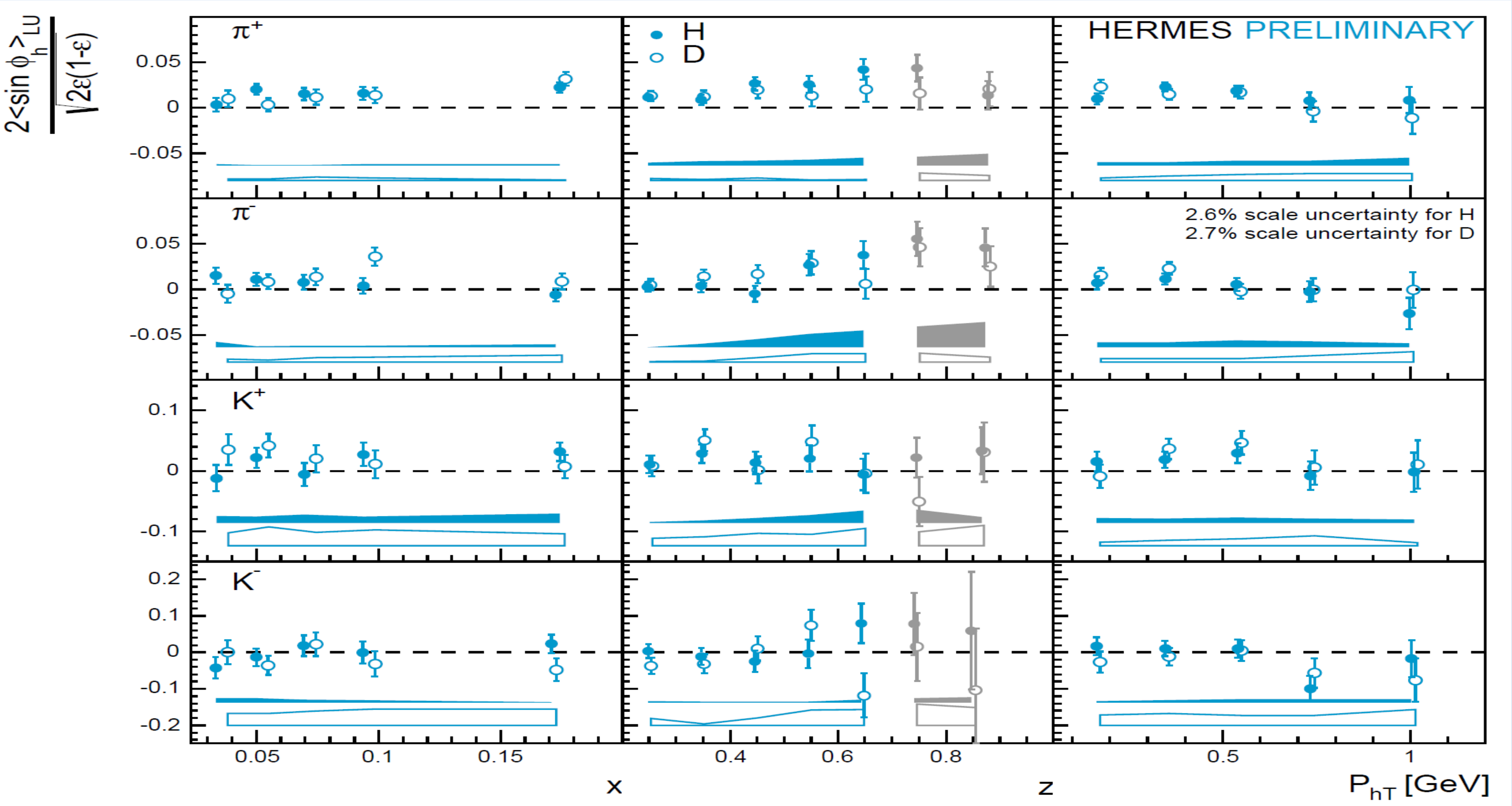
In case of longitudinal beam (L) and unpolarized target (U) only target spin-independent parts can contribute to the asymmetry. The structure function of interest :

$$F_{LU}^{\sin\phi_h}$$

A_{LU} amplitudes: Subleading twist

$$F_{LU}^{\sin(\phi_h)} \propto \frac{M_h}{M_z} h_1^\perp E \oplus x g^\perp D_1 \oplus \frac{M_h}{M_z} f_1 G^\perp \oplus x e H_1^\perp$$

Convolution of twist–2 & twist–3



- Significant positive amplitudes for (in particular positive) pions

A_{LU} amplitudes: Subleading twist

$$F_{LU}^{\sin(\phi_h)} \propto \frac{M_h}{M_z} h_1^{\perp} E \oplus x g^{\perp} D_1 \oplus \frac{M_h}{M_z} f_1 G^{\perp} \oplus x e H_1^{\perp}$$

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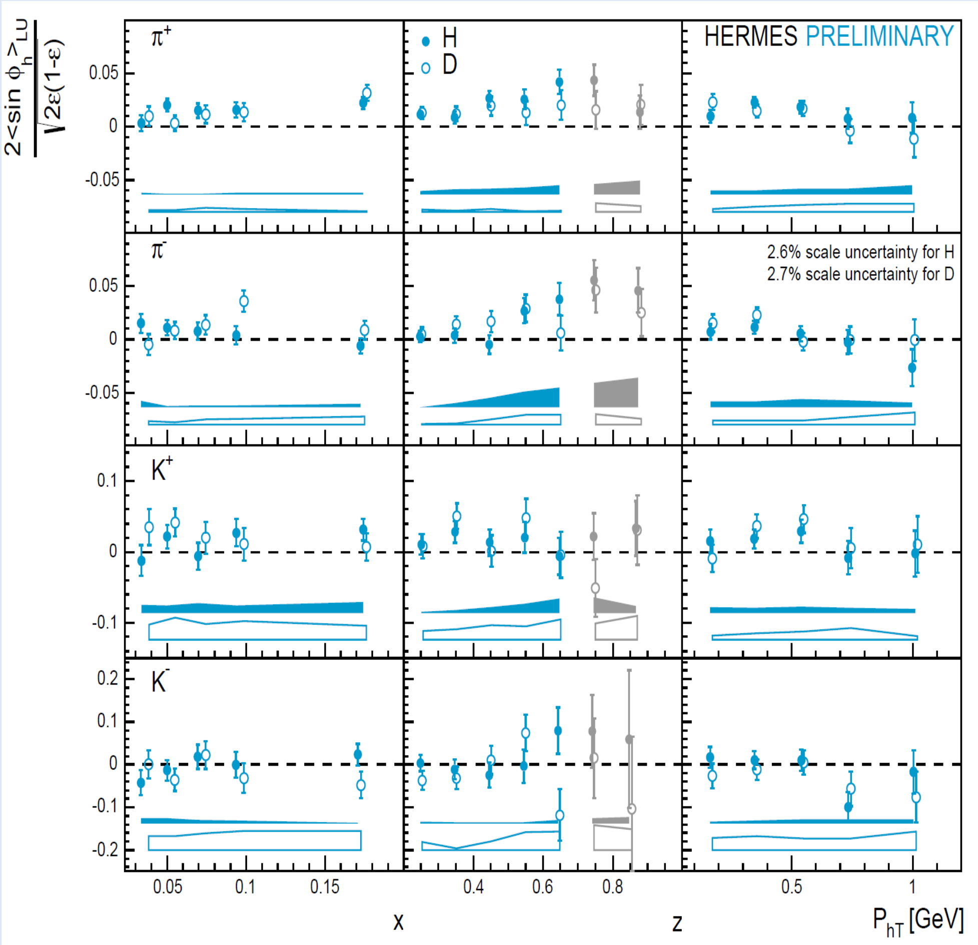
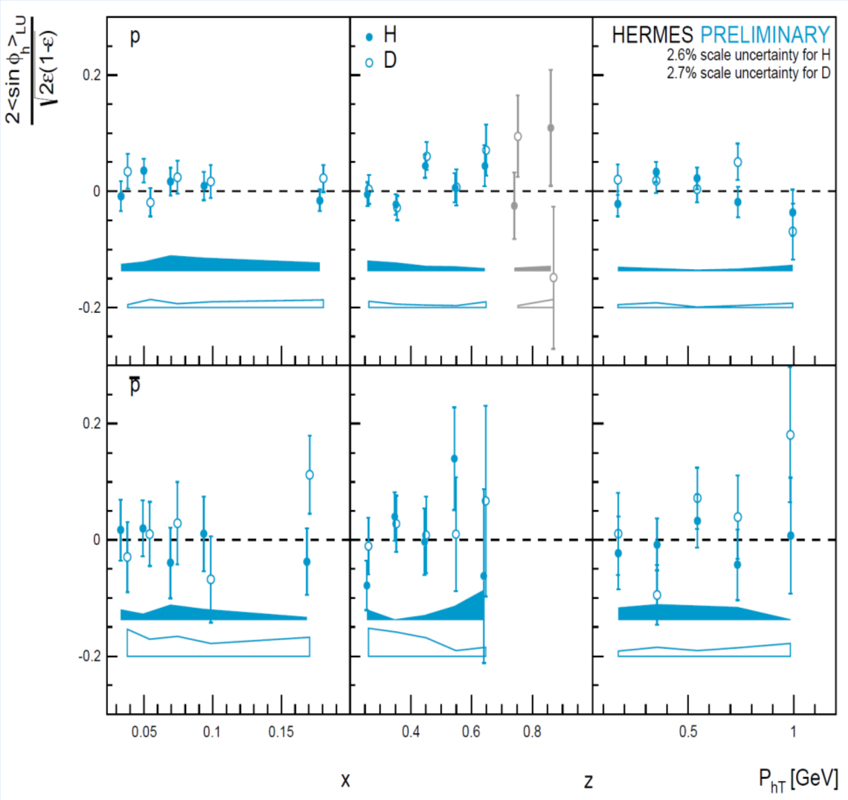


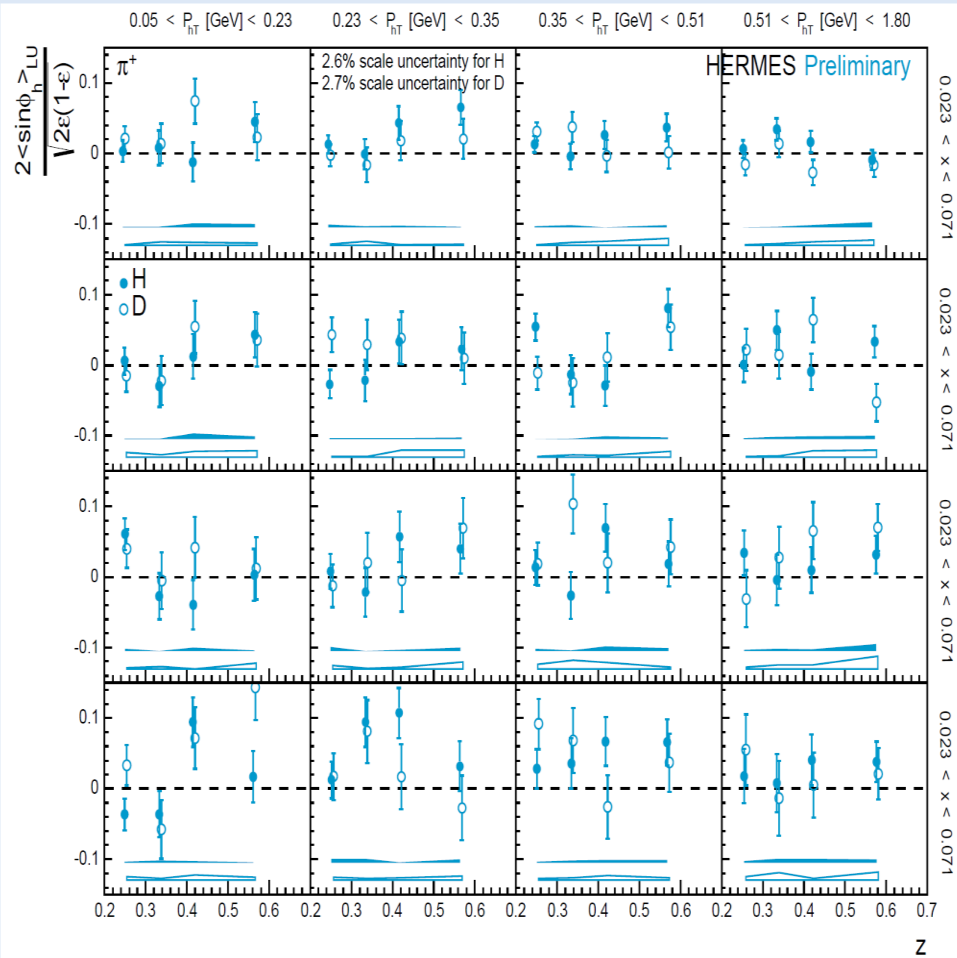


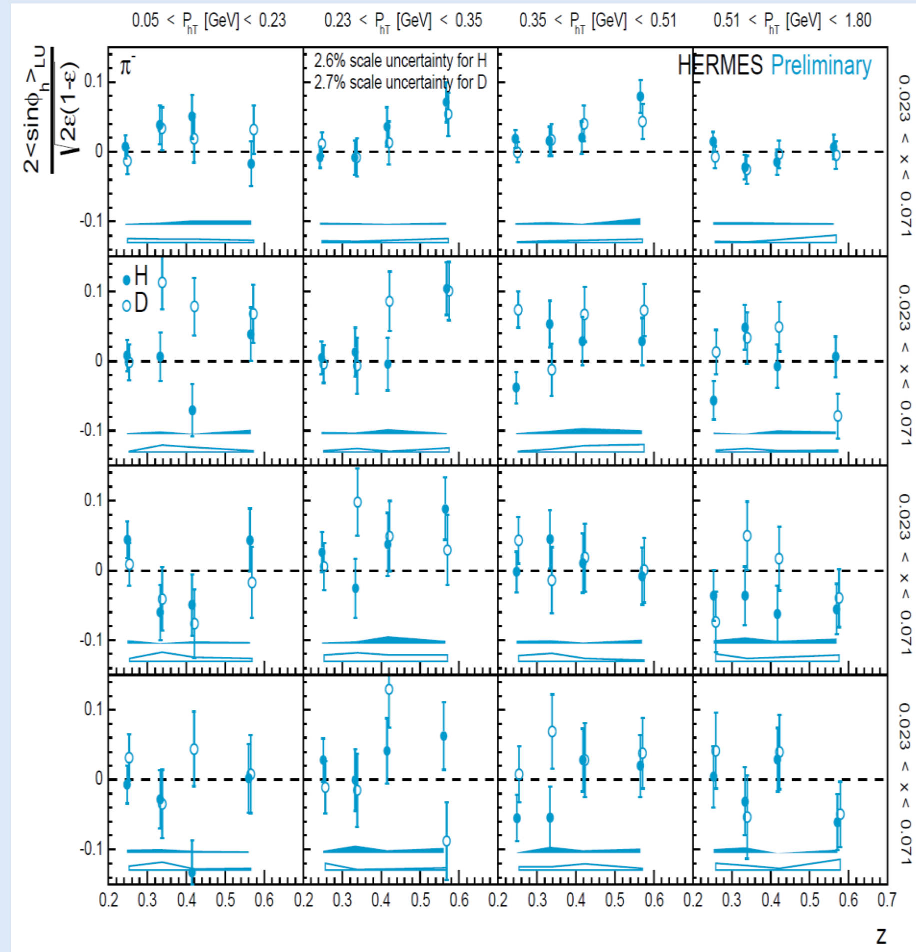
- Mostly consistent with zero for other hadrons (except maybe K^+)

A_{LU} amplitudes: Subleading twist; 3D extraction

$$F_{LU}^{\sin(\phi_h)} \propto \frac{M_h}{M_z} h_1^{\perp} E \oplus x g^{\perp} D_1 \oplus \frac{M_h}{M_z} f_1 G^{\perp} \oplus x e H_1^{\perp}$$

Convolution of twist–2 & twist–3





- 3D projections allow to constrain global fits in a more profound way

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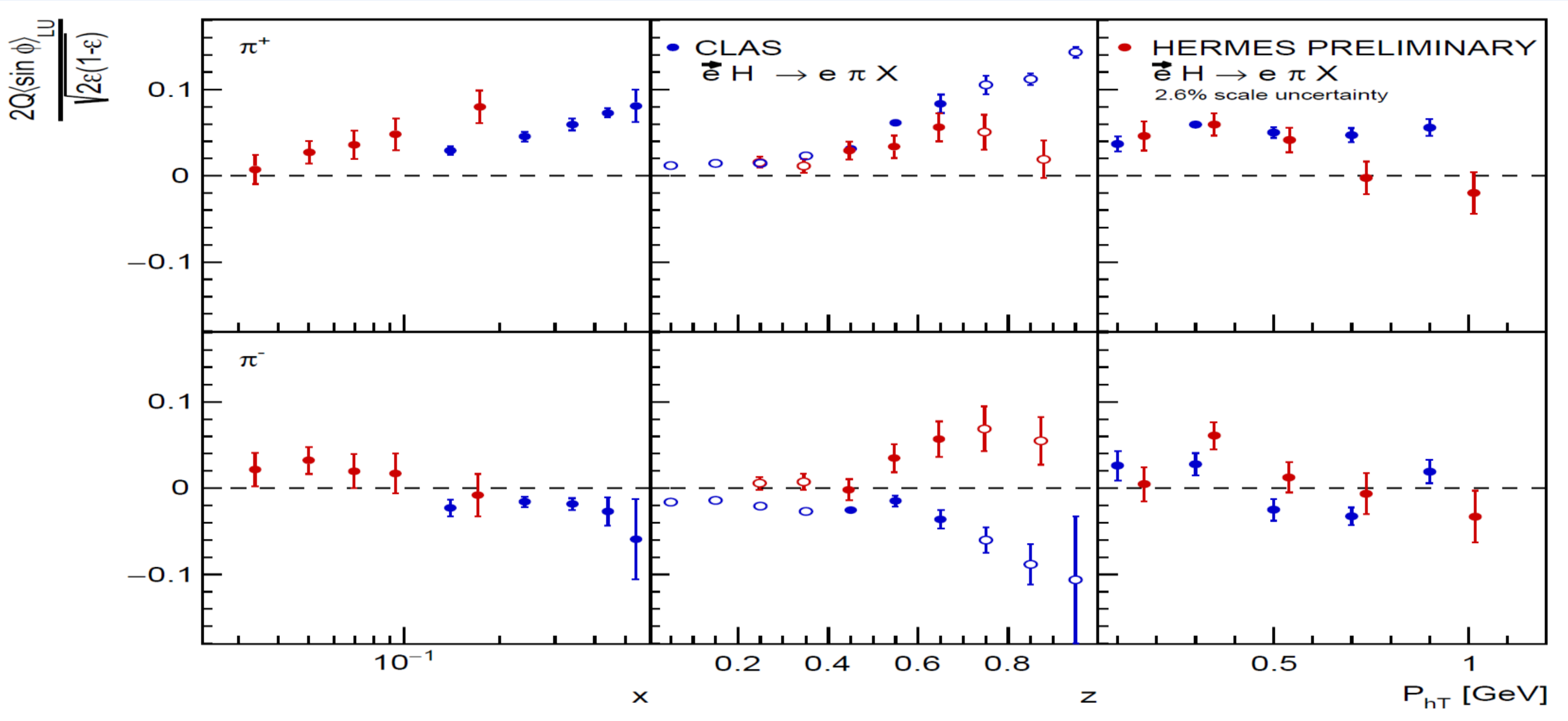

- Opposite behavior at HERMES/CLAS negative pions in z projection due to x-range probed in different experiments.
- CLAS is more sensitive to e(x) Collins term due to higher x?

A_{LU} amplitudes: Subleading twist

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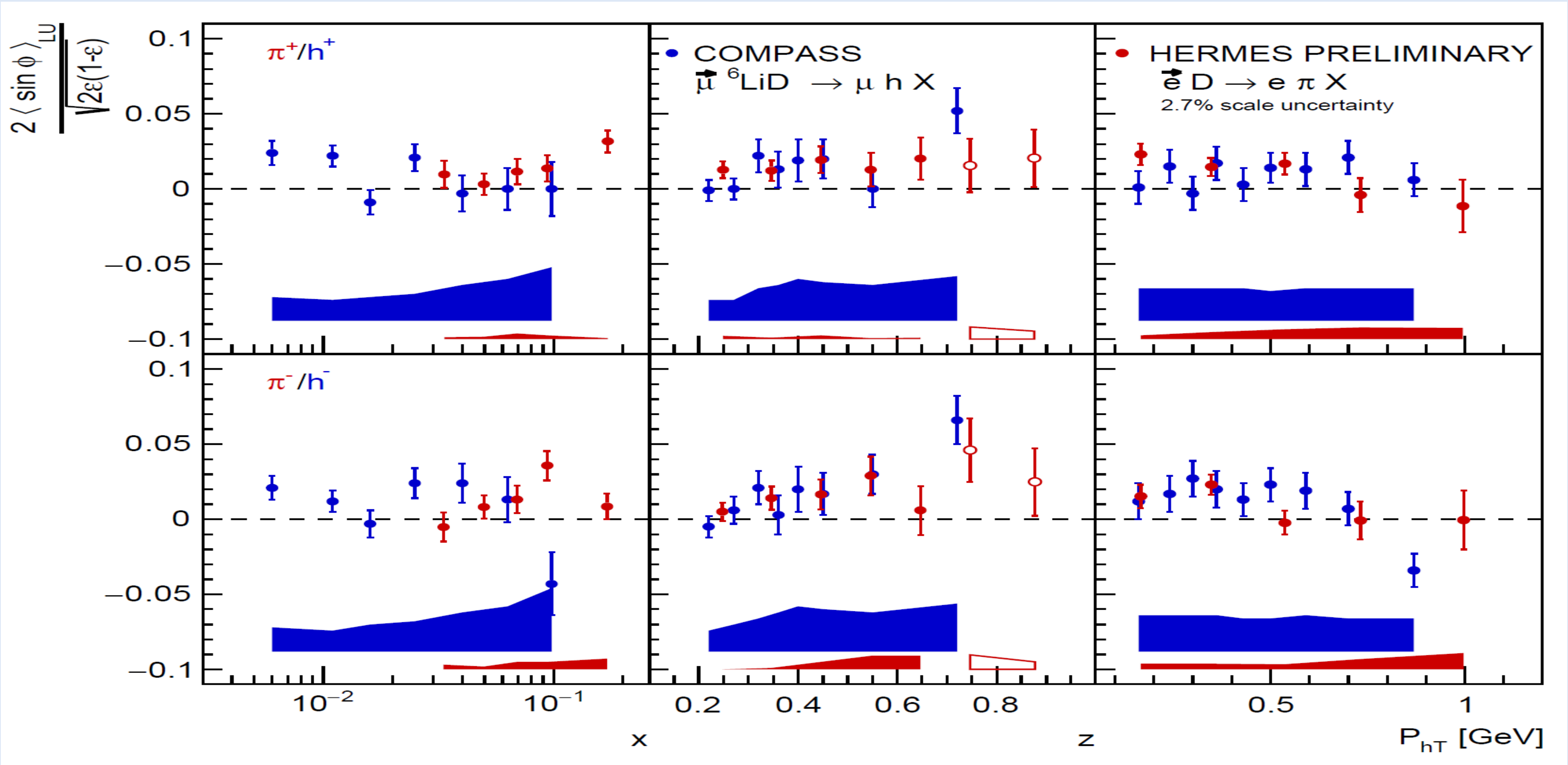
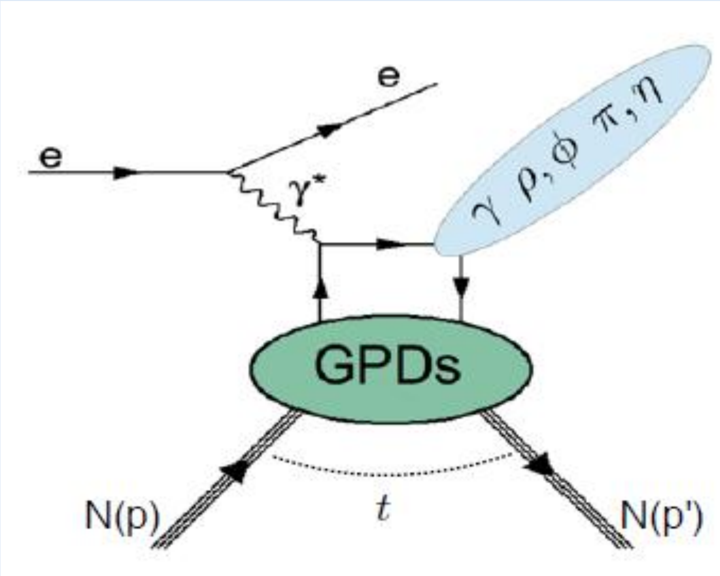


- Consistent behavior for charged pions (hadrons) at HERMES/COMPASS for isoscalar targets

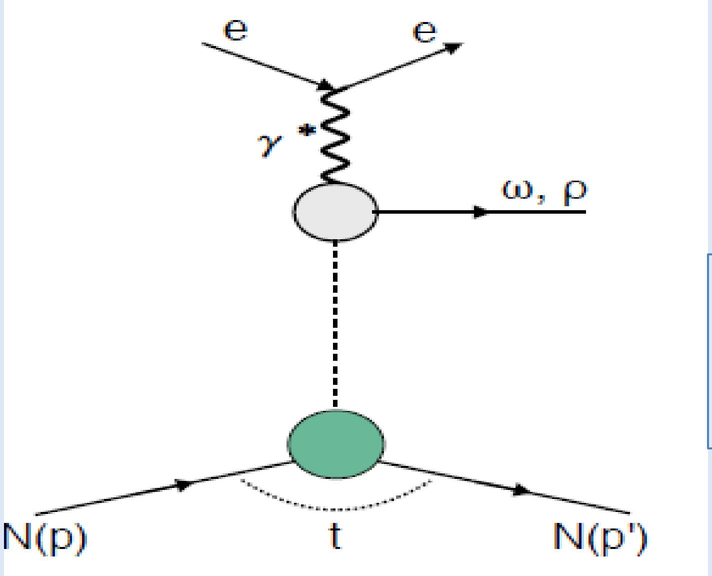
ω–meson production from exclusive DIS: SDMEs & A_{UT}

- *Unpolarized* & longitudinally polarized e^+/e^- beam
- Unpolarized H & D targets
- Transversely polarized H targets

Exclusive meson production



- Probes various types of GPDs with different sensitivity and different flavour combinations
- Complementary to DVCS process
- Unpolarized target: nucleon-helicity-non-flip GPDs $H, \tilde{H}$ and $\bar{E}_T = 2\tilde{H}_T + E_T$.
- Transversely polarized target: nucleon-helicity-flip GPDs $E, \tilde{E}$ and H_T.



NPE ($J^P = 0^+, 1^-, 2^+$ ...) (two-gluon exchange = pomeron, ρ, ω, f_2, a_2, ... reggeons = $\bar{q}q$ exchange).
UPE ($J^P = 0^-, 1^+$, ...) (π, a_1, b_1,...reggeons = $\bar{q}q$ exchange)

Angular distribution and extraction of SDMEs

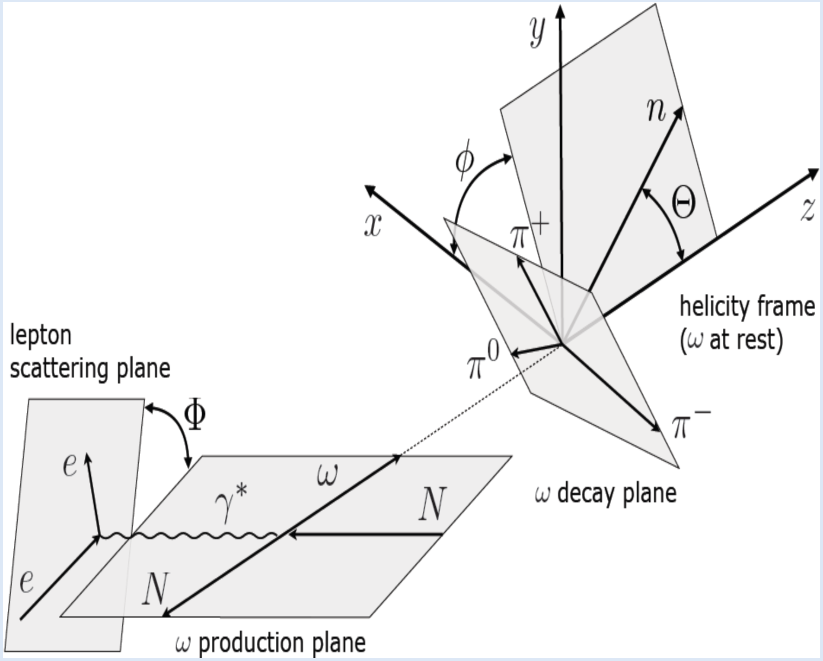
Three-dimensional angular distribution $W^{U+L}(\Phi, \phi, \cos\Theta)$ depends linearly on SDMEs – $r^{\alpha}_{\lambda_V \lambda'_V}$ and beam polarization P_b

$$r^{\alpha}_{\lambda_V \lambda'_V} \sim \rho_{\lambda_V \lambda'_V} = \frac{1}{2N} \sum_{\lambda_\gamma \lambda'_\gamma \lambda_N \lambda'_N} F_{\lambda_V \lambda'_N \lambda_\gamma \lambda_N} \Sigma^{\alpha}_{\lambda_\gamma \lambda'_\gamma} F^{*}_{\lambda'_V \lambda'_N \lambda'_\gamma \lambda_N}$$

$\gamma^* (\lambda_\gamma) + N (\lambda_N) \to V(\lambda_V) + N(\lambda'_N)$

Photon SDMEs

Helicity amplitudes

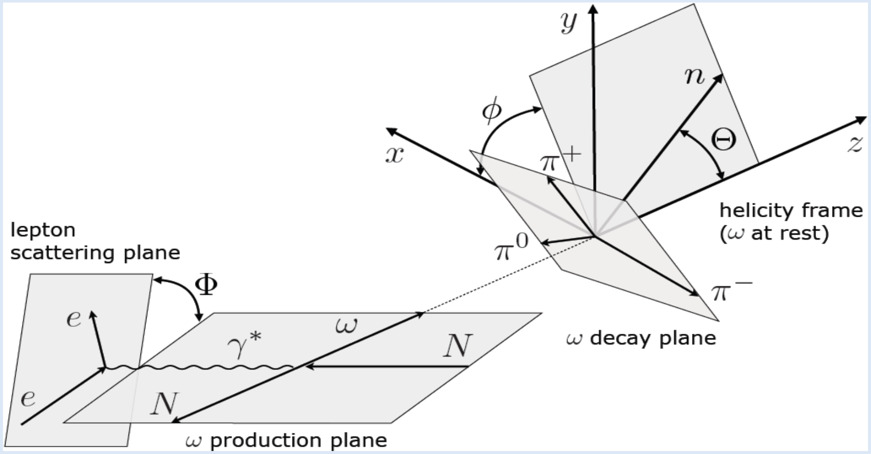


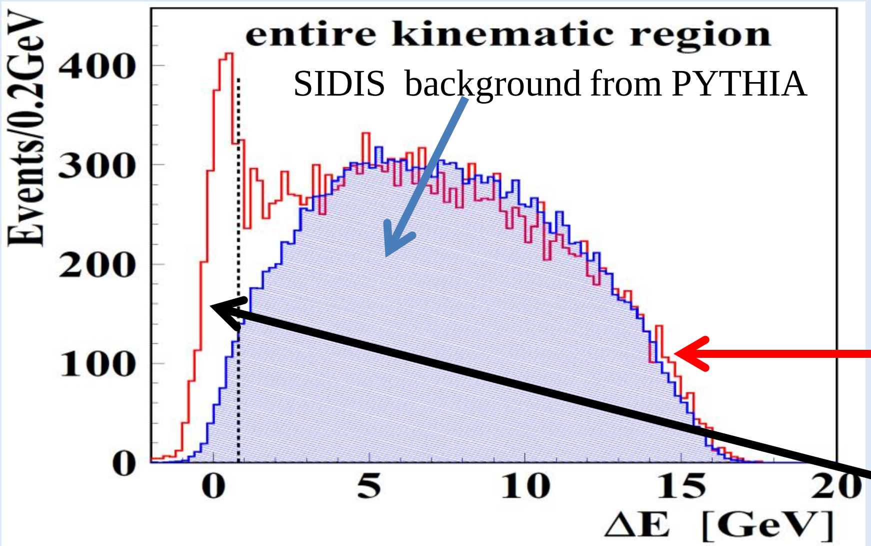
- Helicity amplitudes are the fundamental quantities to be compared with theory.
- They form a basis for the SDMEs.
- For longitudinally polarized beam and unpolarized target there are 23 SDMEs: 15 unpolarized and 8 polarized.
- The SDMEs are extracted by fitting the angular distribution $W^{U+L}(\Phi, \phi, \cos\Theta)$ to the experimental angular distribution of pions from ω - decay using unbinned Maximum Likelihood method.

Exclusive ω - meson production at HERMES

$e(k) + N(p) \dashrightarrow e(k') + N(p') + \omega$

$\omega \dashrightarrow \pi^+ \ \pi^- \ \pi^0, \ \pi^0 \dashrightarrow 2\gamma$





Kinematic conditions:

$1 \text{ GeV}^2 < Q^2 < 10 \text{ GeV}^2,$

$0.01 < x_B < 0.35,$

$3.0 \text{ GeV} < W < 6.3 \text{ GeV},$

$0 \leq -t' = -(t - t_{min}) < 0.2 \text{ GeV}^2$

Two photon invariant mass:

$0.11 \text{ GeV} < M(\gamma\gamma) < 0.16 \text{ GeV}$

Three-pion invariant mass:

$0.71 \text{ GeV} < M(\pi^+\pi^-\pi^0) < 0.87 \text{ GeV}$

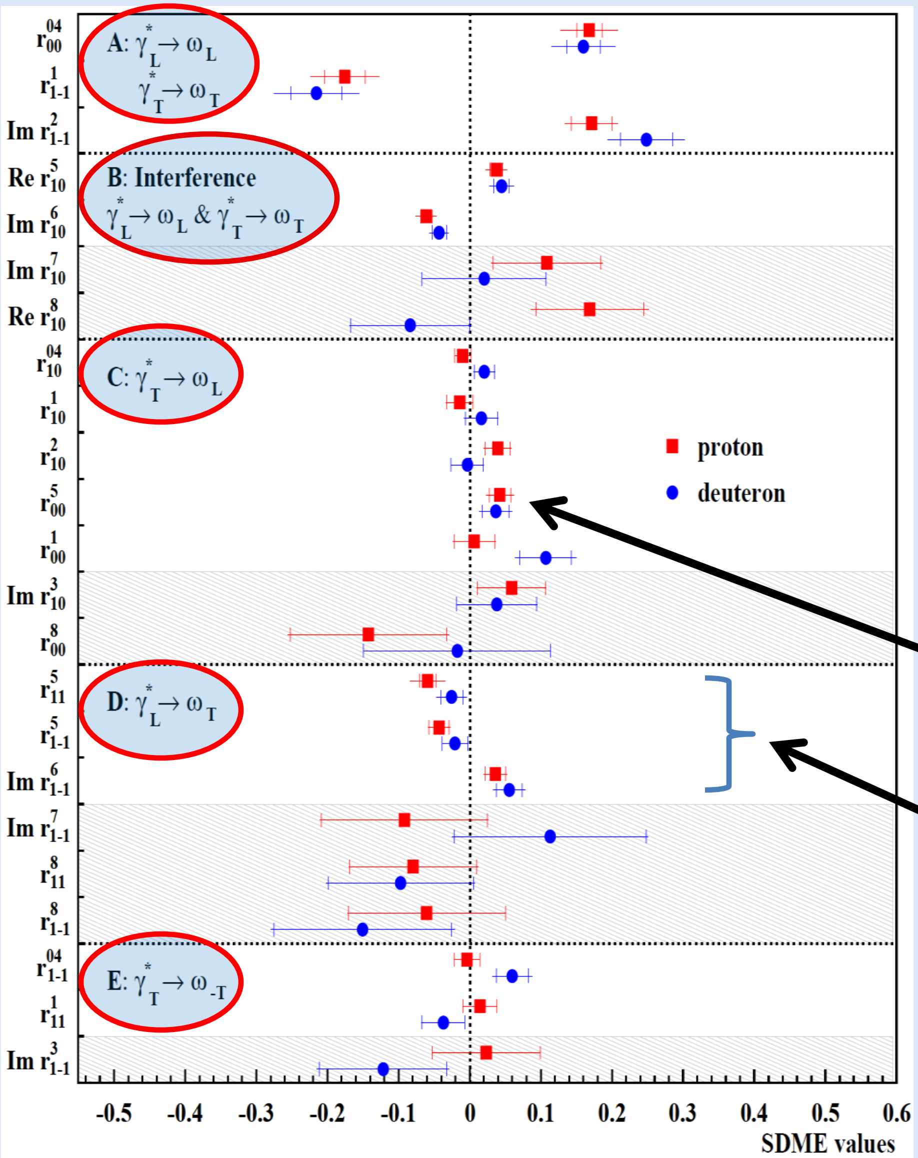
Missing energy:

$$\Delta E = \frac{M_X^2 - M_p^2}{2M_p}, M_X^2 = (p + q - p_{\pi^+} - p_{\pi^-} - p_{\pi^0})^2$$

Exclusive region: $-1.0 \text{ GeV} < \Delta E < 0.8 \text{ GeV}$

SDMEs in exclusive ω production

Eur. Phys. J. C 74 (2014) 3110



- 5 classes of SDMEs
- Unpolarized and polarized SDMEs
- Similar magnitudes of SDMEs on proton & deuteron
- SCHC (S-Channel Helicity Conservation): holds for class – A & class – B SDMEs:

$$\begin{cases} r^1_{1-1} = -\mathrm{Im}\, r^2_{1-1} \\ \mathrm{Re}\, r^5_{10} = -\mathrm{Im}\, r^6_{10} \\ \mathrm{Im}\, r^7_{10} = \mathrm{Re}\, r^8_{10} \end{cases}$$

- SCHC: slightly violated for class – C

  $r^5_{00} \neq 0$ by 3(2) σ for p(d)

- SCHC: slightly violated for class – D

  $r^5_{11} + r^5_{1-1} - \mathrm{Im}\, r^6_{1-1} \neq 0$ by 3(2.5) σ for p(d)

Extraction of πω transition form factor

$$u_1 = 1 - r_{00}^{04} + 2r_{1-1}^{04} - 2r_{11}^{1} - 2r_{1-1}^{1}$$

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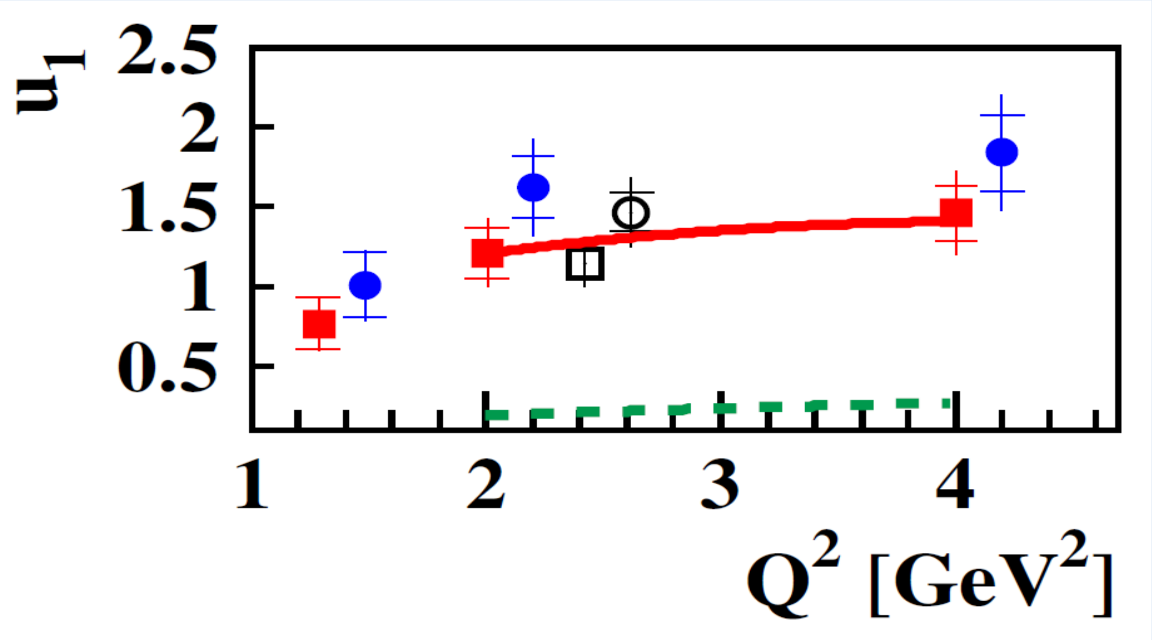


<u>GK model</u>
S. Goloskokov & P. Kroll,
Eur. Phys. J. A 50 (2014) 146

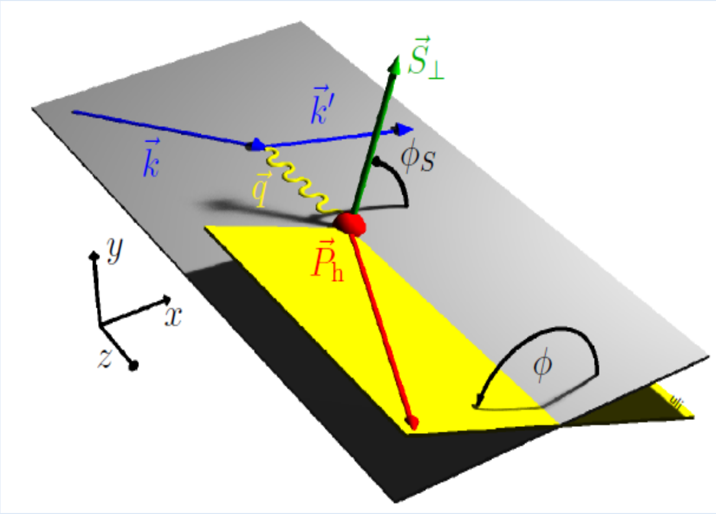
Only the magnitude of the πω transition form factor (not the sign) can be evaluated.

- The solid line show the calculation of the GK model with pion-pole contribution
  Dashed line are the model results without the pion-pole.
- The pion-pole contribution seems to account comletely for UPE.

Exclusive ω - meson production: A_{UT} asymmetry

$e(k) + N(p) \to e(k') + N(p') + \omega$

$\omega \to \pi^+ \ \pi^- \ \pi^0, \ \pi^0 \to 2\gamma$



Angular dependent part

$$w(\phi,\phi_S) = 1 + A_{UU}^{\cos(\phi)}\cos(\phi) + A_{UU}^{\cos(2\phi)}\cos(2\phi)$$
$$+S_\perp\Big[A_{UT}^{\sin(\phi+\phi_S)}\sin(\phi+\phi_S) + A_{UT}^{\sin(\phi-\phi_S)}\sin(\phi-\phi_S)$$
$$+A_{UT}^{\sin(\phi_S)}\sin(\phi_S) + A_{UT}^{\sin(2\phi-\phi_S)}\sin(2\phi-\phi_S) + A_{UT}^{\sin(3\phi-\phi_S)}\sin(3\phi-\phi_S)\Big]$$

$$w(\phi,\phi_{S,}\theta) = \frac{3}{2}r_{00}^{04}\cos^2(\theta)\,w_L(\phi,\phi_S) + \frac{3}{4}\left(1-r_{00}^{04}\right)\sin^2(\theta)\,w_T(\phi,\phi_S)$$

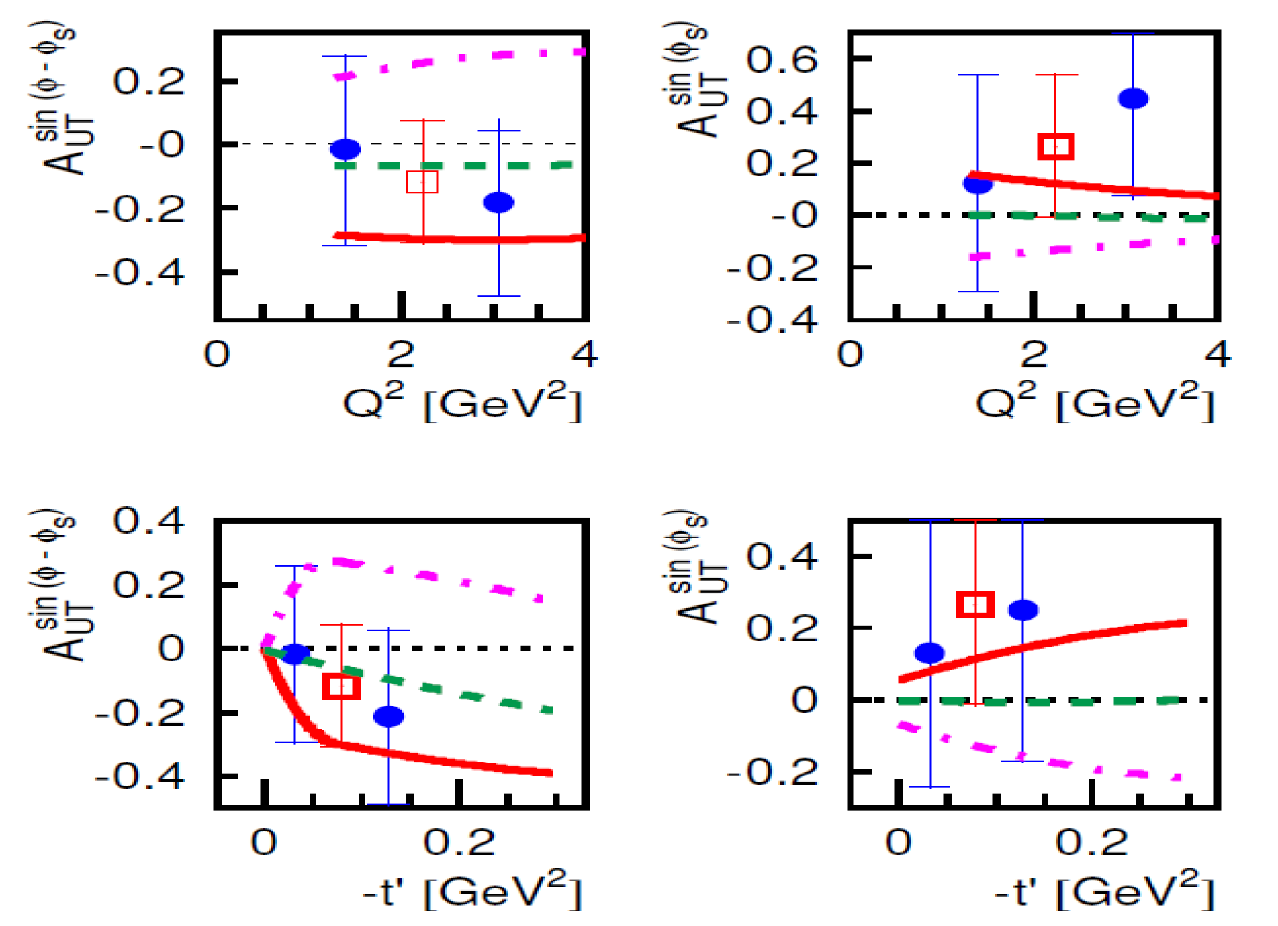
$$w_L(\phi,\phi_S) = 1 + A_{UU,L}(\phi) + S_\perp A_{UT,L}(\phi,\phi_S)$$

$$w_T(\phi,\phi_S) = 1 + A_{UU,T}(\phi) + S_\perp A_{UT,T}(\phi,\phi_S)$$

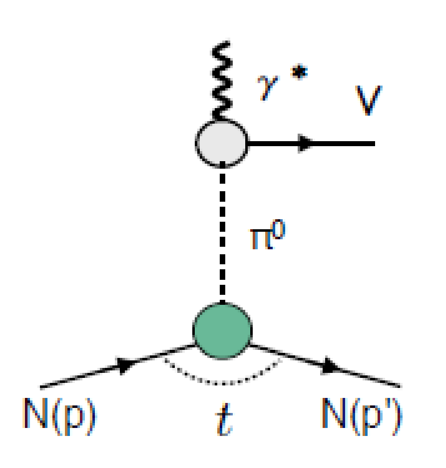
Fit angular distributions of ω–decay pions

Exclusive ω - meson production: amplitudes of A_{UT}

Eur. Phys. J. C 75 (2015) 600



<u>GK model</u>
S. Goloskokov & P. Kroll,
Eur. Phys. J. A 50 (2014) 146



Pion pole

$$\left(\propto \frac{1}{t - m_\pi^2} \right)$$

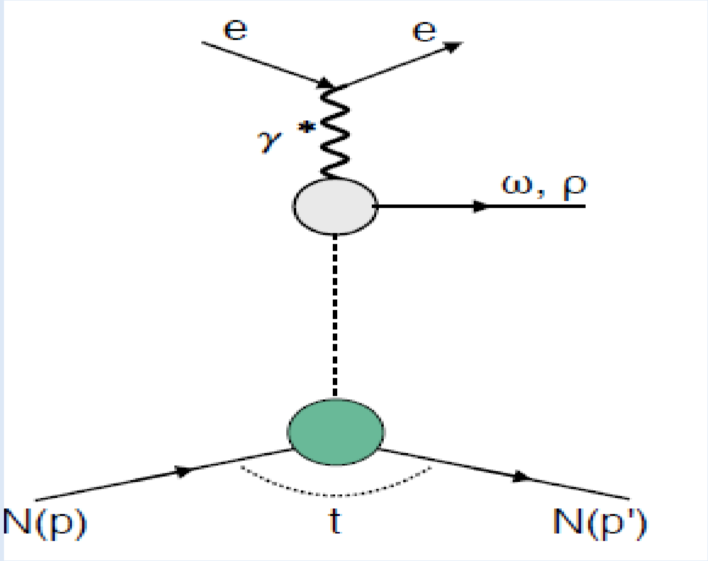
- The solid (dash-dotted) lines show the calculation of the GK model for a positive (negative) πω transition form factor
- Dashed lines are the model results without the pion pole.

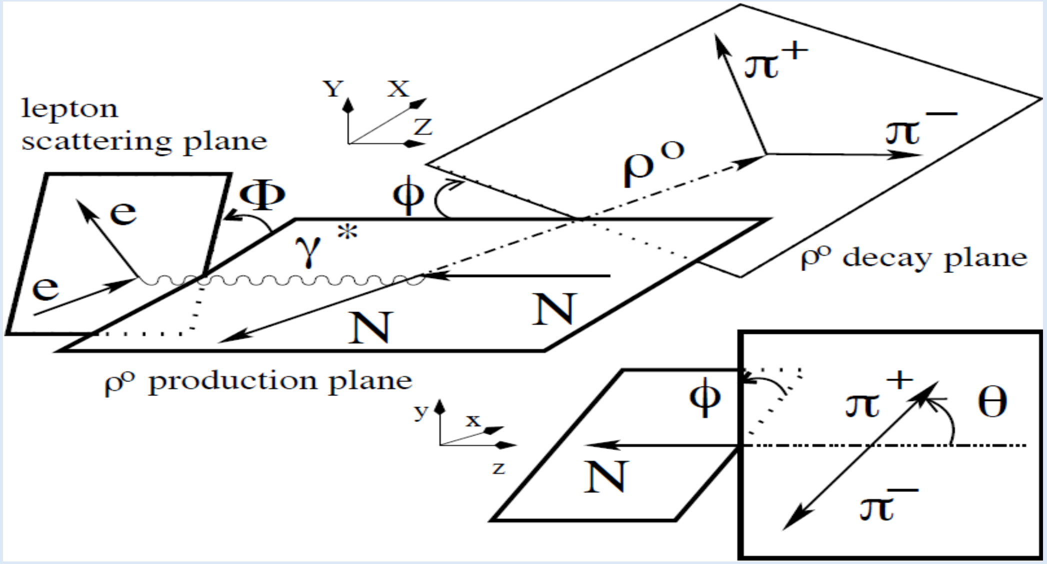
ρ^0 –meson production from exclusive DIS: Ratios of helicity amplitudes

- Transversely polarized H target

Exclusive ρ^0 – meson production , helicity ratios

$$e(k) + N(p) \to e(k') + N(p') + \rho^0$$
$$\rho^0 \to \pi^+ \ \pi^-$$





$$\gamma^* (\lambda_\gamma) + N (\lambda_N) \to V(\lambda_V) + N(\lambda'_N)$$

$$F_{\lambda_V \lambda'_N \lambda_\gamma \lambda_N} = T_{\lambda_V \lambda'_N \lambda_\gamma \lambda_N} + U_{\lambda_V \lambda'_N \lambda_\gamma \lambda_N}$$

Helicity amplitude ratios:

$$t^{(n)}_{\lambda_V \lambda_\gamma} = T^{(n)}_{\lambda_V \lambda_\gamma} / T_{0\frac{1}{2}0\frac{1}{2}}$$
$$u^{(n)}_{\lambda_V \lambda_\gamma} = U^{(n)}_{\lambda_V \lambda_\gamma} / T_{0\frac{1}{2}0\frac{1}{2}}$$

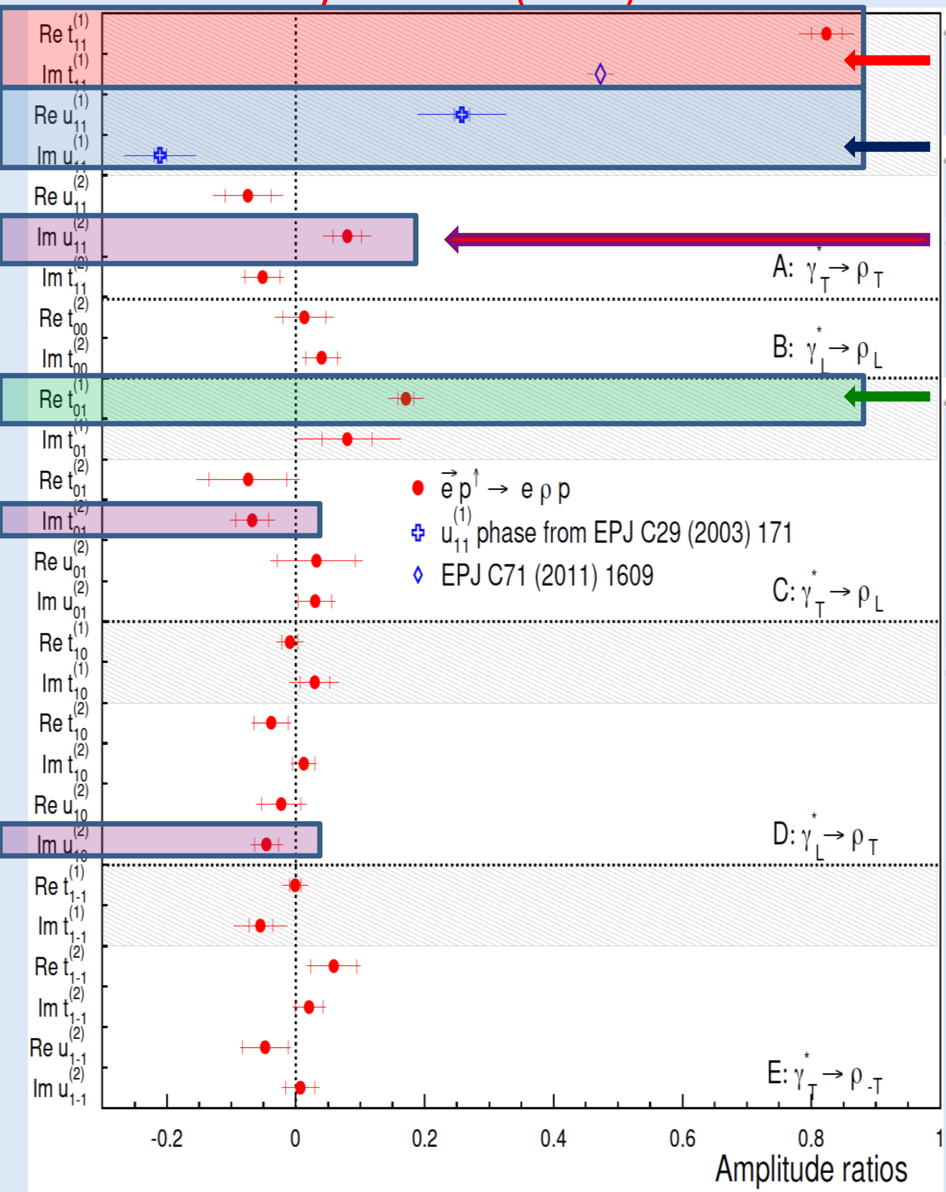
$$n=1 \quad \lambda_N = \lambda'_N$$
$$n=2 \quad \lambda_N \neq \lambda'_N$$

$T^{(n)}_{\lambda_V \lambda_\gamma}$ – NPE Amplitude

$U^{(n)}_{\lambda_V \lambda_\gamma}$ – UPE Amplitude

Exclusive ρ⁰ – meson production: helicity ratios

Eur. Phys. J. C 77 (2017) 378



- Dominant amplitude: NPE nucleon-helicity non-flip $t_{11}^{(1)} \neq 0$ by > 5σ
- UPE nucleon-helicity non-flip $u_{11}^{(1)} \neq 0$ by > 4σ
- Nucleon-helicity flip $\mathrm{Im}\, t_{01}^{(2)}$, $\mathrm{Im}\, u_{11}^{(2)}$, $\mathrm{Im}\, u_{10}^{(2)} \neq 0$ by 2σ
- Significant nucleon-helicity non-flip $\mathrm{Re}\, t_{01}^{(1)} \neq 0$ by > 5σ
- Overall good agreement between direct extraction of SDMEs and SDMEs via helicity amplitude ratios (not shown here).

Newly obtained SDMEs

Talk Mon 18h40
by S. Manaenkov

Summary

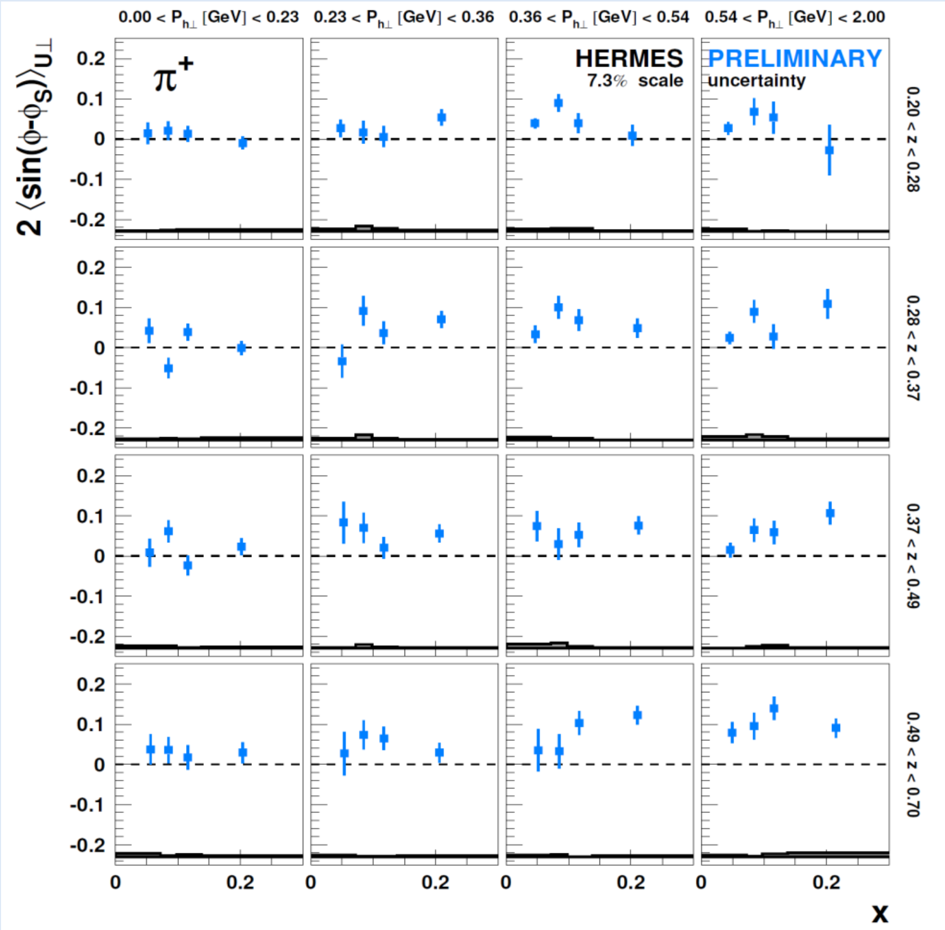
- 3D picture of the nucleon:
  - A_{UT} and A_{LT} in semi-inclusive DIS: 3D extraction, including protons: contribute to understanding of various TMD PDFs @ twist 2 and twist 3.
  - A_{LU} in semi-inclusive DIS: 3D extraction.
- Measurement of ω –meson SDMEs & A_{UT} asymmetry amplitudes from exclusive DIS: good model description with inclusion of pion pole.
  - The sign of the πω transition form factor
- Measurement of helicity ratios from exclusive ρ^0 –meson production in DIS: model description with inclusion of pion pole.

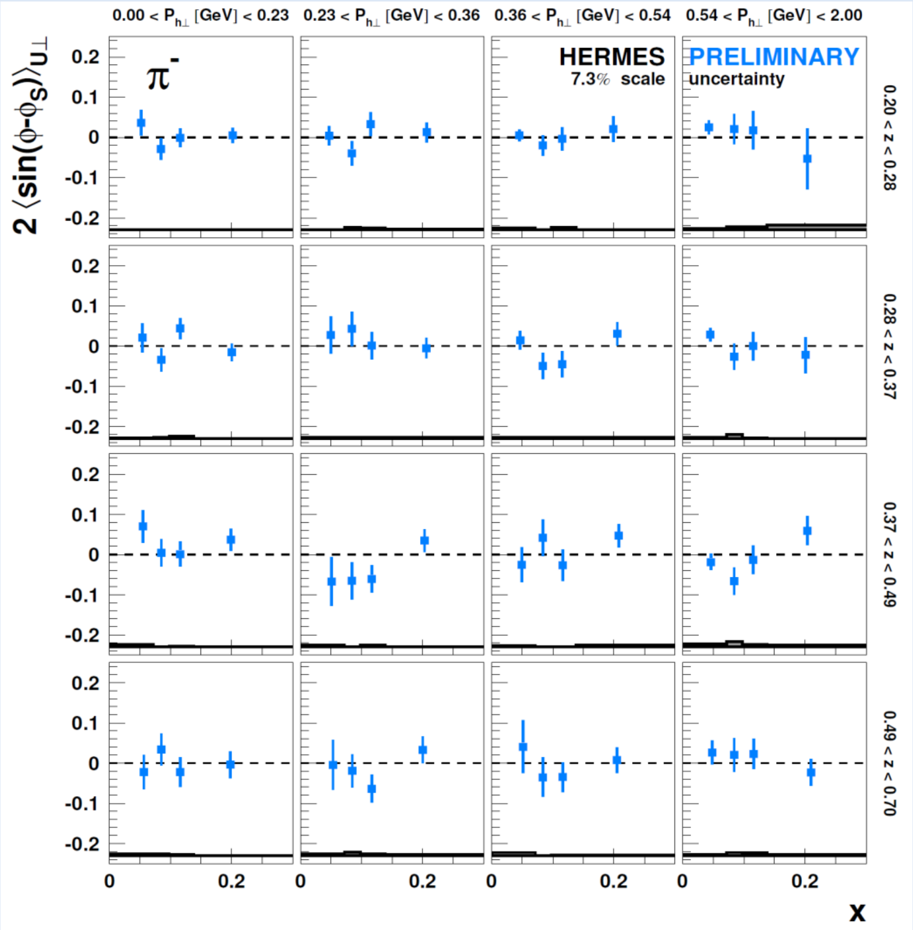
Thank You

Backup Slides

Sivers amplitudes

$$F_{UT}^{\sin(\phi_h-\phi_S)} \propto f_{1T}^{\perp}\left(x,p_T^2\right)\otimes D_1\left(z,k_T^2\right)$$

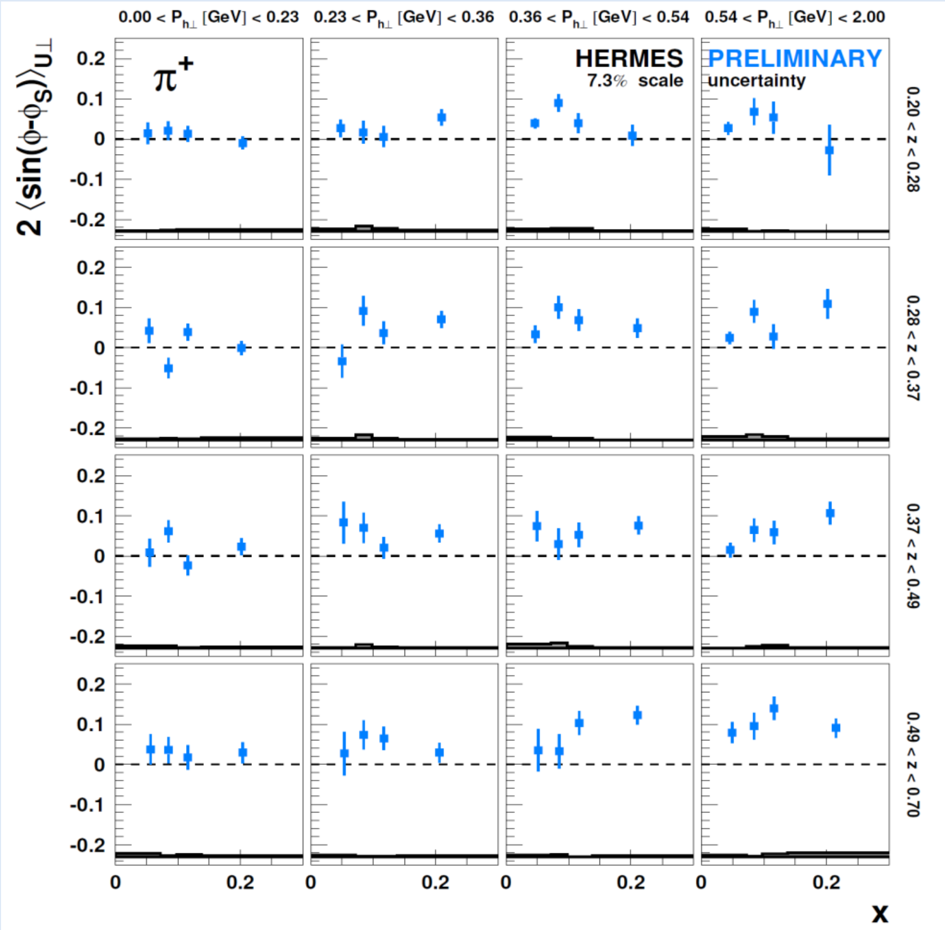


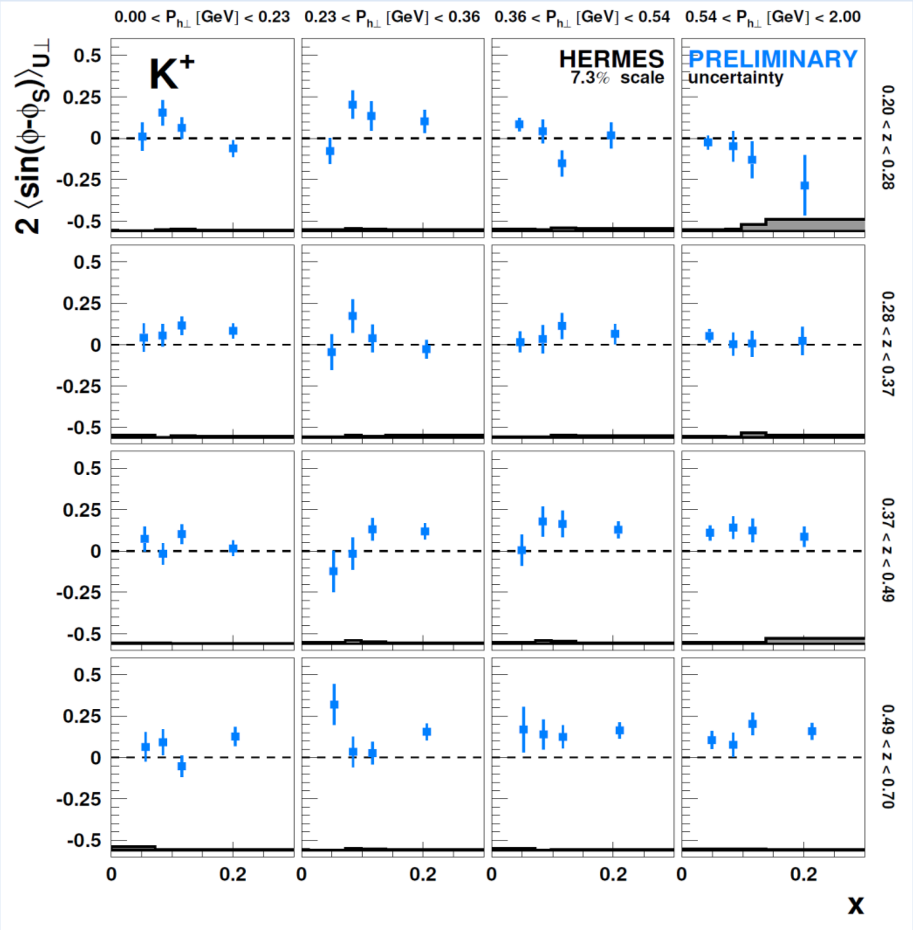


- π^+ amplitudes positive; π^- amplitudes ≈ 0
- π^+ amplitudes increasing with x at large $P_{h\perp}$

Sivers amplitudes

$$F_{UT}^{\sin(\phi_h-\phi_S)} \propto f_{1T}^{\perp}\left(x, p_T^2\right) \otimes D_1\left(z, k_T^2\right)$$



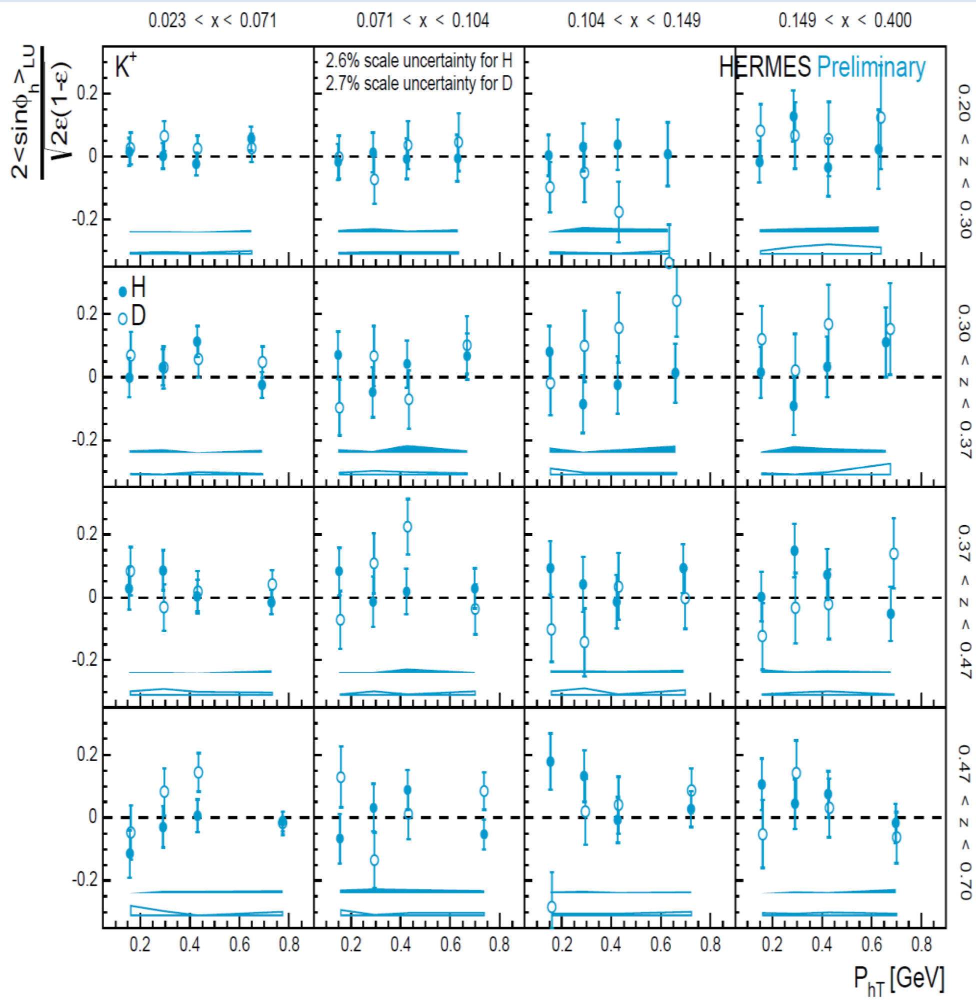


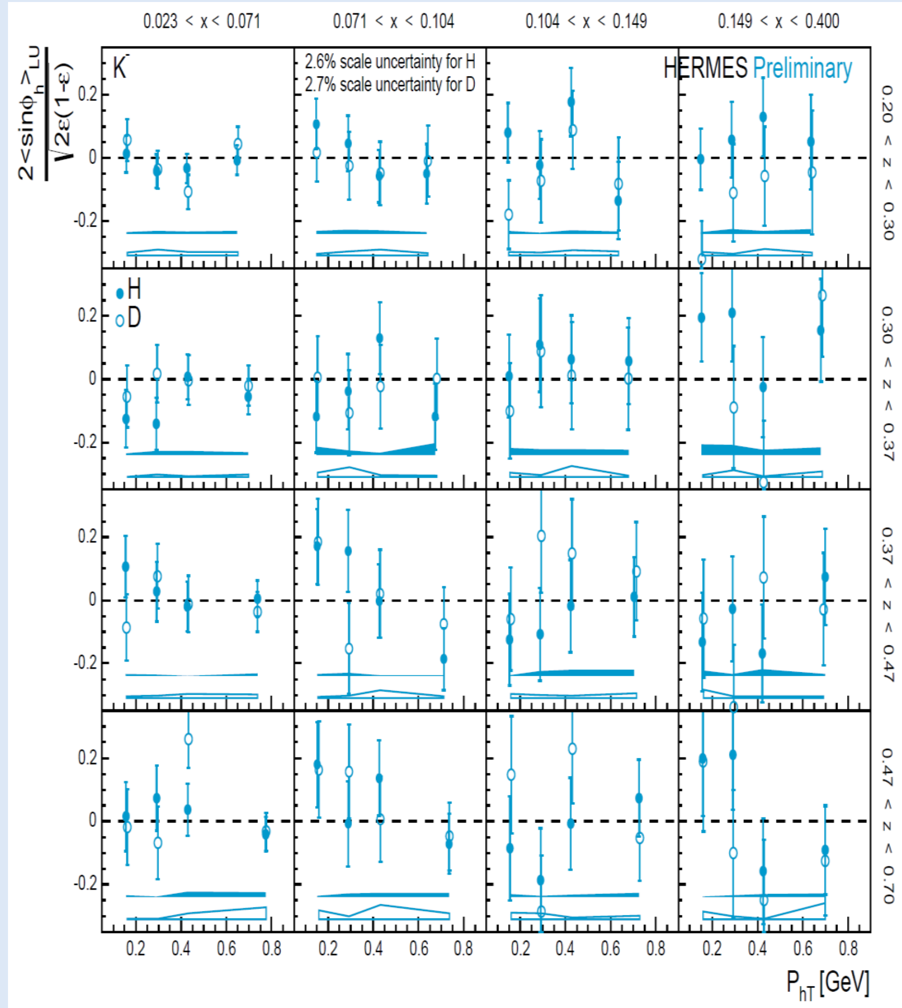
- K^+ amplitudes positive, larger than π^+
- Non-trivial role of sea quarks?

A_{LU} amplitudes: $K^{\pm}$

$$F_{LU}^{\sin(\phi_h)} \propto \frac{M_h}{M_z} h_1^{\perp} E \oplus x g^{\perp} D_1 \oplus \frac{M_h}{M_z} f_1 G^{\perp} \oplus x e H_1^{\perp}$$

Convolution of twist–2 & twist–3





A_{LU} amplitudes: p & p^{bar}

$$F_{LU}^{\sin(\phi_h)} \propto \frac{M_h}{M_z} h_1^{\perp} E \oplus x g^{\perp} D_1 \oplus \frac{M_h}{M_z} f_1 G^{\perp} \oplus x e H_1^{\perp}$$

Convolution of twist–2 & twist–3