Some recent hermes results

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FAKULTÄT

COMPASS Meeting, June 2018

Some (not really) recent hermes results

(still awaiting publication)

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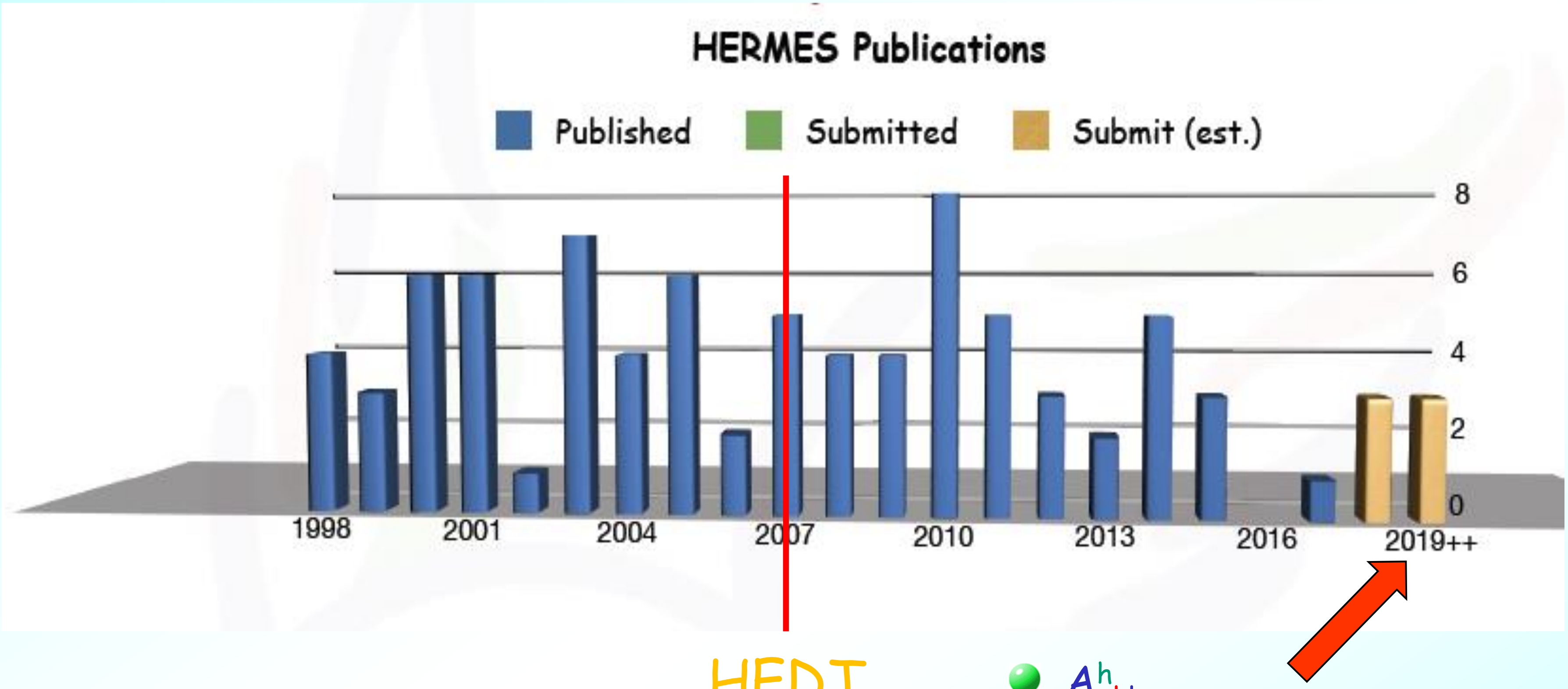
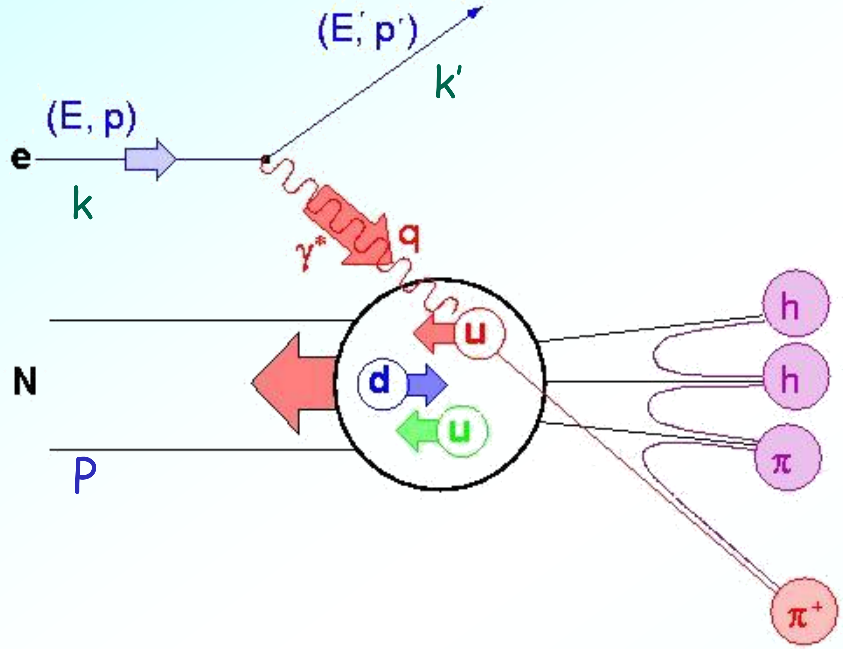


HEDT

- A^h_{LL}
- $A^h_{U(L)T}$ ('all' TMDs)
- A^{2h}_{UT}
- A^h_{LU}
- Λ Polarization
- Kaons from nuclei

So far:
80 papers (~8600 citations)

Semi-inclusive Deep-Inelastic Scattering



$Q^2 = -q^2 = -(k-k')^2$

$\nu = Pq/M$

$x = Q^2/(2Pq)$

$z = E_h/\nu$

Factorisation ⇒ $\sigma^{eN\rightarrow ehX} = \sum_q \sigma^{eq\rightarrow eq} \otimes DF^{N\rightarrow q} \otimes FF^{q\rightarrow h}$

DF(x,Q^2): Parton Distribution Function - $f_1(x,Q^2)$, $g_{1L}(x,Q^2)$,$h_1(x,Q^2)$,...

FF(z,Q^2): Fragmentation Function - $D_1^{q\rightarrow h}(z,Q^2)$, $H_1^{\perp q\rightarrow h}(z,Q^2)$, ...

Azimuthal modulations of SIDIS cross section

$$d\sigma = \frac{d^6\sigma}{dx\, dy\, dz\, d\phi\, d\phi_s\, dP^2_{h\perp}}$$

All studied by HERMES

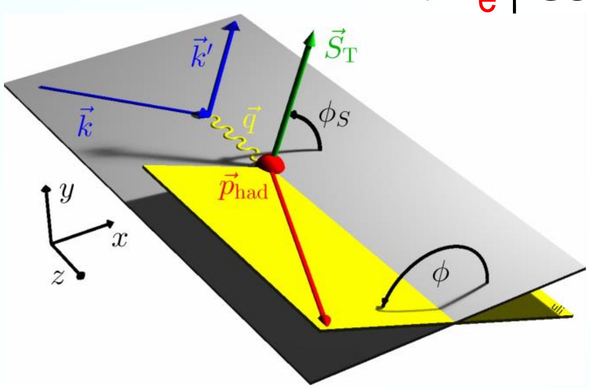
$$d\sigma = d\sigma^0_{UU} + \cos 2\phi\, d\sigma^1_{UU} + \frac{1}{Q}\cos\phi\, d\sigma^2_{UU} + \lambda_e \frac{1}{Q}\sin\phi\, d\sigma^3_{LU}$$

$$+ S_T\Big\{ \sin(\phi-\phi_S)\, d\sigma^8_{UT} + \sin(\phi+\phi_S)\, d\sigma^9_{UT} + \sin(3\phi-\phi_S)\, d\sigma^{10}_{UT}$$

$d\sigma_{XY}$: X → Beam, Y → Target Polarisation

$$+ \frac{1}{Q}\sin(2\phi-\phi_S)\, d\sigma^{11}_{UT} + \frac{1}{Q}\sin\phi_S\, d\sigma^{12}_{UT}$$

$$+\lambda_e\left[\cos(\phi-\phi_S)\, d\sigma^{13}_{LT} + \frac{1}{Q}\cos\phi_S\, d\sigma^{14}_{LT} + \frac{1}{Q}\cos(2\phi-\phi_S)\, d\sigma^{15}_{LT}\right]\Big\}$$



$$+S_L\left\{\sin 2\phi\, d\sigma^4_{UL} + \frac{1}{Q}\sin\phi\, d\sigma^5_{UL} + \lambda_e\left[d\sigma^6_{LL} + \frac{1}{Q}\cos\phi\, d\sigma^7_{LL}\right]\right\}$$

Azimuthal modulations of SIDIS cross section

$$d\sigma = \frac{d^6\sigma}{dx\,dy\,dz\,d\phi\,d\phi_s\,dP^2_{h\perp}}$$

6 leading-twist contributions

$$d\sigma = d\sigma^0_{UU} + \cos 2\phi\, d\sigma^1_{UU} + \frac{1}{Q}\cos\phi\, d\sigma^2_{UU} + \lambda_e \frac{1}{Q}\sin\phi\, d\sigma^3_{LU}$$

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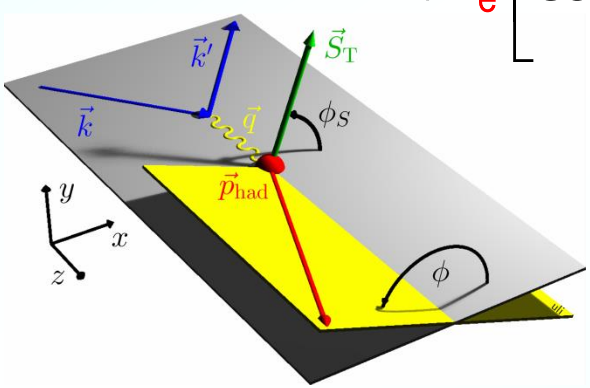

Azimuthal modulations of SIDIS cross section

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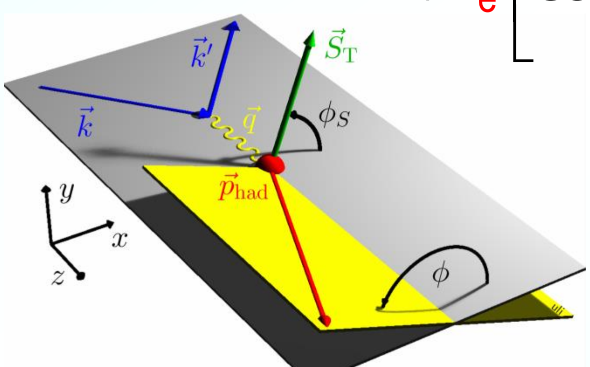

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The others are subleading, i.e., suppressed by 1/Q

Azimuthal modulations of SIDIS cross section

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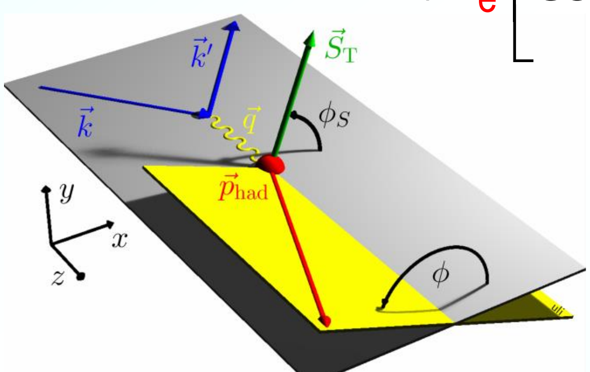

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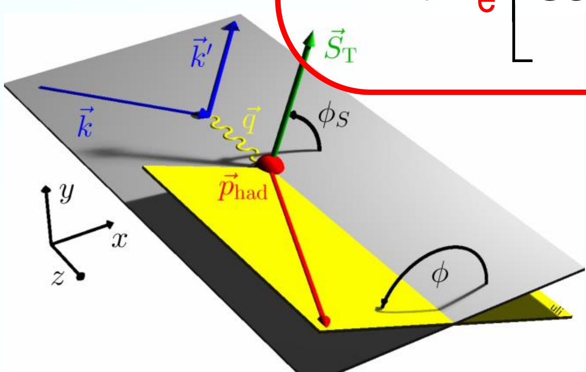

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Azimuthal modulations of SIDIS cross section

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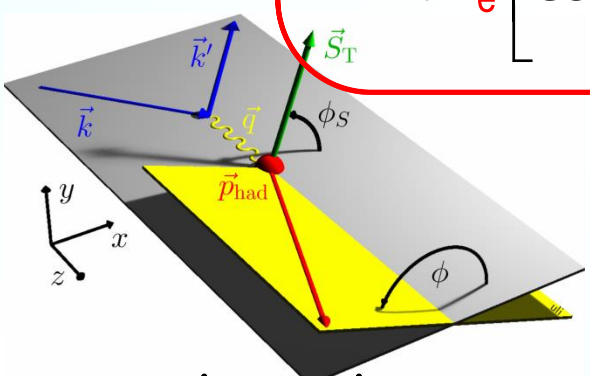

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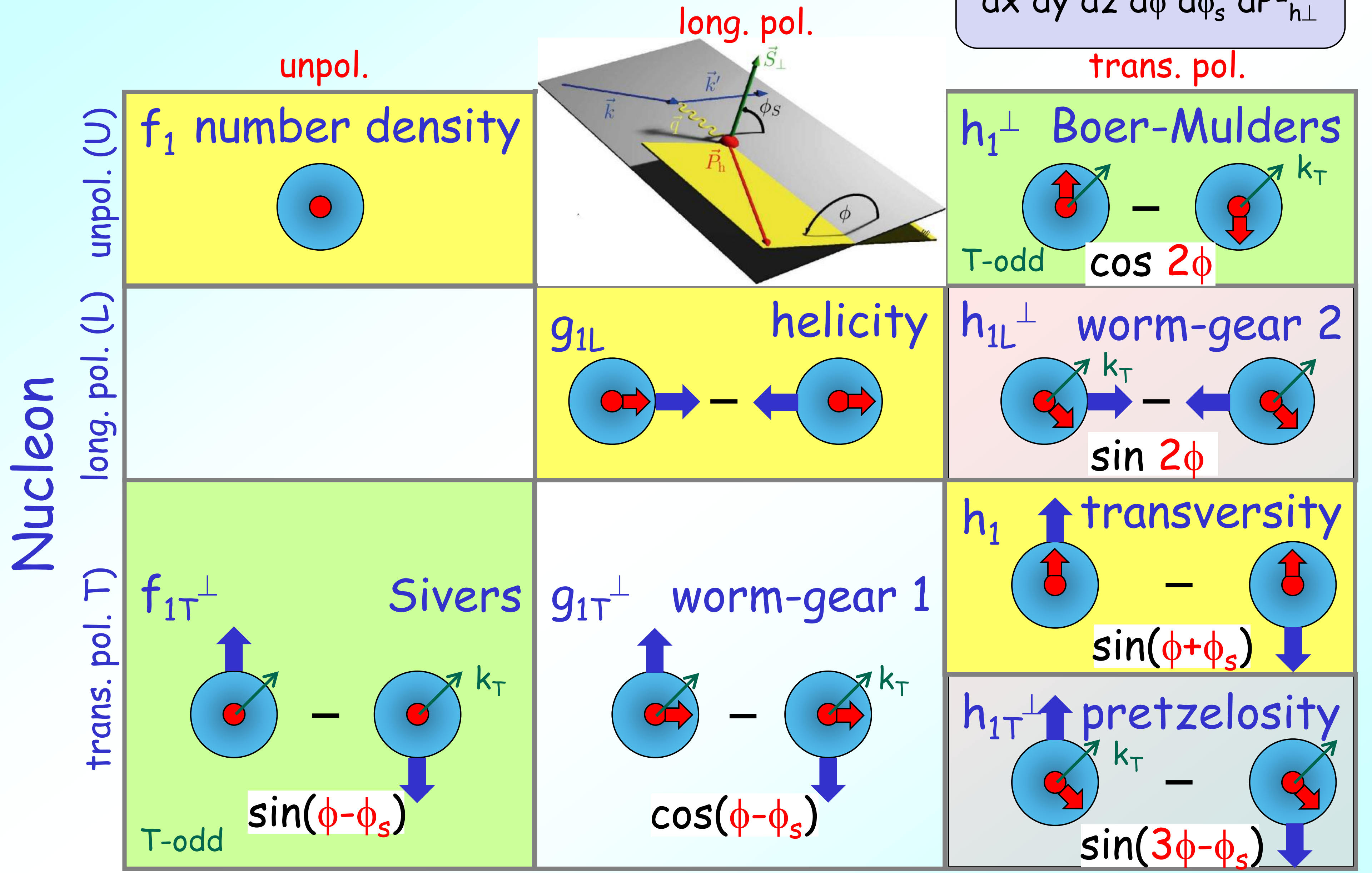
Leading Twist TMDs

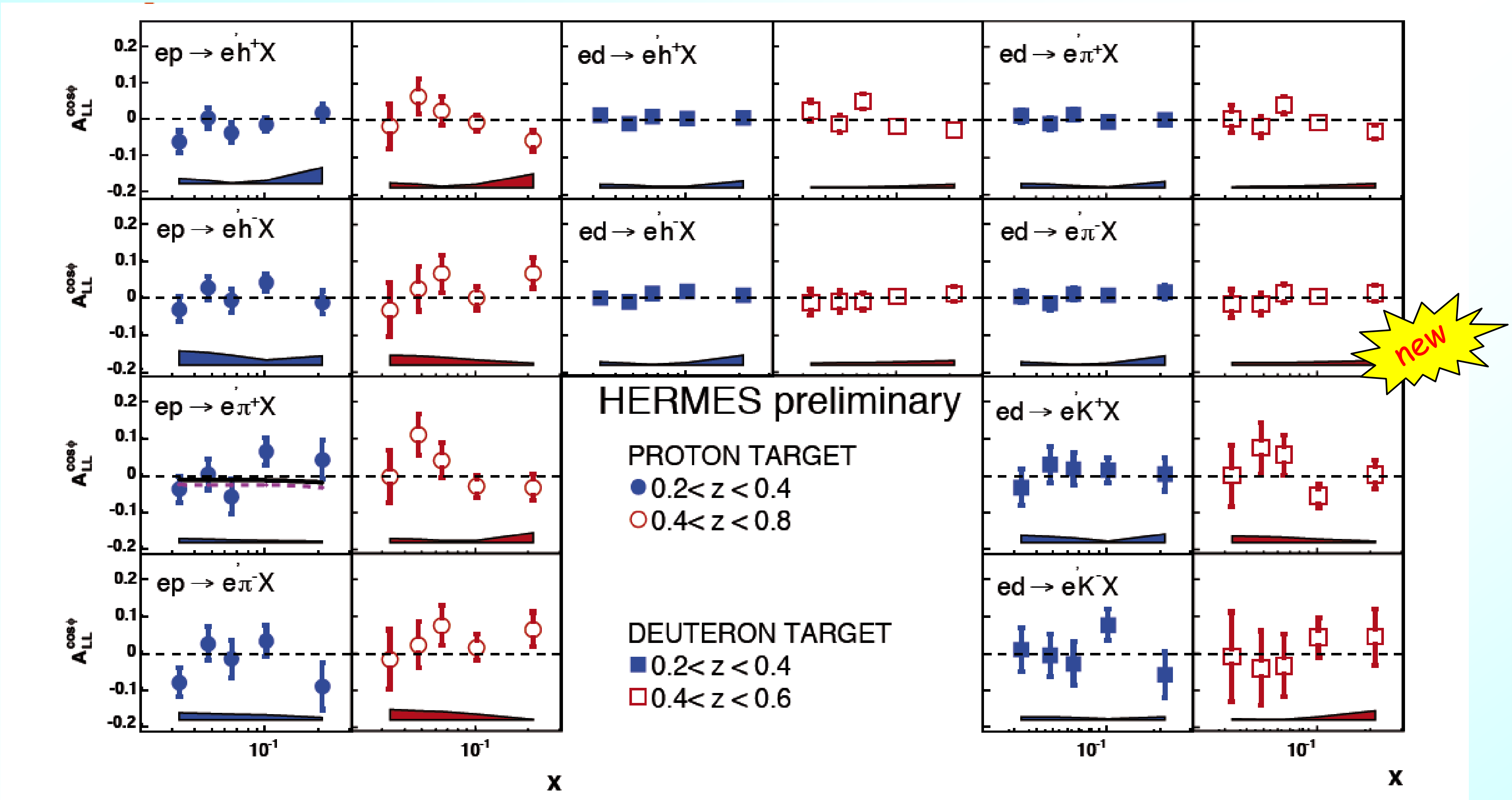
$$\frac{d^6\sigma}{dx\, dy\, dz\, d\phi\, d\phi_s\, dP^2_{h\perp}}$$



chiral-odd ↑$h_i(x) \otimes H_1^\perp(z)$

Topic 1: A_{LL}^{h}

cosϕ moment of asymmetry A_{LL}



- Consistent with zero
- No significant kinematic dependence observed
- Compatible result for proton and deuteron

publication coming soon

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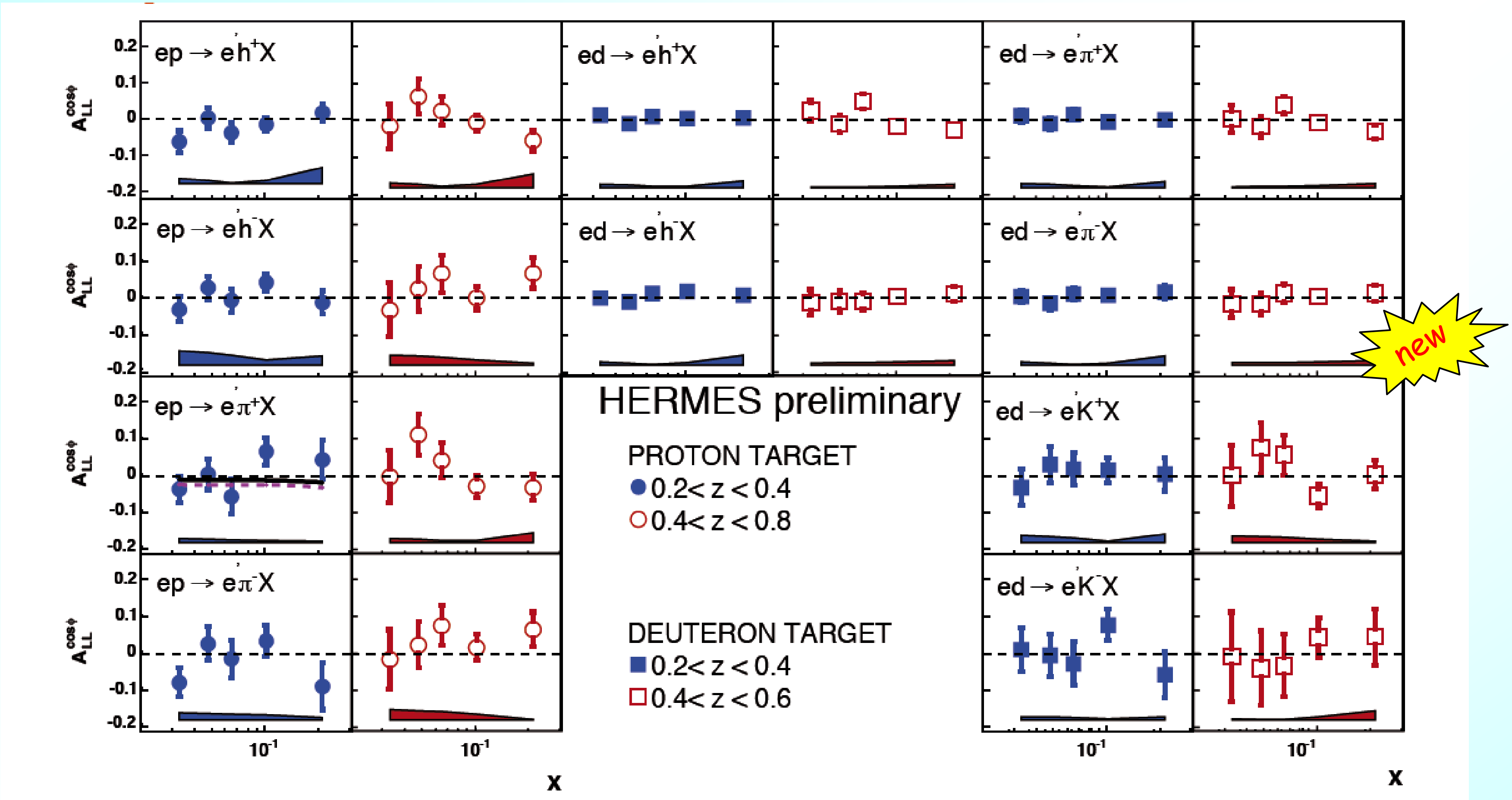

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Presented at Praha, July 2012 !!!

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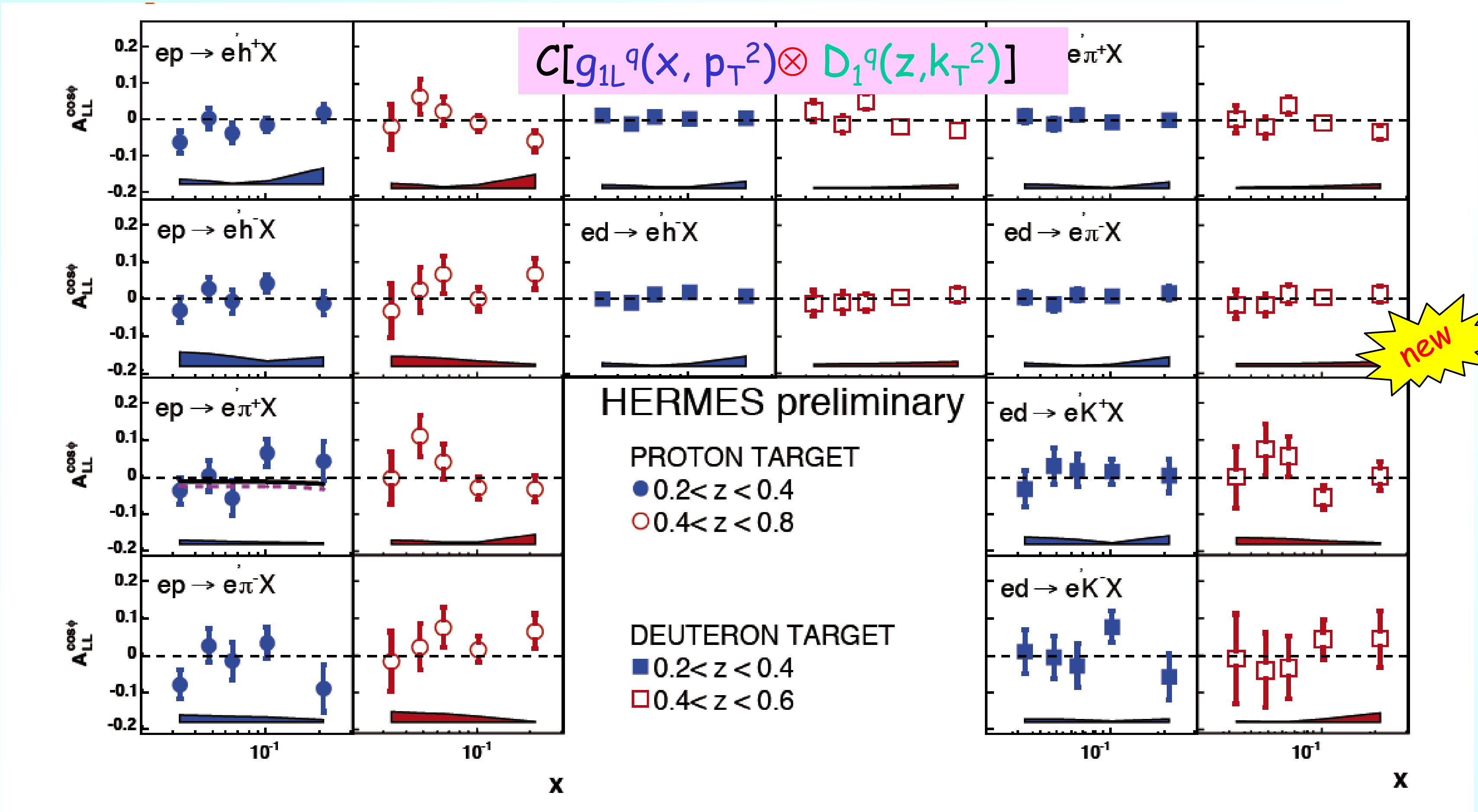
hermes

cosϕ moment of asymmetry A_{LL}



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Presented at Praha, July 2012 !!!

publication coming soon

Topic 2: $A_{U(L)T}^{h}$ ('all' TMDs)

TMDs from transversely polarized proton target

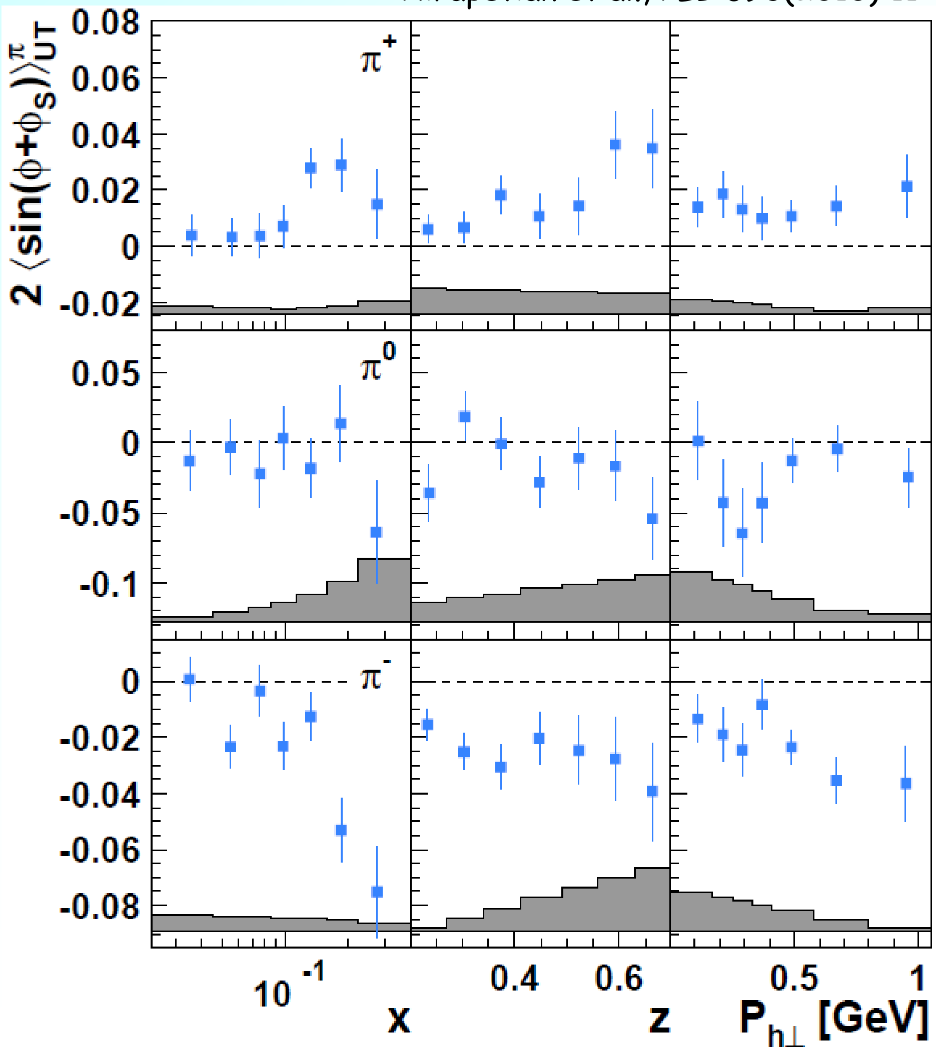
- Data taken in 2002-2005
- 5 PhD theses in 2004-2010
- 3 publications (Sivers and Collins for pions and charged kaons)
  [PRL 94 (2005) 012002, PRL 1003 (2009) 152002, PLB 693 (2010) 11];
  (So far ~1140 citations)
- Since then - include protons and antiprotons
  - extend analysis to 3D in (x, z, $P_{h\perp}$) for all but antiprotons
    (important for global fits)
  - detailed study of systematics
- Simultaneous fit of the Fourier amplitudes for
  $\sin(\phi-\phi_s)$, $\sin(\phi+\phi_s)$, $\sin(3\phi-\phi_s)$, $\sin(\phi_s)$, $\sin(2\phi-\phi_s)$, $\sin(2\phi+\phi_s)$ (UT)
  $\cos(\phi-\phi_s)$, $\cos(\phi_s)$, $\cos(2\phi-\phi_s)$ (LT)
- >200 plots

N/q	U	L	T
U	f_1		$h_1^{\perp}$
L		g_1	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	h_1 $h_{1T}^{\perp}$

Transversity and Collins FF

$$C[h_1^q(x) \otimes H_1^{\perp,q}(z)]$$

Airapetian et al., PLB 693(2010) 11



- Transversity DF and Collins FF non-zero, lead to large effects
- Opposite in sign for charged pions
- Disfavored Collins FF large and opposite in sign to favored one

N/q	U	L	T
U	f_1		$h_1^{\perp}$
L		g_1	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	h_1 $h_{1T}^{\perp}$

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$$C[h_1^q(x) \otimes H_1^{\perp,q}(z)]$$

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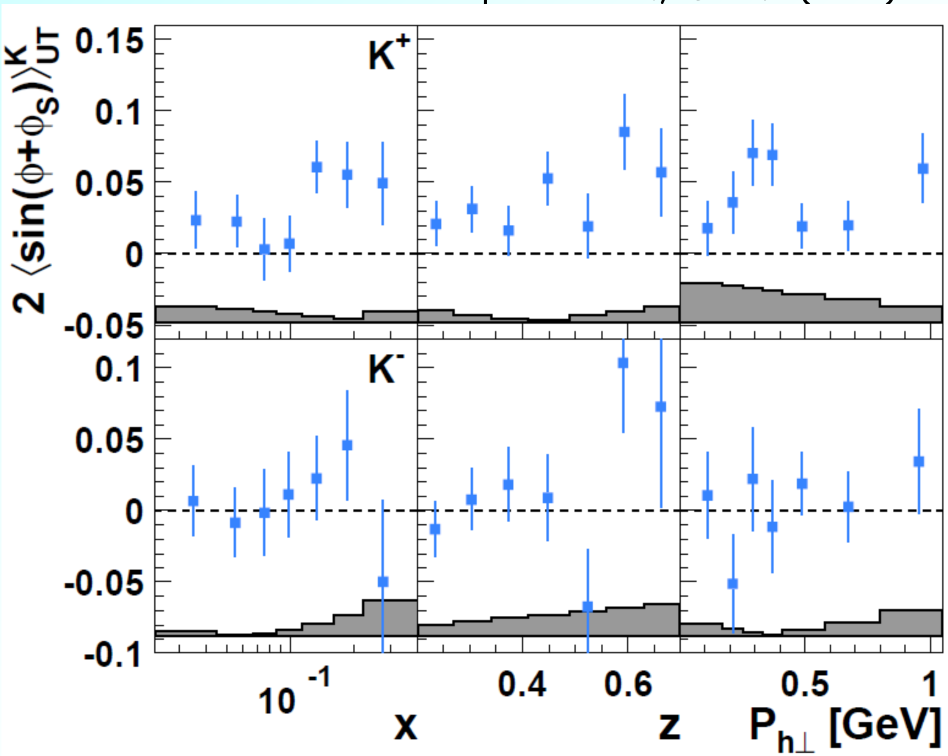

- Positive Collins SSA for positive Kaons
- Consistent with zero for negative Kaons

N/q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	h_1 $h_{1T}^\perp$

Transversity and Collins FF

$$C[h_1^q(x) \otimes H_1^{\perp,q}(z)]$$

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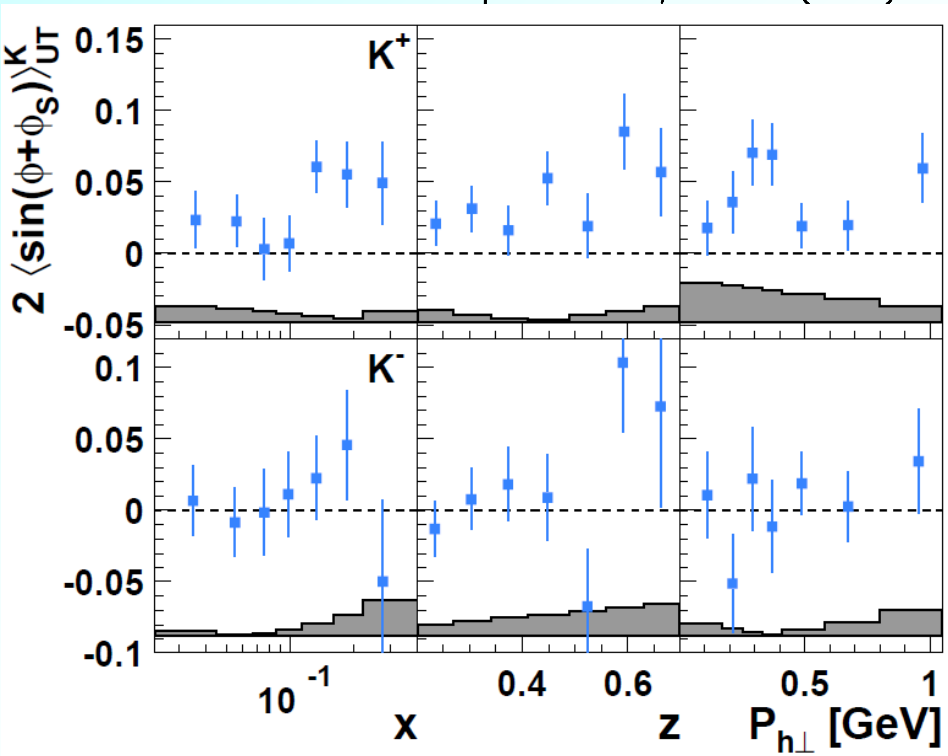
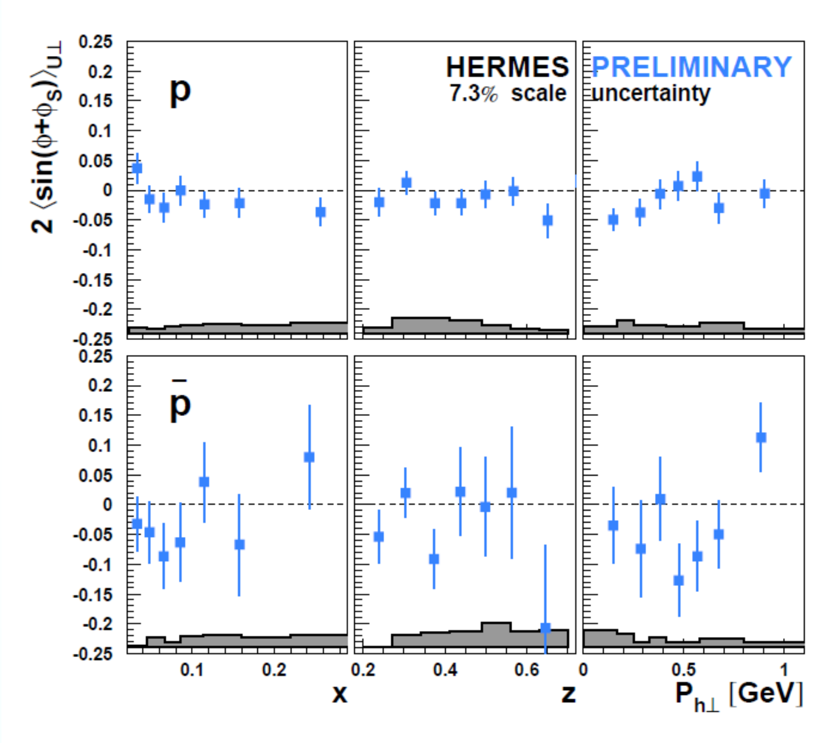




- Positive Collins SSA for positive Kaons
- Consistent with zero for negative Kaons and (anti-)protons

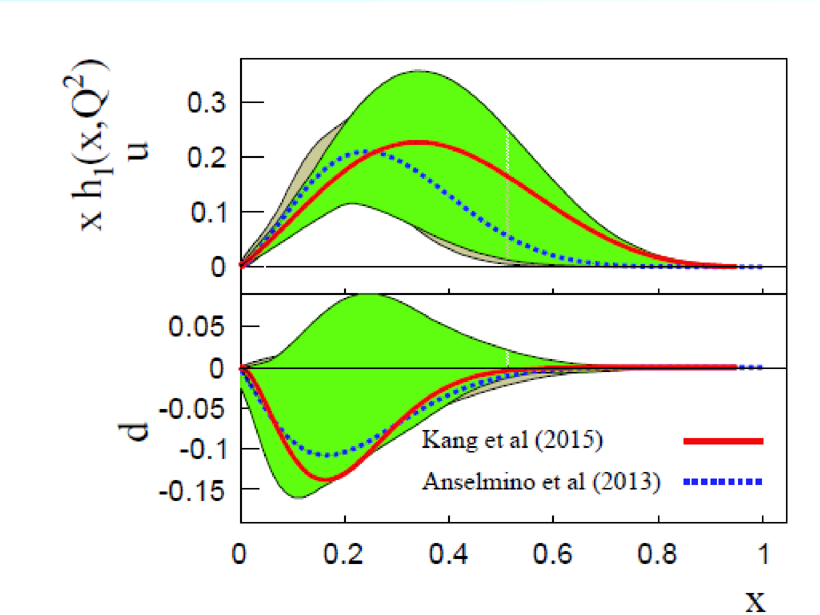
➡ Vanishing sea-quark transversity and baryon Collins effect ?

N/q	U	L	T
U	f_1		$h_1^{\perp}$
L		g_1	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	h_1 $h_{1T}^{\perp}$

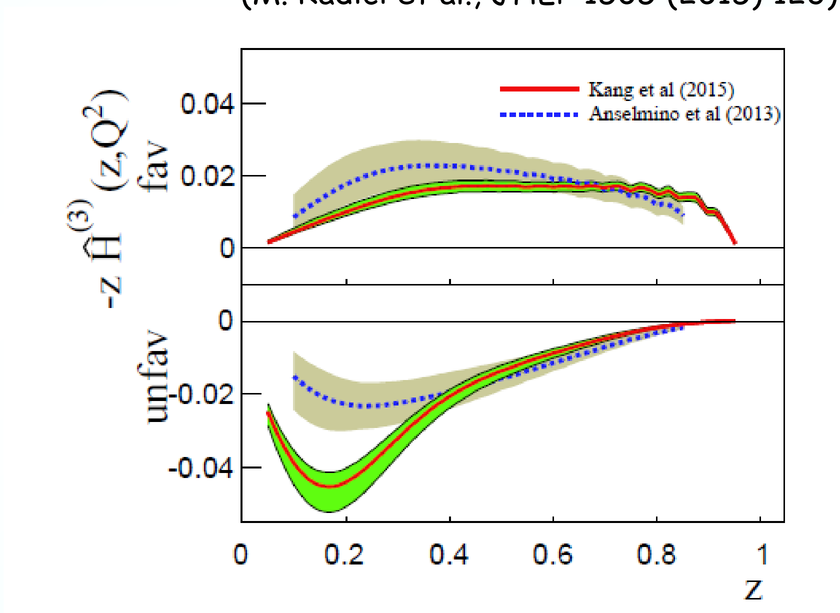
Transversity and Collins FF

$$C[h_1^q(x) \otimes H_1^{\perp,q}(z)]$$

Z. Kang et al., PRD 93 (2016) 014009



M. Anselmino et al., PRD 87 (2013) 094019
(M. Radici et al., JHEP 1505 (2015) 123)



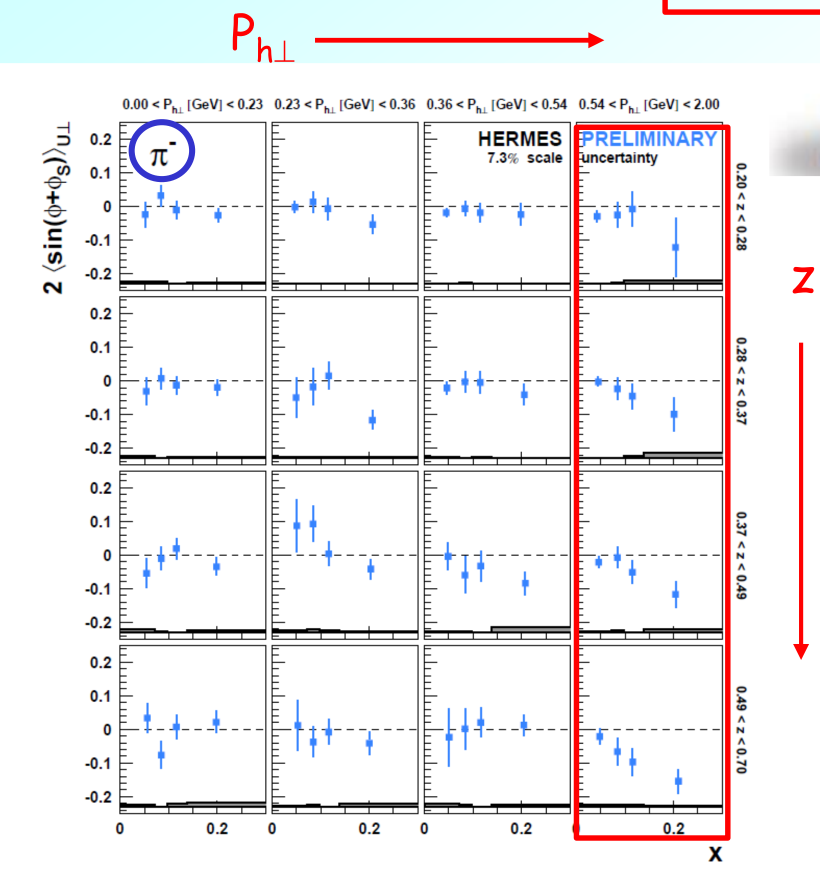
Pion SIDIS data from COMPASS (PLB 673 (2009) 127, PLB 744 (2015) 250)
HERMES (PRL 1003 (2009) 152002)
JLAB – Hall A (PRL 107 (2011) 072003)

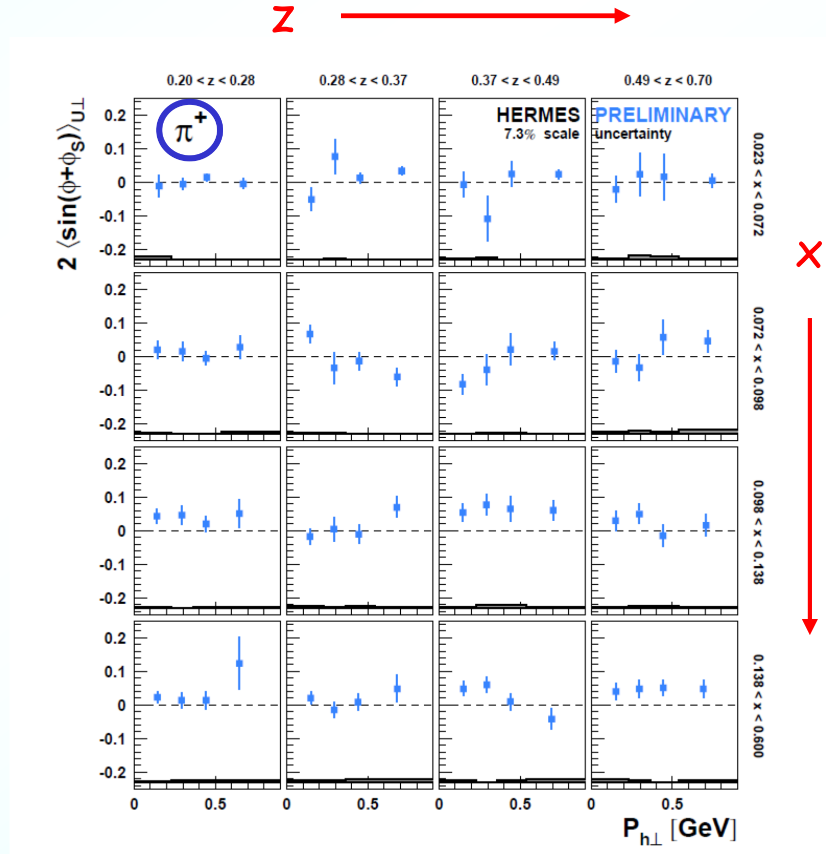
e+e- data from BELLE (PRD 78 (2008) 032011)
BABAR (PRD 90 (2014) 052003

Transversity and Collins FF

N/q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	h_1 $h_{1T}^\perp$

$$C[h_1^q(x) \otimes H_1^{\perp,q}(z)]$$





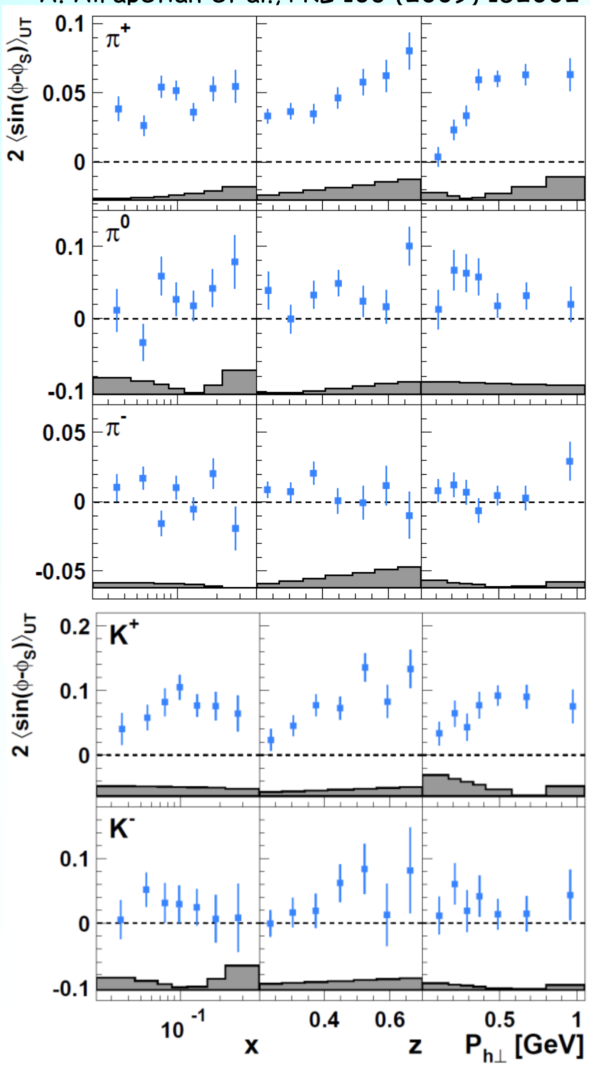
- π^- amplitudes increasing with x at large $P_{h\perp}$, increasing with z
- Other hadrons: no such clear kinematic dependencies
- No 3D for antiprotons

N/q	U	L	T
U	f_1		$h_1^{\perp}$
L		g_1	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	h_1 $h_{1T}^{\perp}$

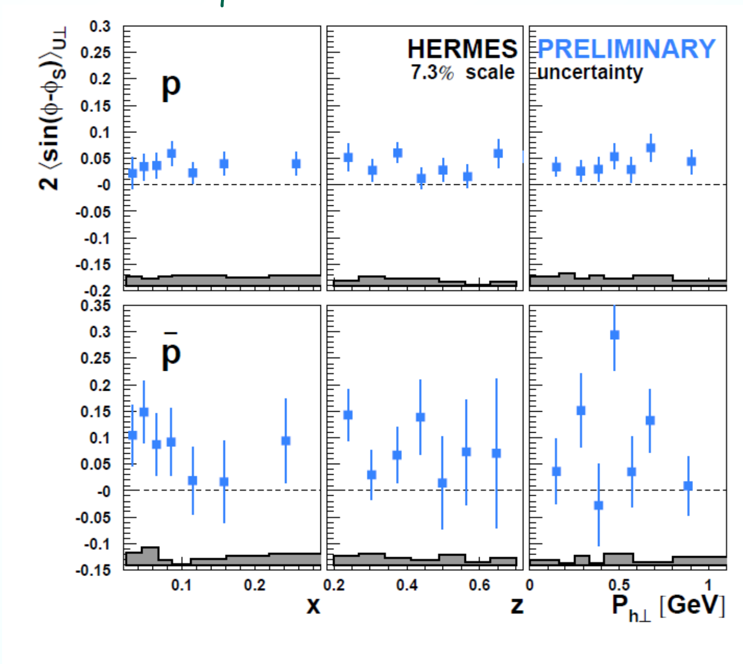
Sivers amplitudes

$$C[f_{1T}^{\perp,q}(x) \otimes D_1^q(z)]$$

A. Airapetian et al., PRL 103 (2009) 152002



- Positive Sivers amplitude for positive pions and kaons
- Experimental evidence for orbital angular momentum L_q of quarks



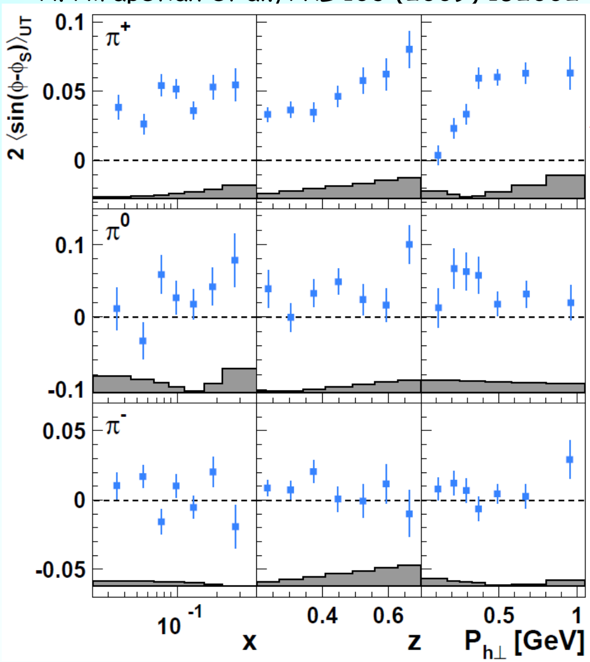
- Positive Sivers amplitude for (anti-)protons, Similar magnitude as for π^+

N/q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	h_1 $h_{1T}^\perp$

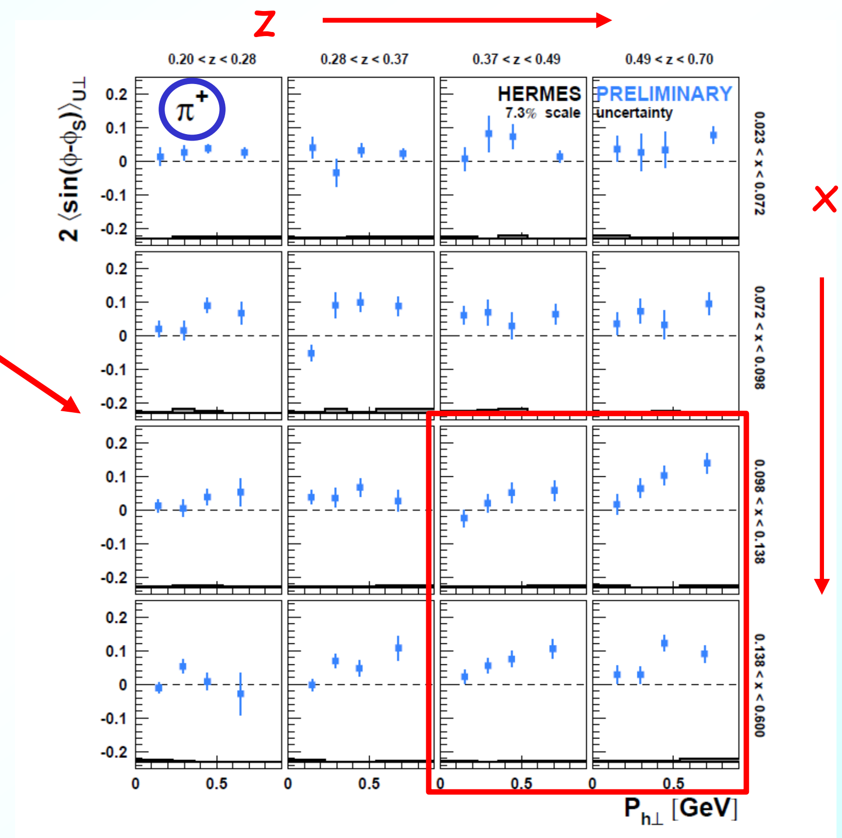
Sivers amplitudes

$$C[f_{1T}^{\perp,q}(x)\otimes D_1^q(z)]$$

A. Airapetian et al., PRL 103 (2009) 152002



3D



- 3D for pions, kaons, protons

- Largest at large x and z,
  region of purest „u-quark probe“

N/q	U	L	T
U	f_1		$h_1^{\perp}$
L		g_1	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	h_1 $h_{1T}^{\perp}$

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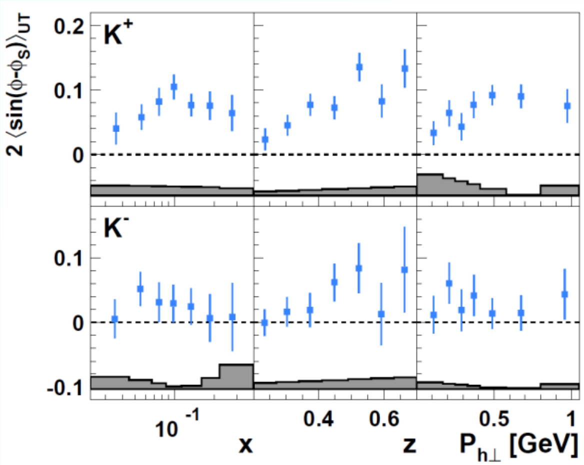

- Large K^+ Sivers amplitude

N/q	U	L	T
U	f_1		$h_1^{\perp}$
L		g_1	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	h_1 $h_{1T}^{\perp}$

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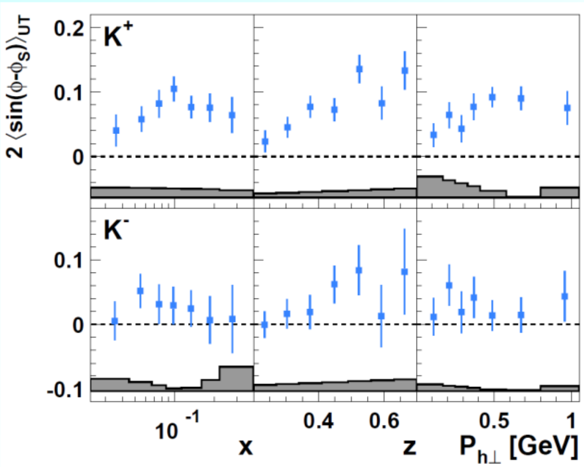
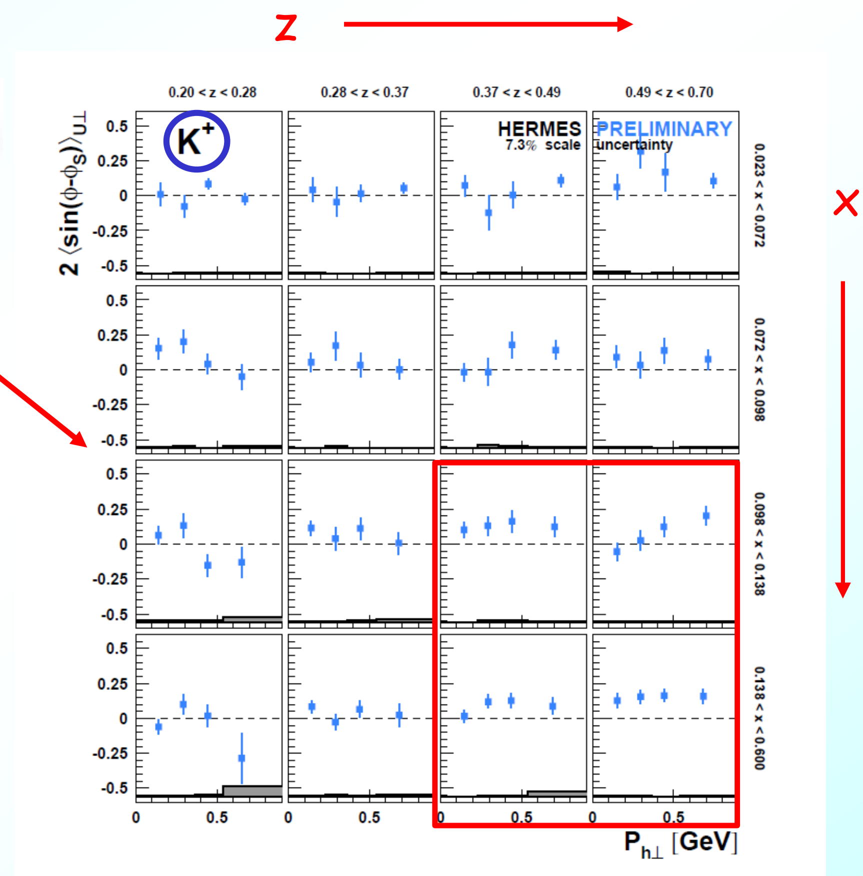




- Large K^+ Sivers amplitude

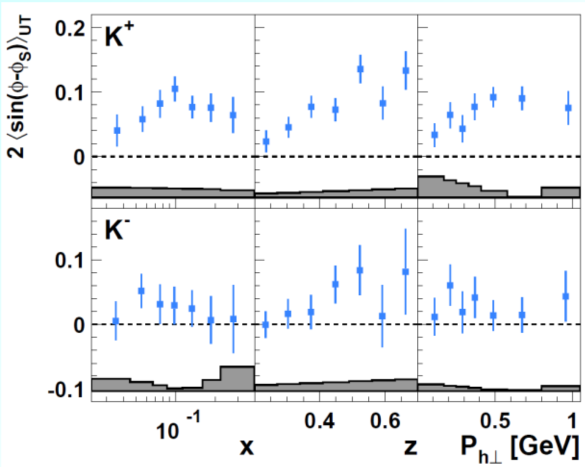
- Largest at large x and z,
  Region of purest „u-quark probe"

N/q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	h_1 $h_{1T}^\perp$

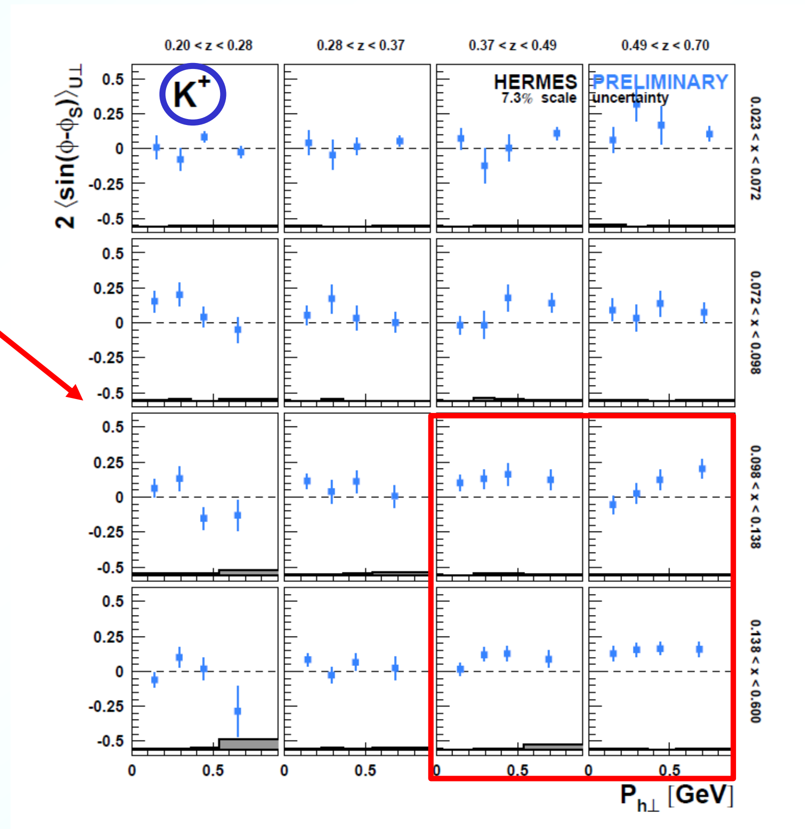
Sivers amplitudes

$$C[f_{1T}^{\perp,q}(x) \otimes D_1^q(z)]$$

A. Airapetian et al., PRL 103 (2009) 152002



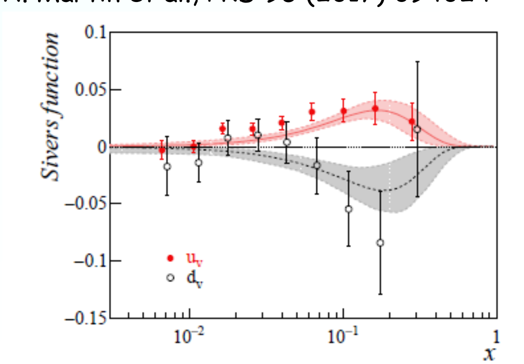
z →



x ↓

- Large K^+ Sivers amplitude

A. Martin et al., PRD 95 (2017) 094024

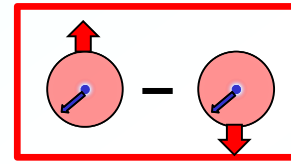


COMPASS data only

- Largest at large x and z,
  Region of purest „u-quark probe"

N/q	U	L	T	
U	f_1		$h_1^{\perp}$	
L		g_1	$h_{1L}^{\perp}$	
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	h_1	$h_{1T}^{\perp}$

Pretzelosity DF $h_{1T}^{\perp}$



Sideways transversely polarised quarks in transversely polarised nucleon

$$F_{UT}^{\sin(3\phi_h-\phi_S)} =$$
$$\mathcal{C}\left[\frac{2\left(\hat{h}\cdot p_T\right)\left(p_T\cdot k_T\right)+p_T^2\left(\hat{h}\cdot k_T\right)-4\left(\hat{h}\cdot p_T\right)^2\left(\hat{h}\cdot k_T\right)}{2M^2M_h}\, h_{1T}^{\perp} H_1^{\perp}\right]$$

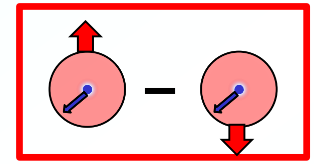
- leading-twist
- Related to parton orbital motion: requires interference between wave functions with OAM difference by 2 units
- Expected to scale with $(p_T)^2 k_T$
- Suppressed w.r.t - Collins and Sivers (these scale with k_T, p_T)

  - Cahn, Boer-Mulders ($\langle\cos\phi\rangle$ scales with k_T, p_T)

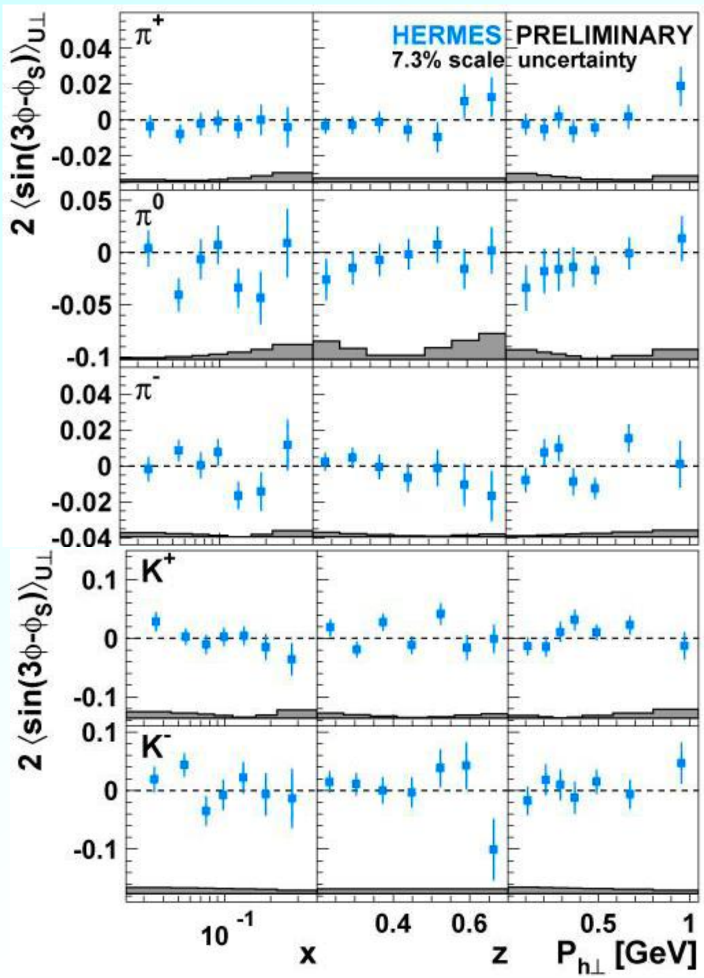
  - Boer-Mulders ($\langle\cos 2\phi\rangle$ scales with $k_T p_T$)

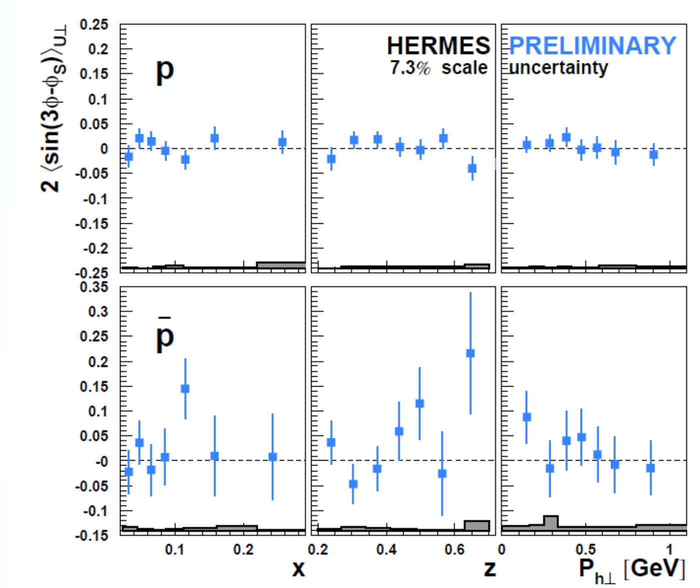
N/q	U	L	T
U	f_1		$h_1^{\perp}$
L		g_1	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	h_1 $h_{1T}^{\perp}$

Pretzelosity DF $h_{1T}^{\perp}$



$$C[h_1^{\perp,q}(x) \otimes H_1^{\perp,q}(z)]$$

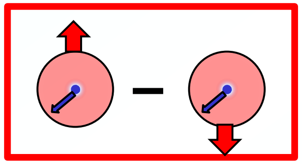




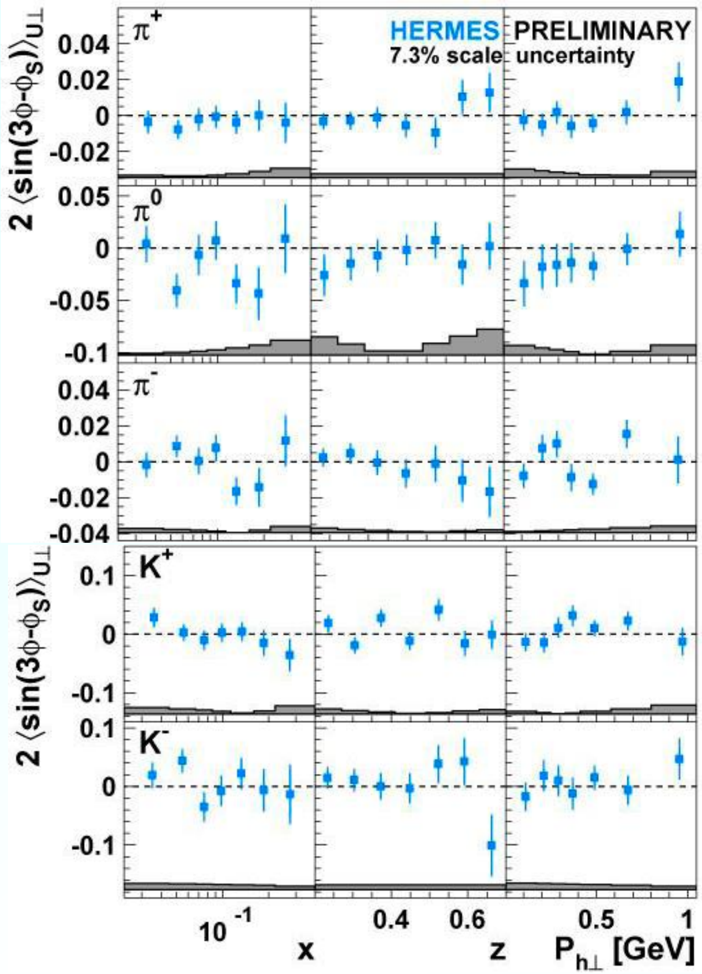
- Compatible with zero within uncertainties
- $h_{1T}^{\perp}$ might be non-zero, look at higher p_T
- 3D for pions, kaons, protons

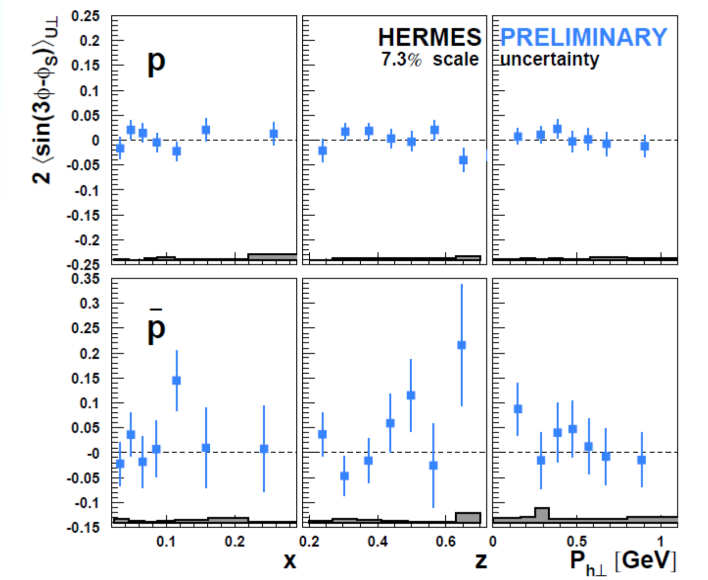
N/q	U	L	T
U	f_1		$h_1^{\perp}$
L		g_1	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	h_1 $h_{1T}^{\perp}$

Pretzelosity DF $h_{1T}^{\perp}$



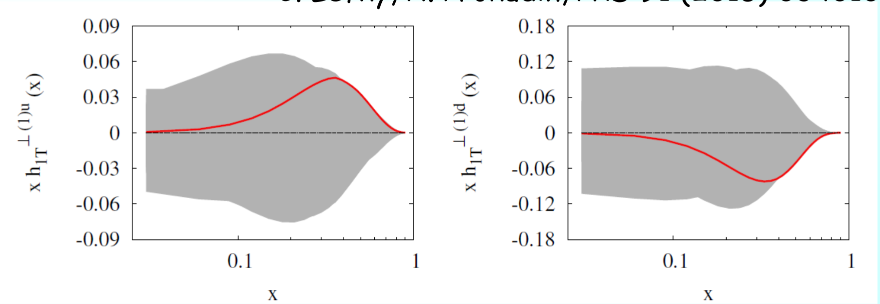
$C[h_1^{\perp,q}(x) \otimes H_1^{\perp,q}(z)]$





- Compatible with zero within uncertainties
- $h_{1T}^{\perp}$ might be non-zero, look at higher p_T

C. Lefky, A. Prokudin, PRD 91 (2015) 034010

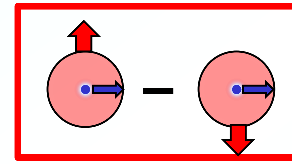


- for pions, kaons, protons

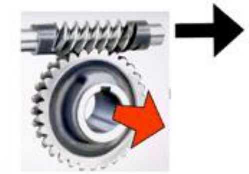
Data from COMPASS, HERMES, JLAB

N/q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	h_1 $h_{1T}^\perp$

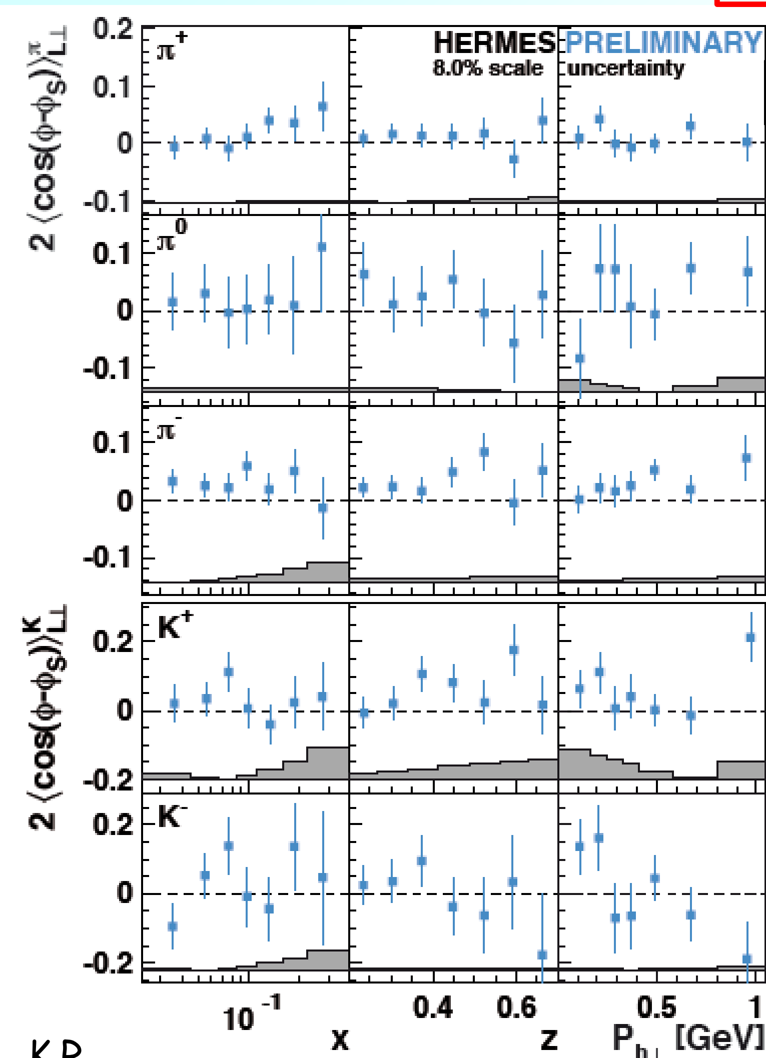
Worm-gear DF $g_{1T}^{\perp,q}$



longitudinally polarised quarks in transversely polarised nucleon



$C[g_{1T}^{\perp,q}(x) \otimes D_1^q(z)]$



- Related to parton orbital motion: requires interference between wave functions with OAM difference by 1 unit
- $g_{1T}^{\perp,q} = -\,h_{1L}^{\perp,q}$ (supported by many models)

  $$g_{1T}^{\perp,q} \approx x \int_x^1 \frac{dy}{y}\, g_1^q(y)$$ (Wandzura-Wilczek type approximation)
- Slightly non-zero
- 3D for pions, kaons, protons

K.R.

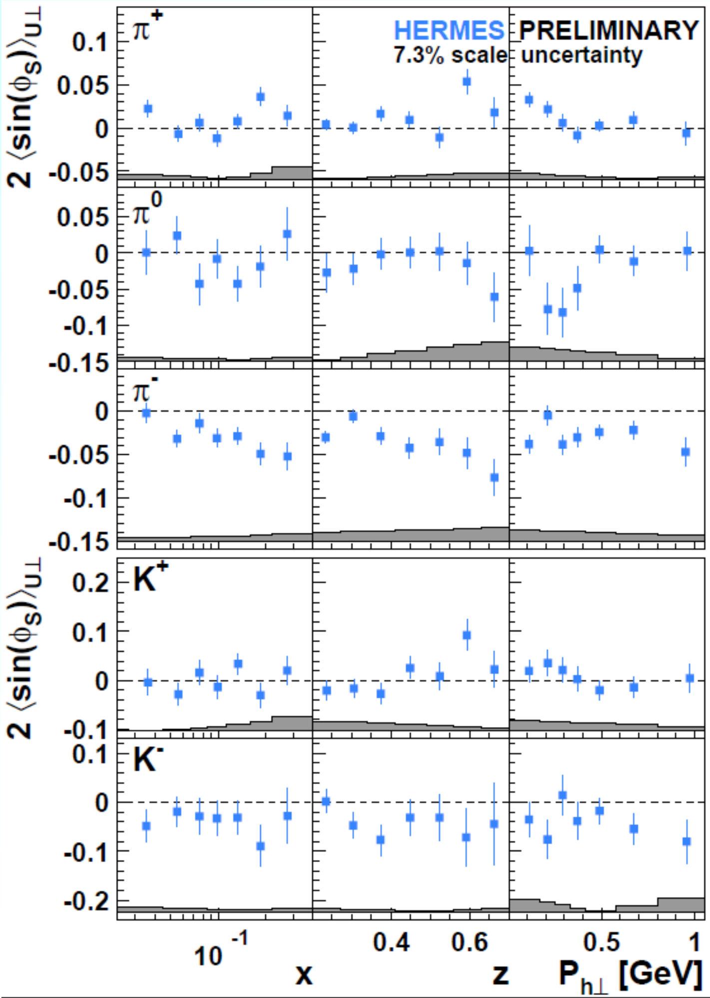
Twist-3 $\langle \sin(\phi_S) \rangle_{UT}$

twist-3

$$\propto \mathcal{C}[f_T^q \times D_1^q, h_{1T}^q \times \tilde{H}^q, h_T^q \times H_1^{\perp,q}, g_{1T}^{\perp,q} \times \tilde{G}^{\perp,q}, h_T^{\perp,q} \times H_1^{\perp,q}, f_{1T}^{\perp,q} \times \tilde{D}^{\perp,q}]$$

$\int \ldots \, dP_{h\perp}^2$

$$\langle \sin(\phi_S) \rangle_{UT} = -x \frac{2M_h}{Q} \sum_q e_q^2 h_{1T}^q \frac{\tilde{H}^q}{z}$$

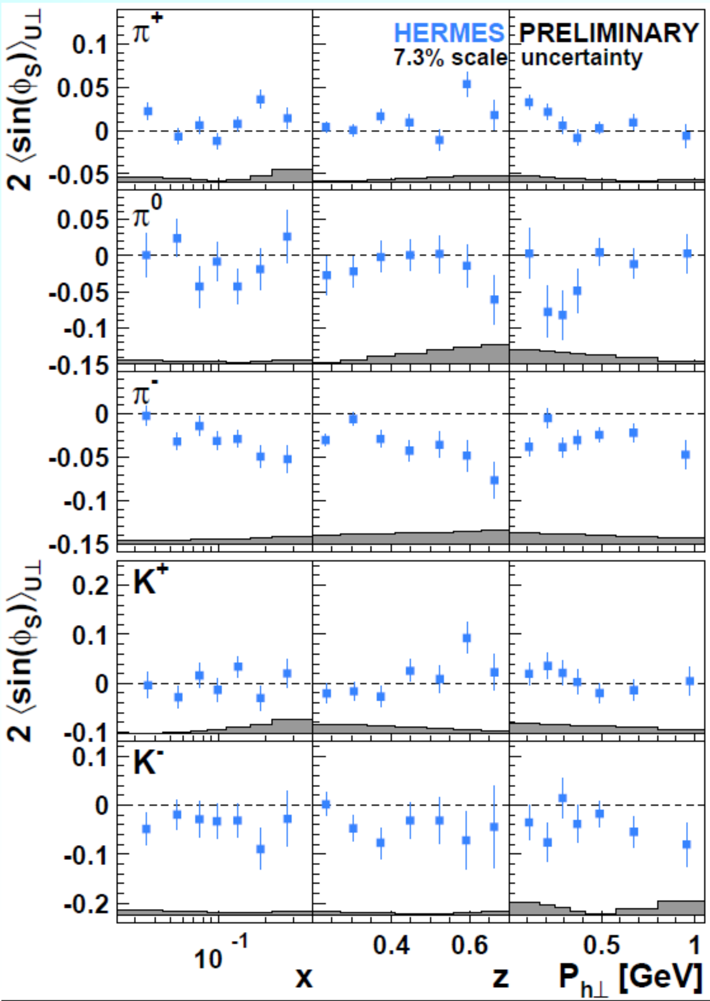


- Significant non-zero amplitude for π^- increasing with x, z

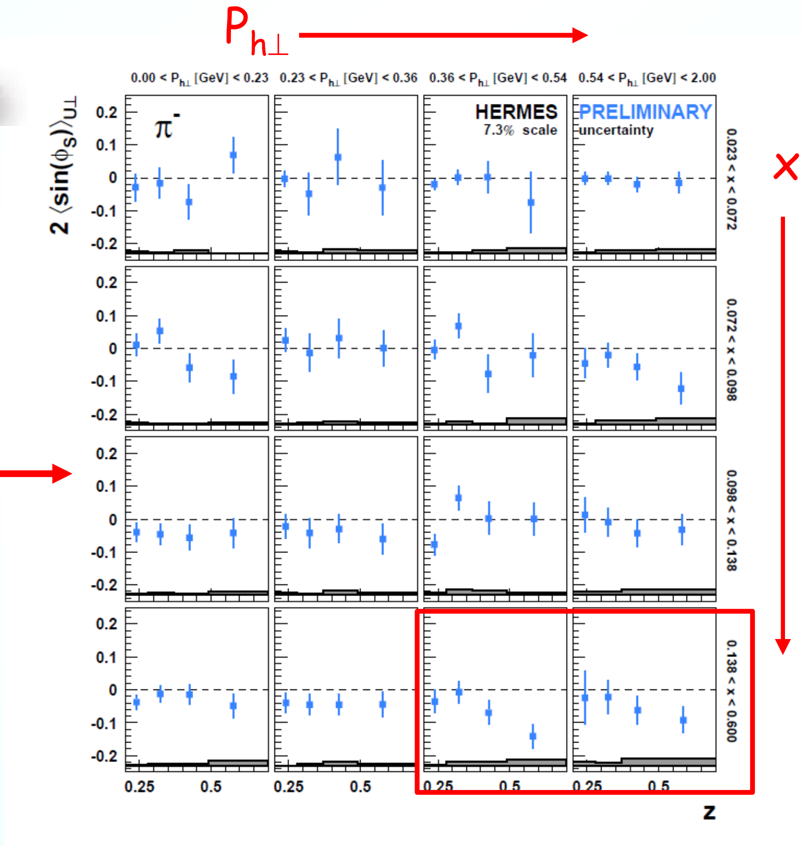
Twist-3 $\langle \sin(\phi_S) \rangle_{UT}$

twist-3

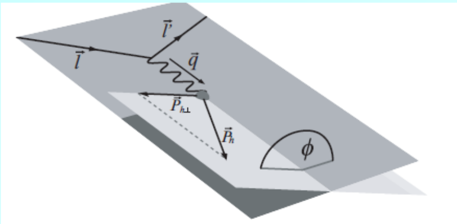
$$\propto \mathcal{C}[f_T^q \times D_1^q, h_{1T}^q \times \tilde{H}^q, h_T^q \times H_1^{\perp,q}, g_{1T}^{\perp,q} \times \tilde{G}^{\perp,q}, h_T^{\perp,q} \times H_1^{\perp,q}, f_{1T}^{\perp,q} \times \tilde{D}^{\perp,q}]$$



3D



Topic 4: $A_{LU}{}^{h}$



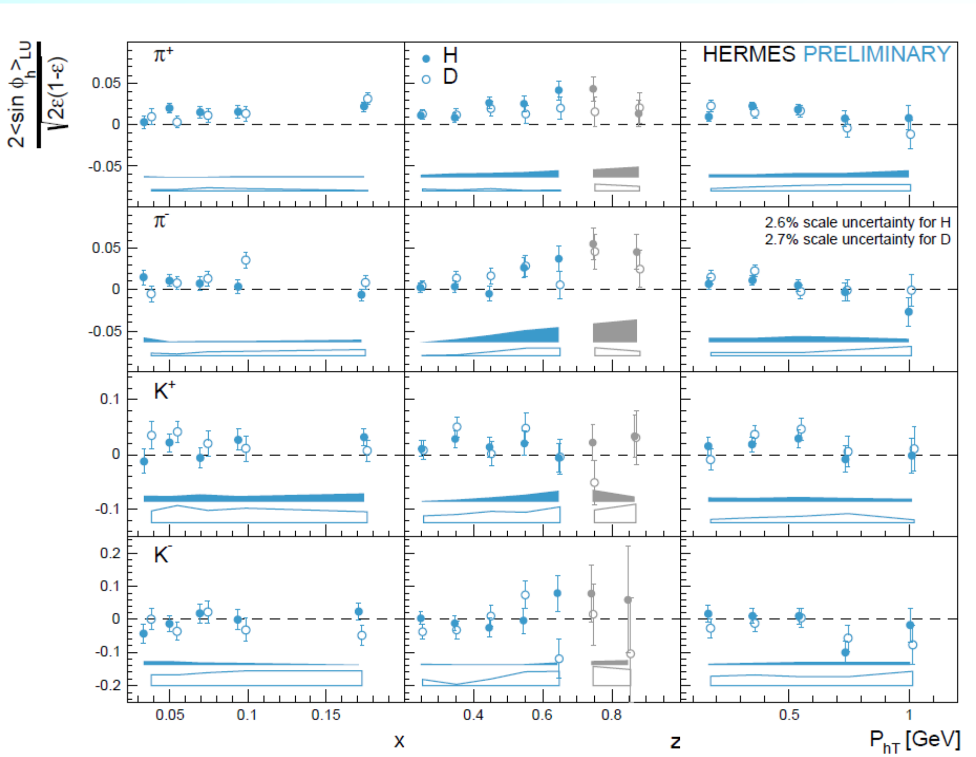
Twist-3 $\langle \sin(\phi) \rangle_{LU}$

$$\sim \propto C[h_1^{\perp,q} \otimes \tilde{E}^q,\ x e^q \otimes H_1^{\perp};\ x g^{\perp,q} \otimes D_1^q,\ f_1^q \otimes \tilde{G}^{\perp,q}]$$

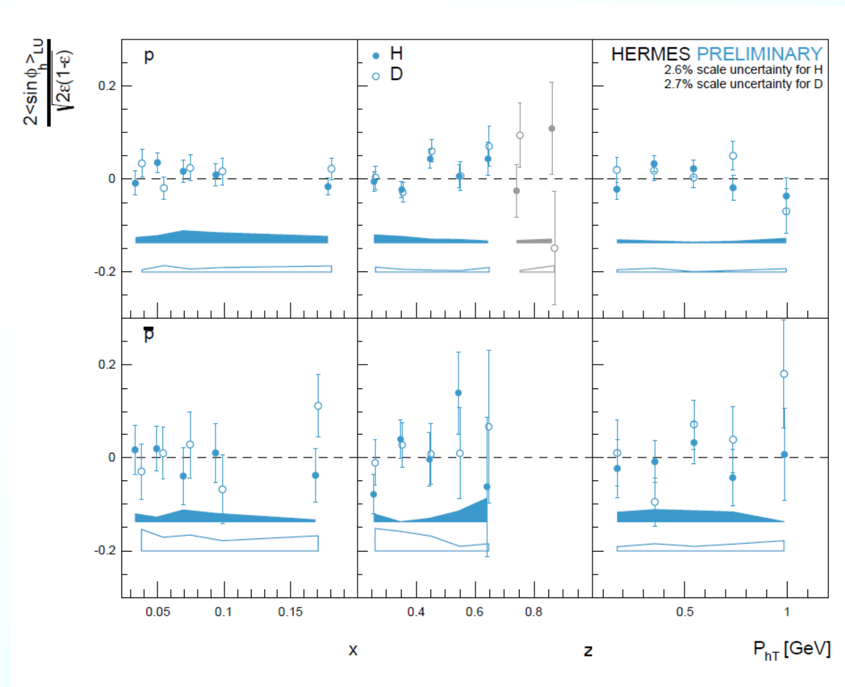
Chiral-odd T-even ($\tilde{E}^q$, e^q)

Chiral-even T-odd ($g^{\perp,q}$, $\tilde{G}^{\perp,q}$)

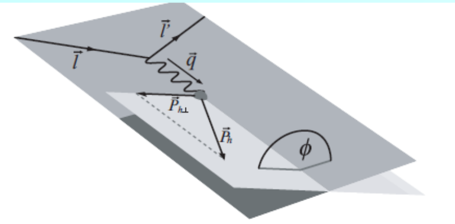
- H, D data from 1996-2007



- Virtual-photon asymmetries



- Agreement between H and D data
- Positive asymmetries for pions



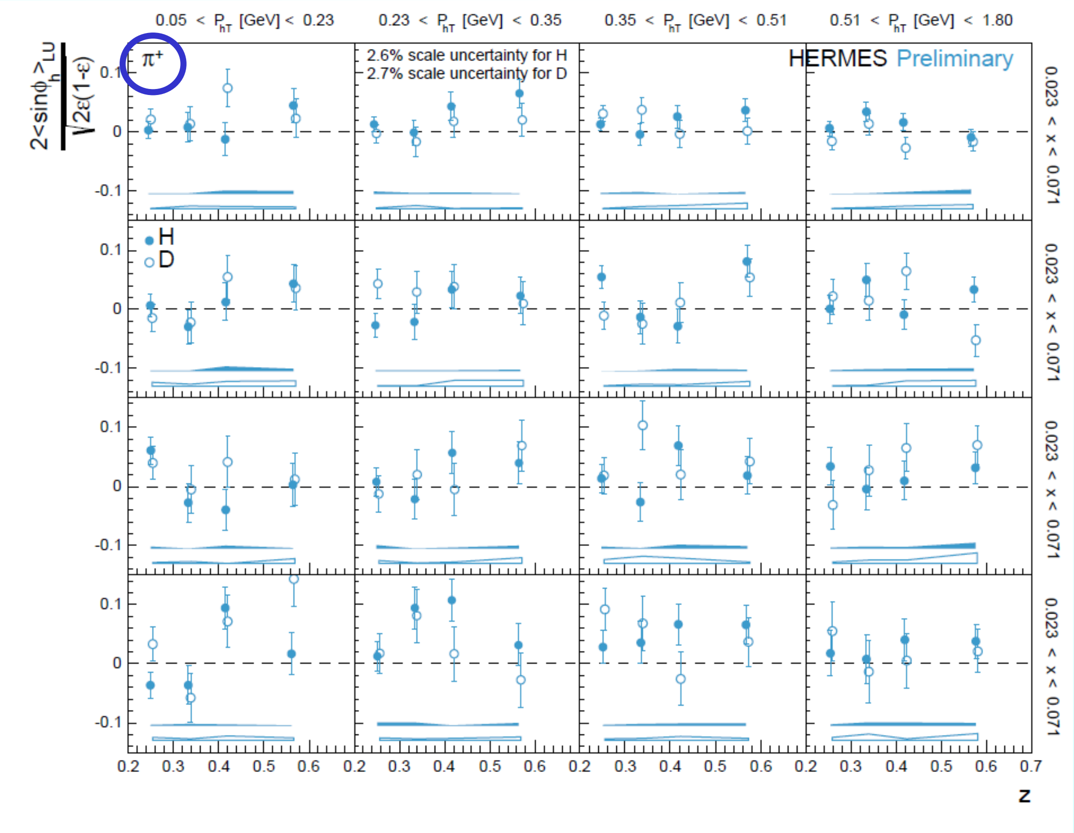
Twist-3 $\langle \sin(\phi) \rangle_{LU}$

$$\propto C[h_1^{\perp,q} \otimes \tilde{E}^q,\ x\, e^q \otimes H_1^{\perp};\ x\, g^{\perp,q} \otimes D_1^q,\ f_1^q \otimes \tilde{G}^{\perp,q}]$$

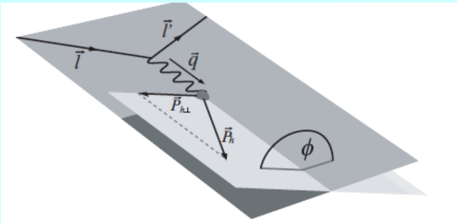
Chiral-odd
T-even

Chiral-even
T-odd

- H, D data from 1996-2007



- No clear kinematic dependencies in 3D



Twist-3 $\langle \sin(\phi) \rangle_{LU}$

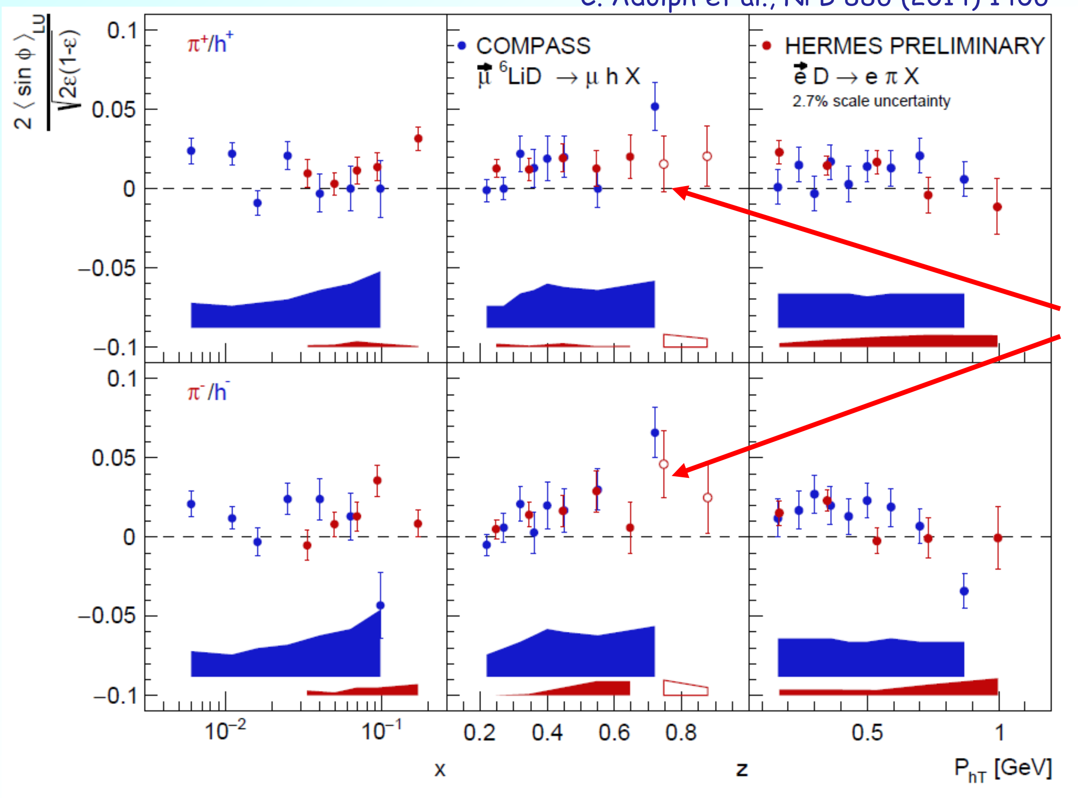
$$\propto C[h_1^{\perp,q} \otimes \tilde{E}^q, x e^q \otimes H_1^{\perp}; x g^{\perp,q} \otimes D_1^q, f_1^q \otimes \tilde{G}^{\perp,q}]$$

Chiral-odd T-even ($\tilde{E}^q$, e^q)

Chiral-even T-odd ($g^{\perp,q}$, $\tilde{G}^{\perp,q}$)

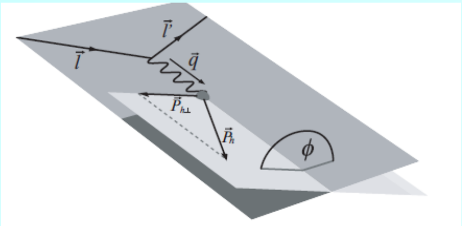
- D data from 1999-2007

C. Adolph et al., NPB 886 (2014) 1406



- Data at high z not used for other projections

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



Twist-3 $\langle\sin(\phi)\rangle_{LU}$

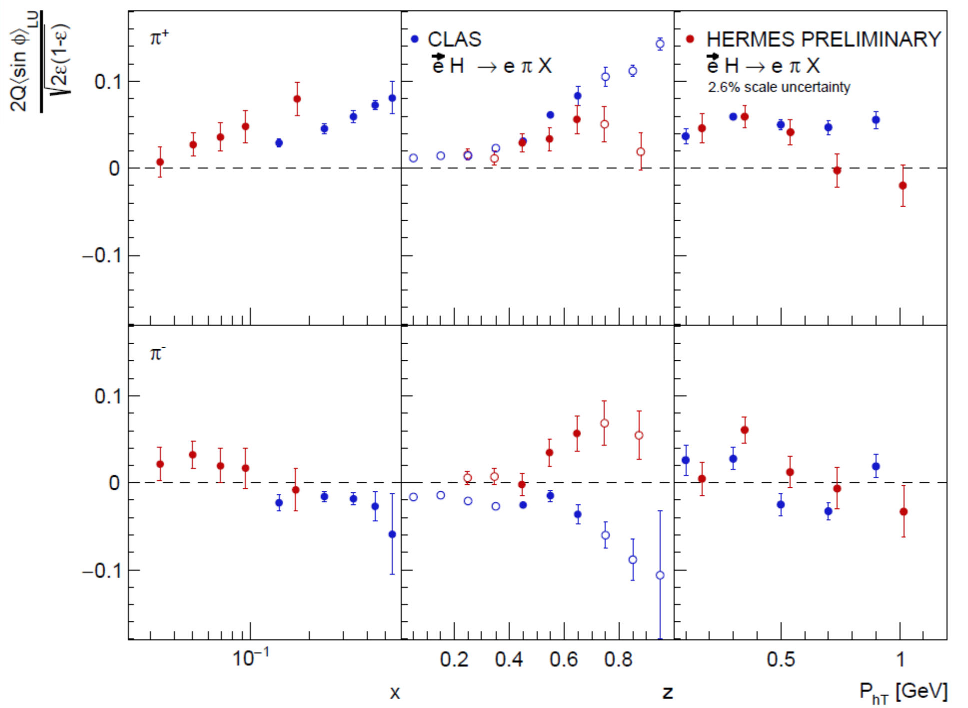
$\propto C[h_1^{\perp,q} \otimes \tilde{E}^q,\ x\,e^q \otimes H_1^{\perp,q};\ x\,g^{\perp,q} \otimes D_1^q,\ f_1^q \otimes \tilde{G}^{\perp,q}]$

Chiral-odd
T-even

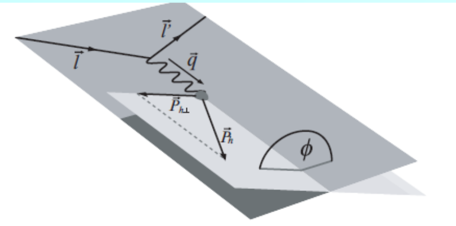
Chiral-even
T-odd

- H data from 1996-2007

W. Gohn et al., PRD 89 (2014) 072011



- Opposite behavior for π^- z projection
  CLAS probes higher x region; more sensitive to $x\,e^q \otimes H_1^{\perp,q}$?



Twist-3 $\langle \sin(\phi) \rangle_{LU}$

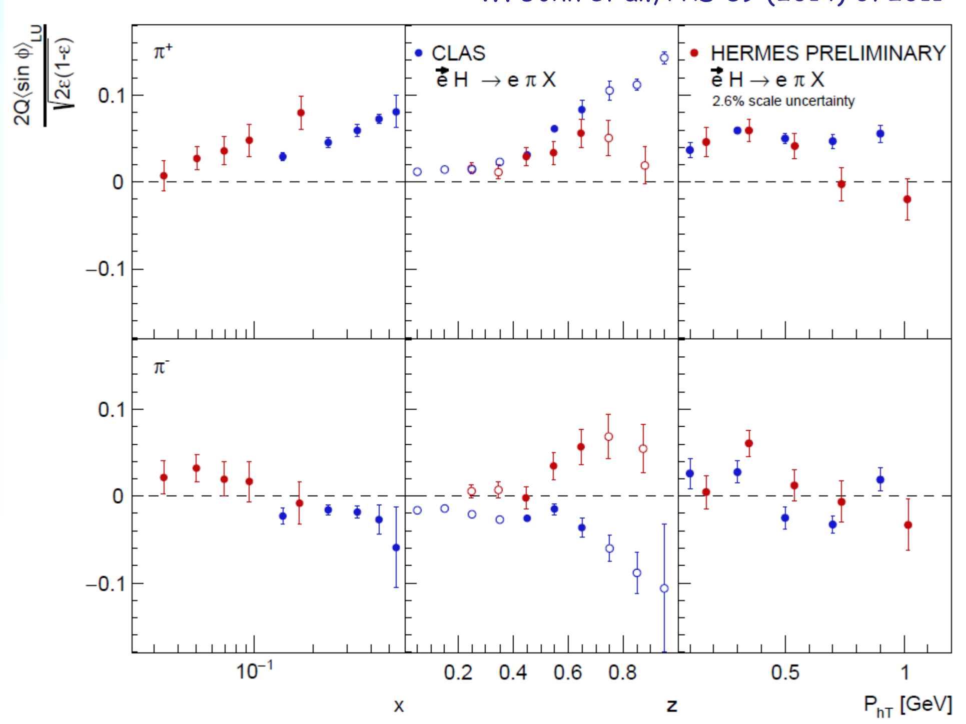
$$\propto C[h_1^{\perp,q} \otimes \tilde{E}^q,\ x\, e^q \otimes H_1^{\perp,q};\ x\, g^{\perp,q} \otimes D_1^q,\ f_1^q \otimes \tilde{G}^{\perp,q}]$$

Chiral-odd T-even ($\tilde{E}^q$, e^q)

Chiral-even T-odd ($g^{\perp,q}$, $\tilde{G}^{\perp,q}$)

- H data from 1996-2007

W. Gohn et al., PRD 89 (2014) 072011



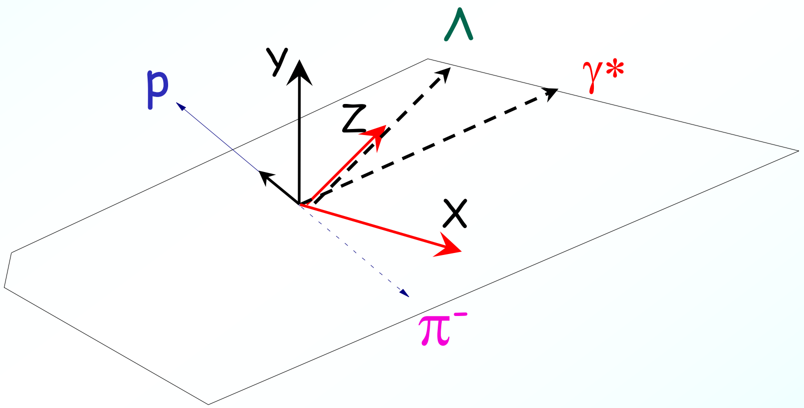
- Opposite behavior for π^- z projection
  CLAS probes higher x region; more sensitive to $x\, e^q \otimes H_1^{\perp,q}$?

Draft in 1st circulation

Topic 5: Λ Polarization

Beam-helicity induced Λ and $\bar{\Lambda}$ polarization

$\vec{l} + N \to l' + \vec{\Lambda} + X$ $\Lambda \to p + \pi^-$



- Λ polarization $\vec{P}^\Lambda$ from proton angular distribution in Λ rest frame

$$\propto (1 + \alpha \vec{P}^\Lambda \cdot \hat{p}) = (1 + \alpha \sum_i P_i^\Lambda \cos\theta_i) \quad (i = X, Y, Z)$$

- $P_Z^\Lambda = P_B \sqrt{1-\varepsilon^2} \; D_{LZ}(x,z)$ $P_B = |P_B| \lambda_e$ longitudinal beam polarization

  $P_X^\Lambda = P_B \, 2\sqrt{2\varepsilon(1-\varepsilon)} \, D_{LX}(x,z)$

  $P_Y^\Lambda = \; 2\sqrt{2\varepsilon(1+\varepsilon)} \, D_{LY}(x,z)$ beam-helicity independent transverse Λ pol.

- $D_{LX}(x,z)$, $D_{LY}(x,z)$, $D_{LZ}(x,z)$: "spin-transfer coefficients"

- Asymmetry for helicity balanced data set: P_Y^Λ drops out

Beam-helicity induced Λ and $\bar{\Lambda}$ polarization

- Relations between spin-transfer coefficients and TMDs:
  (P. Mulders and R. Tangerman, Nucl. Phys. B461 (1996) 197)

$$D_{LZ}(x,z) = \frac{\sum_q e_q^2 x f_1^q(x)\, G_1^{q\to\Lambda}(z)}{\sum_q e_q^2 x f_1^q(x)\, D_1^{q\to\Lambda}(z)}$$

Production of longitudinally polarized Λs from originally unpolarized quarks and longitudinally polarized virtual photons

Beam-helicity induced Λ and $\bar{\Lambda}$ polarization

- Relations between spin-transfer coefficients and TMDs:
  (P. Mulders and R. Tangerman, Nucl. Phys. B461 (1996) 197)

$$D_{LZ}(x,z) = \frac{\sum_q e_q^2 x f_1^q(x)\, G_1^{q\to\Lambda}(z)}{\sum_q e_q^2 x f_1^q(x)\, D_1^{q\to\Lambda}(z)}$$

Production of longitudinally polarized Λs from originally unpolarized quarks and longitudinally polarized virtual photons

$$D_{LX}(x,z) = \frac{-\frac{M}{Q}\left\{\sum_q e_q^2 x^2 e^q(x)\, H_1^{\perp,q\to\Lambda}(z) + \frac{M_\Lambda}{M}\sum_q e_q^2 x f_1^q(x)\, \tilde{G}^{\perp,q\to\Lambda}(z)/z\right\}}{\sum_q e_q^2 x f_1^q(x)\, D_1^{q\to\Lambda}(z)}$$

Beam-helicity induced Λ and $\bar{\Lambda}$ polarization

- Relations between spin-transfer coefficients and TMDs:
  (P. Mulders and R. Tangerman, Nucl. Phys. B461 (1996) 197)

$$D_{LZ}(x,z) = \frac{\sum_q e_q^2 x f_1^q(x)\, G_1^{q\to\Lambda}(z)}{\sum_q e_q^2 x f_1^q(x)\, D_1^{q\to\Lambda}(z)}$$

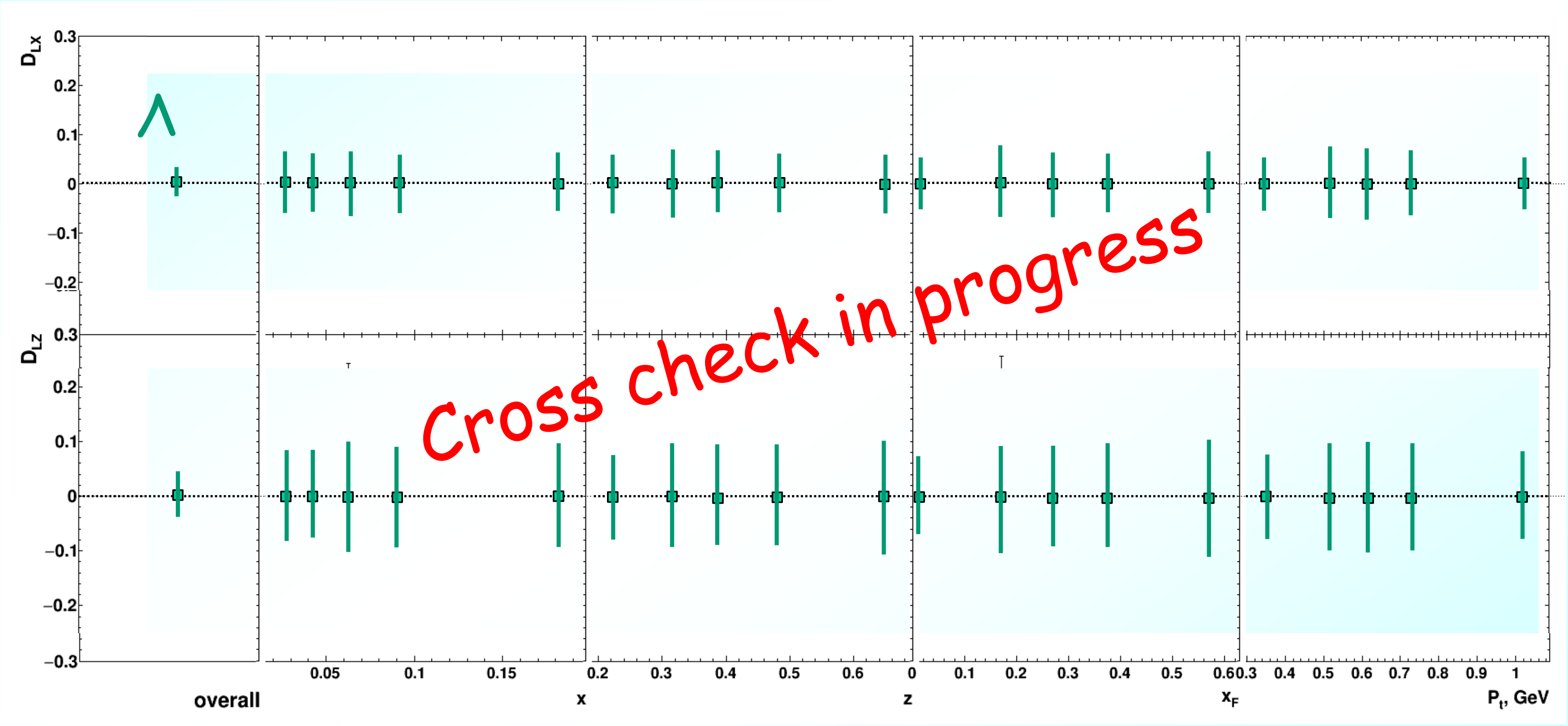
Production of longitudinally polarized Λs from originally unpolarized quarks and longitudinally polarized virtual photons

$$D_{LX}(x,z) = \frac{-\frac{M}{Q}\left\{\sum_q e_q^2 x^2 e^q(x)\, H_1^{\perp,q\to\Lambda}(z) + \frac{M_\Lambda}{M}\sum_q e_q^2 x f_1^q(x)\, \tilde{G}^{\perp,q\to\Lambda}(z)/z\right\}}{\sum_q e_q^2 x f_1^q(x)\, D_1^{q\to\Lambda}(z)}$$

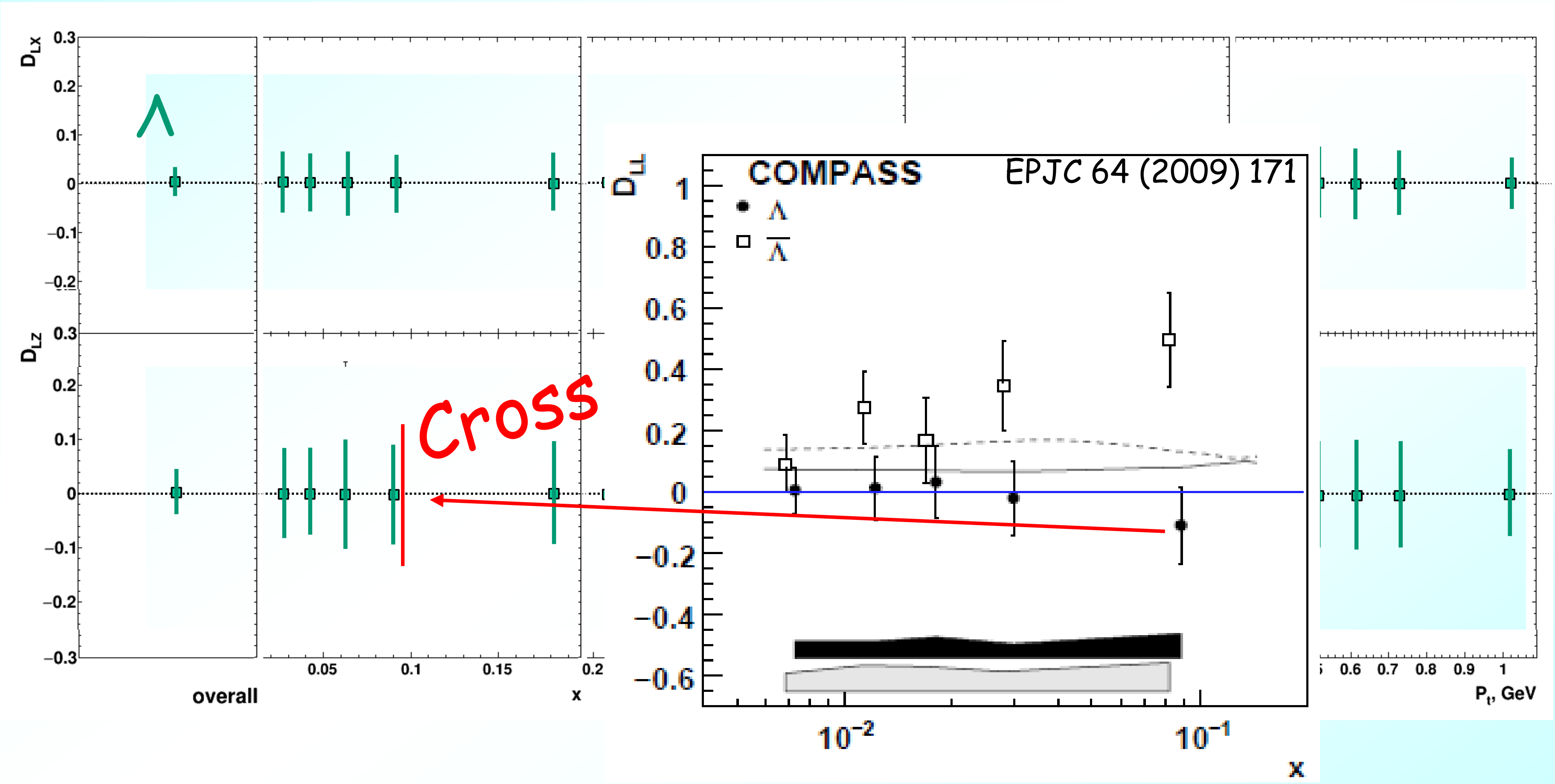
Same combinations of PDFs and FF as in **Twist-3 $\langle\sin(\phi)\rangle_{LU}$**

$$\propto C[h_1^{\perp,q}\otimes\tilde{E}^q,\ x\,e^q\otimes H_1^{\perp,q};\ x\,g^{\perp,q}\otimes D_1^q,\ f_1^q\otimes\tilde{G}^{\perp,q}]$$

Beam-helicity induced Λ and $\bar{\Lambda}$ polarization

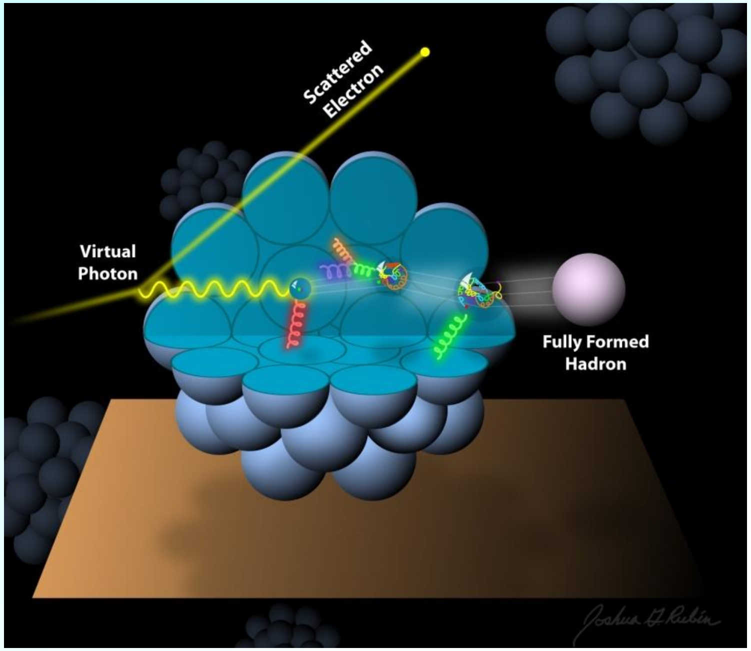


Beam-helicity induced Λ and $\bar{\Lambda}$ polarization



Topic 6: Kaons from nuclei

Fragmentation in nuclear matter



Courtesy of J. Rubin)

- typical hadronisation length ∝ (1-z) ν is of order of nucleus size (1-10 fm)
- time development of hadronisation can be studied with nuclei of increasing size
- struck quark or qq-pair propagate through ‚cold' nuclear matter
- interaction signature: reduction of the numer of hadrons per DIS event and per nucleon

Useful for understanding the fundamental aspects of hadronisation

Input for calculations of nuclear PDFs and FF

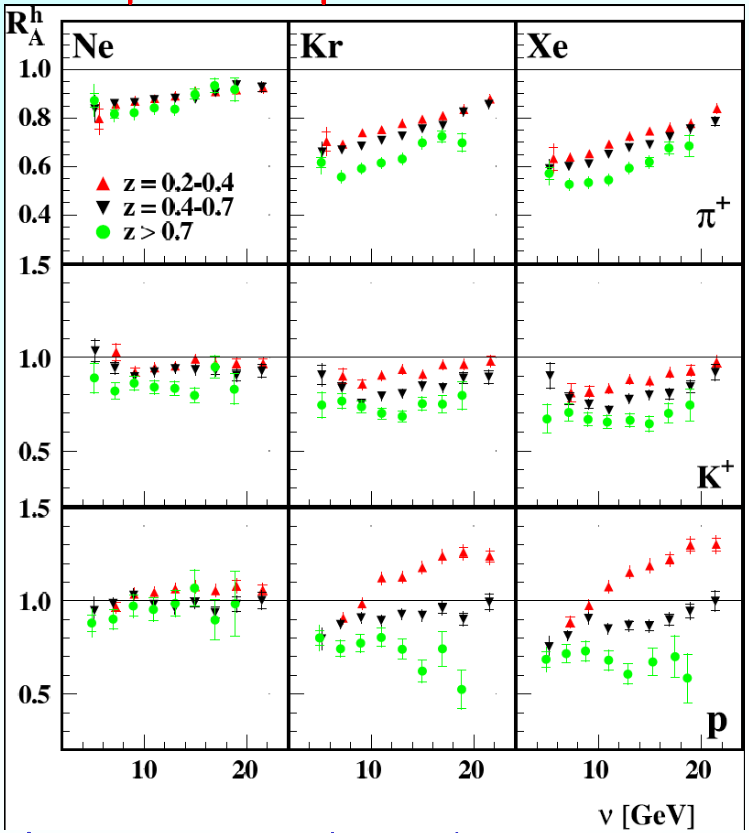
$$R_A^h(\nu, Q^2, z, p_t^2) = \frac{\left(\frac{N^h(\nu,Q^2,z,p_t^2)}{N^e(\nu,Q^2)}\right)_A}{\left(\frac{N^h(\nu,Q^2,z,p_t^2)}{N^e(\nu,Q^2)}\right)_D}$$

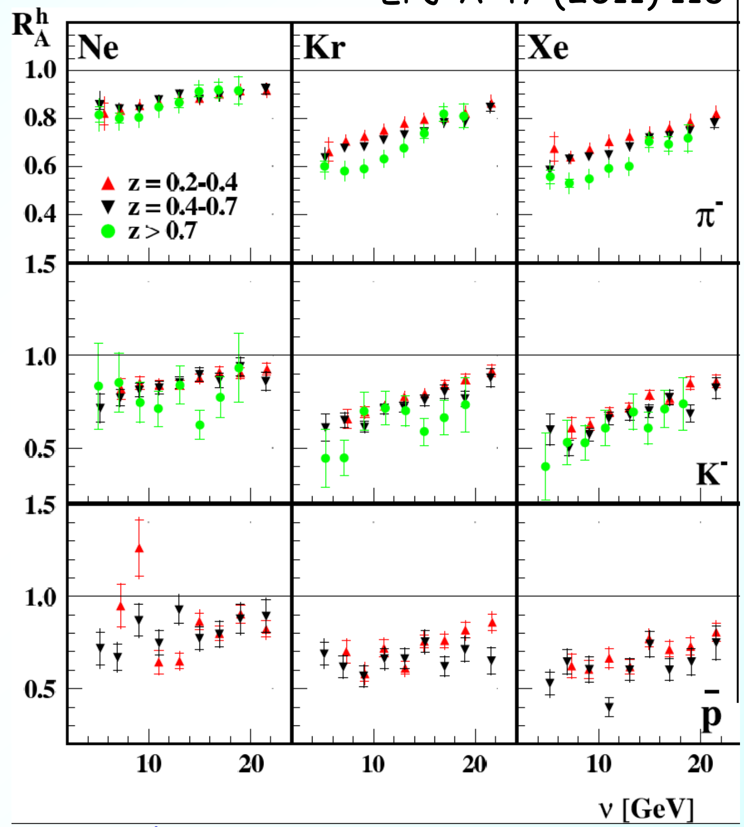
Multi-dimensional study

Fragmentation in nuclear matter

Example: ν-dependence

EPJ A 47 (2011) 113





- less pronounced trends in Ne compared to Kr and Xe
- π+, π-, K-: increase of R_A with ν
- K+: increase of R_A with ν for lowest z-slize, flatter behaviour for higher z
- $\bar{p}$: weak ν-dependence
- p: R_A exceeding unity at high ν and low z (apart from hadronisation other production mechanisms contribute)

Charged Kaon production in nuclear matter

N.B. Chang et al., PRC 89 (2014) 034911

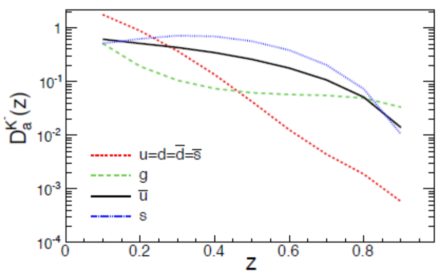


FIG. 1: (color online) Parton fragmentation functions to K^- in vacuum at $Q^2 \approx 10$ GeV^2 from the HKN parametrization [27].

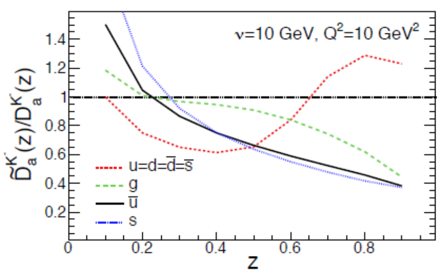


FIG. 2: (color online) Ratios of mFF's to the vacuum ones for K^- from different partons with initial energy $\nu = 10$ GeV and $Q^2 = 10$ GeV^2 in SIDIS off Pb.

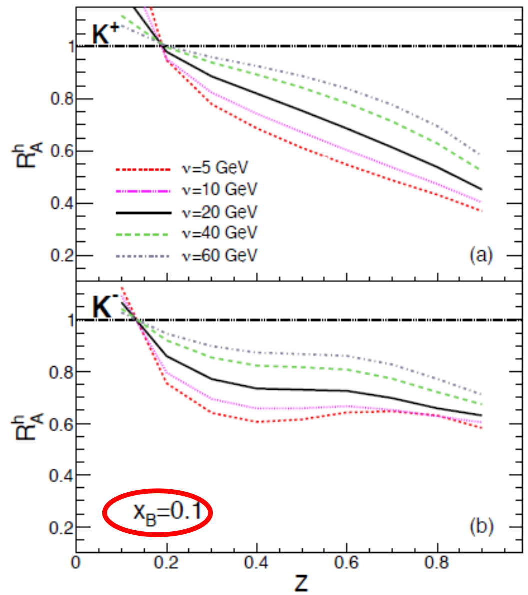


FIG. 3: (color online) The nuclear modification factor for (a) K^+ and (b) K^- for different initial quark energy ν in SIDIS at $x_B = 0.1$.

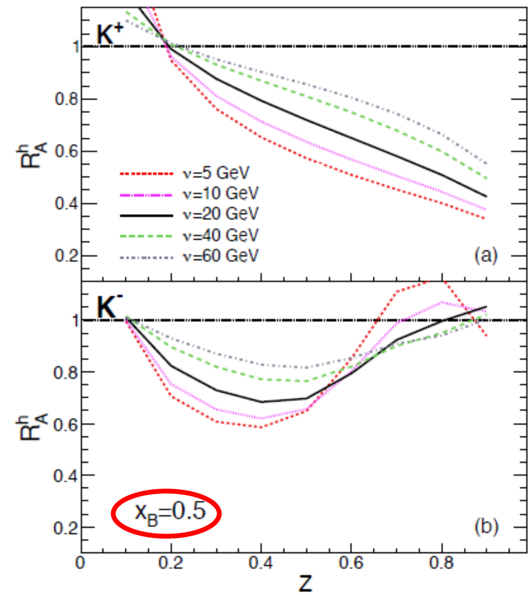


FIG. 4: (color online) The same as Fig. 3 except for $x_B = 0.5$.

- Prediction: enhanced medium modified FF for K^- and enhanced K-/K+ production ratio at large x and z

Charged Kaon production in nuclear matter

N.B. Chang et al., PRC 89 (2014) 034911

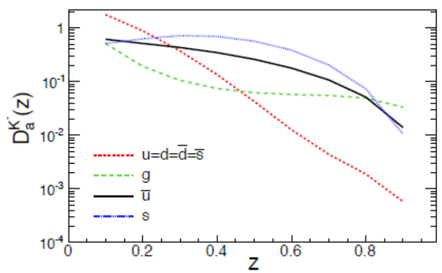


FIG. 1: (color online) Parton fragmentation functions to K^- in vacuum at $Q^2 \approx 10$ GeV^2 from the HKN parametrization [27].

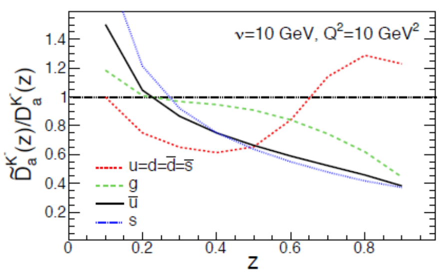


FIG. 2: (color online) Ratios of mFF's to the vacuum ones for K^- from different partons with initial energy $\nu = 10$ GeV and $Q^2 = 10$ GeV^2 in SIDIS off Pb.

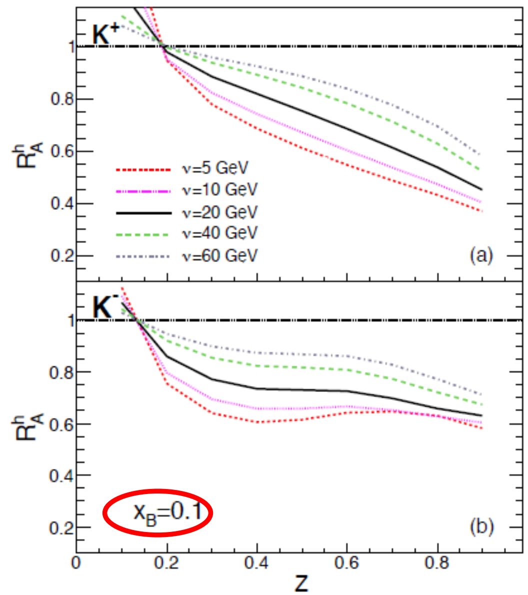


FIG. 3: (color online) The nuclear modification factor for (a) K^+ and (b) K^- for different initial quark energy ν in SIDIS at $x_B = 0.1$.

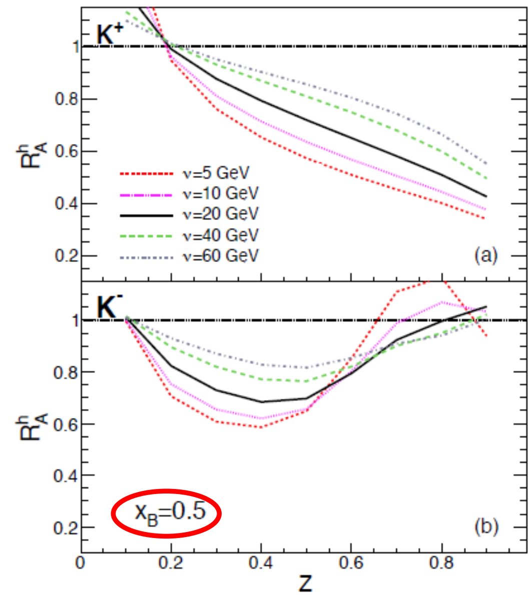


FIG. 4: (color online) The same as Fig. 3 except for $x_B = 0.5$.

- Prediction: enhanced medium modified FF for K^- and enhanced K-/K+ production ratio at large x and z

Analysis completed. Results to be released in a few weeks