HERMES measurements of nucleon transverse spin structure

Pacific Spin 2009, Yamagata, Japan

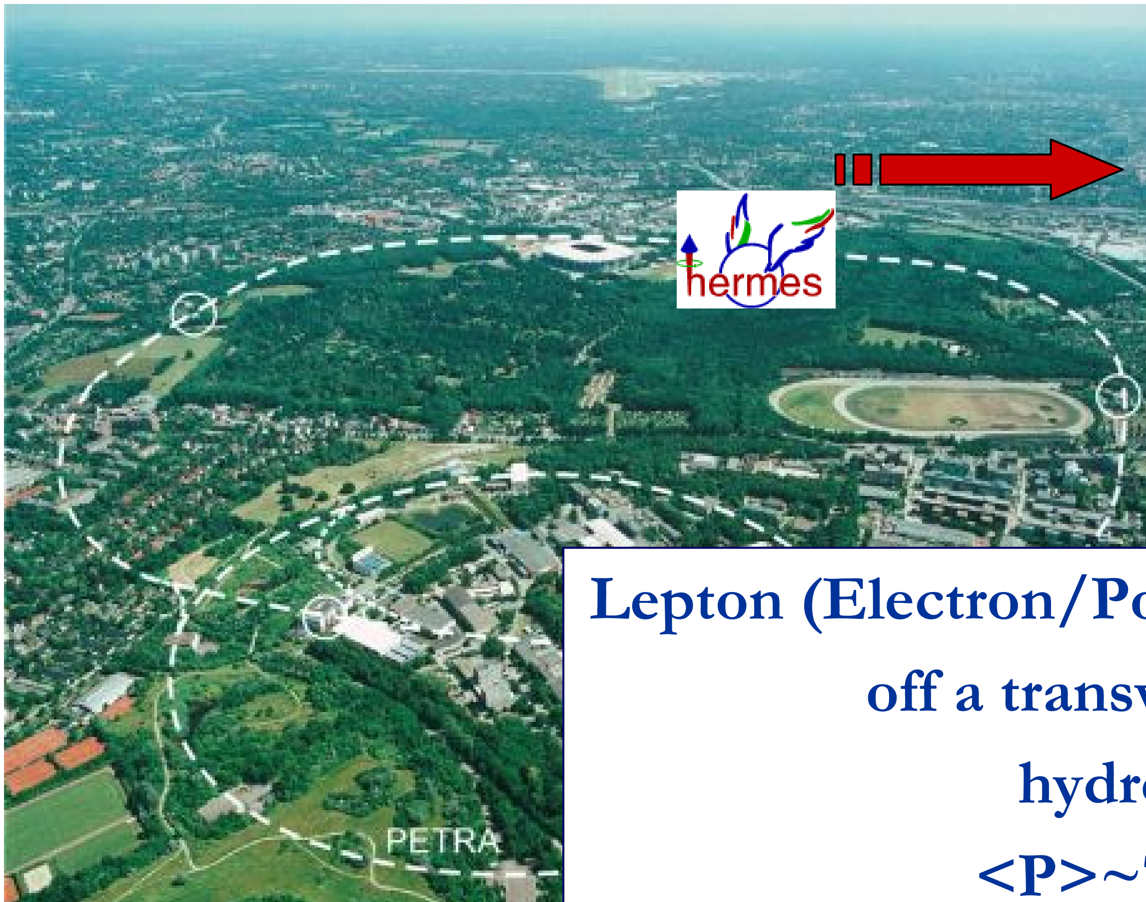
Francesca Giordano
DESY, Hamburg

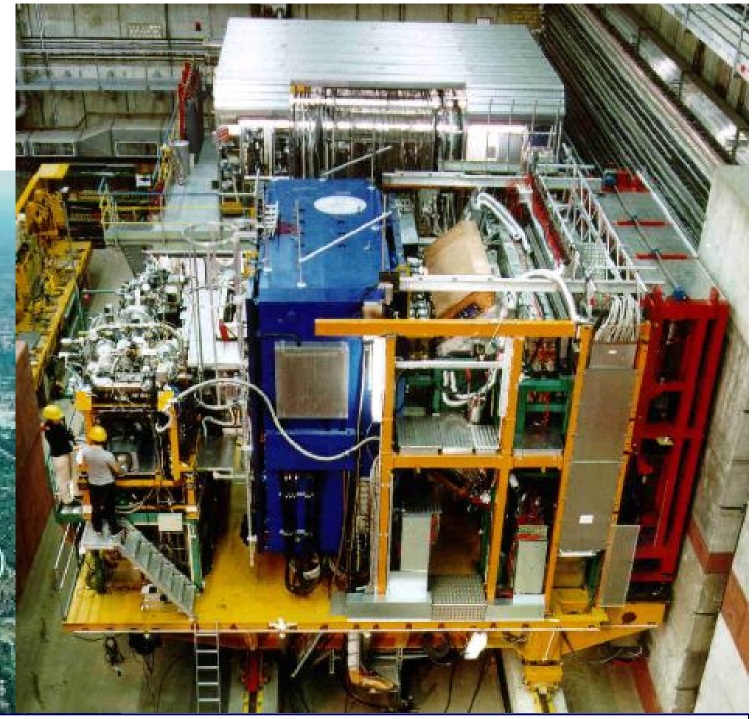
For the hermes collaboration

HERa MEasurement of Spin

HERA storage ring @ DESY

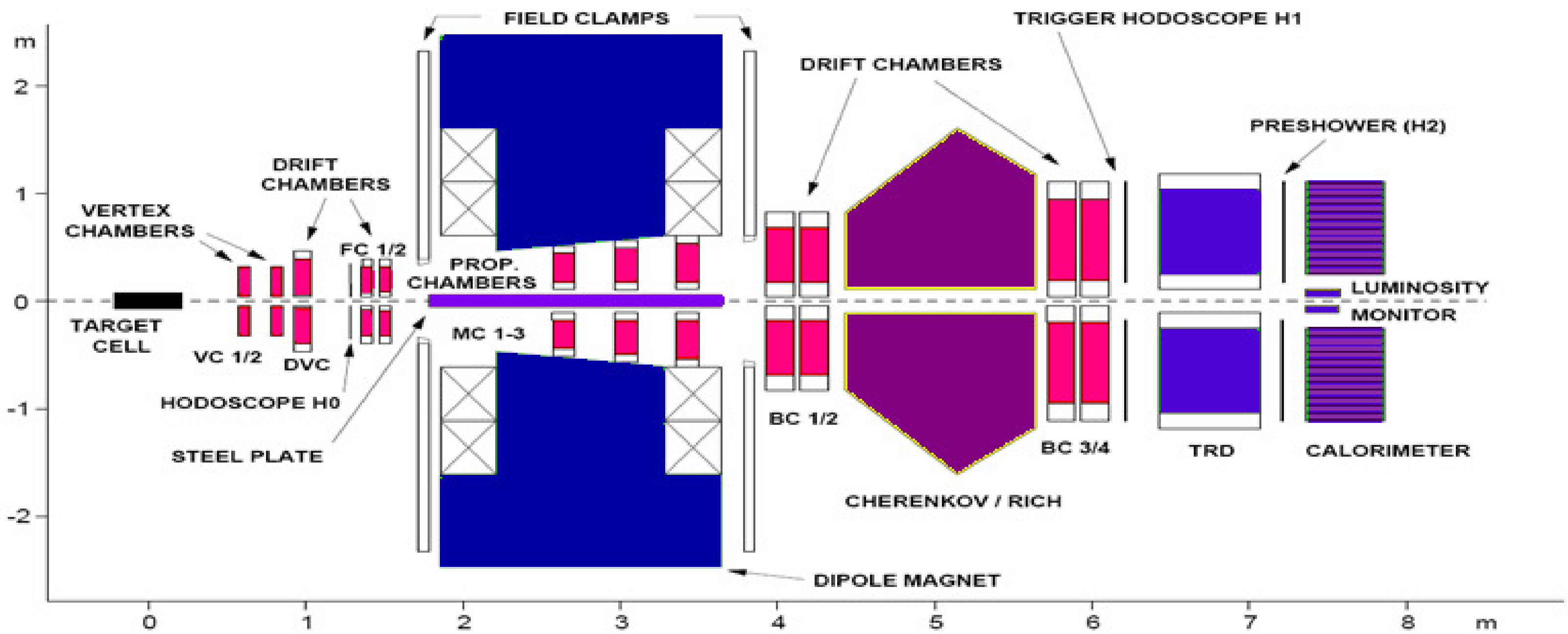
HERa MEasurement of Spin





Lepton (Electron/Positron) beam (27.6GeV/c)
off a transversely polarised
hydrogen target
<P>~72.5±0.053%

HERMES spectrometer



Resolution: Δp/p ~ 1-2% Δθ <~0.6 mrad

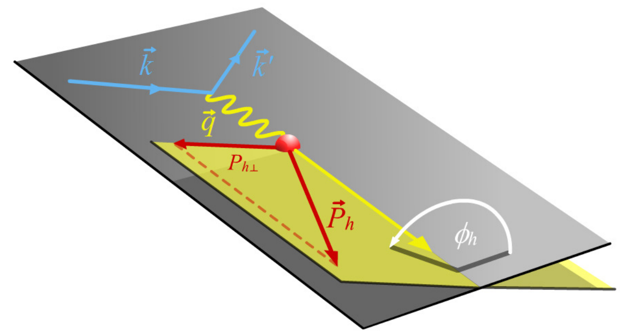
Electron-hadron separation efficiency ~ 98-99%

Hadron identification with dual-radiator RICH

Semi-Inclusive DIS cross section

$$\frac{d^5\sigma}{dx\,dy\,dz\,d\phi_h dP_{h\perp}^2} = \frac{\alpha^2}{xyQ^2}\left(\frac{y^2}{2(1-\varepsilon)}\right)\left(1+\frac{\gamma^2}{2x}\right)\Big\{F_{UU,T} + \varepsilon\,F_{UU,L}$$

$$+\sqrt{2\varepsilon(1+\varepsilon)}\cos\phi_h F_{UU}^{\cos\phi_h} + \varepsilon\cos 2\phi_h\ F_{UU}^{\cos 2\phi_h}$$



$$F_{...} = F_{...}(x, y, z, P_{h\perp})$$

Semi-Inclusive DIS cross section

$$\frac{d^5\sigma}{dx\,dy\,dz\,d\phi_h dP_{h\perp}^2} = \frac{\alpha^2}{xyQ^2}\left(\frac{y^2}{2(1-\varepsilon)}\right)\left(1+\frac{\gamma^2}{2x}\right)\Big\{F_{UU,T} + \varepsilon\, F_{UU,L}$$

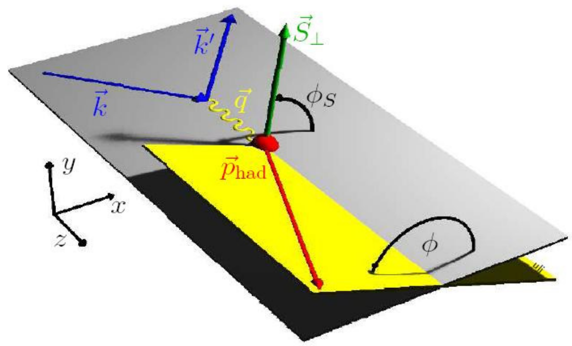
$$+\sqrt{2\varepsilon(1+\varepsilon)}\cos\phi_h F_{UU}^{\cos\phi_h} + \varepsilon\cos 2\phi_h\; F_{UU}^{\cos 2\phi_h}$$

$$+|S_T|\,\Big[\,\sin(\phi_h-\phi_S)\left(F_{UT,T}^{\sin(\phi_h-\phi_S)} + \varepsilon\; F_{UT,L}^{\sin(\phi_h-\phi_S)}\right)$$

$$+\varepsilon\sin(\phi_h+\phi_S)F_{UT}^{\sin(\phi_h+\phi_S)}$$

$$+\sqrt{2\varepsilon(1+\varepsilon)}\sin\phi_S F_{UT}^{\sin\phi_S} + \varepsilon\sin(3\phi_h-\phi_S)F_{UT}^{\sin(3\phi_h-\phi_S)}$$

$$+\sqrt{2\varepsilon(1+\varepsilon)}\sin(2\phi_h-\phi_S)F_{UT,L}^{\sin(2\phi_h-\phi_S)}\Big]\Big\}$$



$$F_{...} = F_{...}(x, y, z, P_{h\perp})$$

Leading twist expansion

FF

$$F_{UU,T} \propto \mathcal{C}\left[f_1 D_1\right]$$

DF

Leading twist expansion

Distribution Functions (DF)			
N / q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	$h_1, h_{1T}^\perp$

Fragmentation Functions (FF)	
q/h	U
U	D_1
T	$H_1^\perp$

FF

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Leading twist expansion

Distribution Functions (DF)			
N / q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	$h_1, h_{1T}^\perp$

Fragmentation Functions (FF)	
q/h	U
U	D_1
T	$H_1^\perp$

$h_1^\perp$ = **Boer-Mulders function**

CHIRAL-ODD

$$C\left[h_1^\perp H_1^\perp\right]$$

chiral-odd DF | **chiral-odd FF**

CHIRAL-EVEN!

Unpolarized Semi-Inclusive DIS

<u>**leading twist**</u>

$$F_{UU}^{\cos 2\phi_h} \propto C\left[-\frac{2(\hat{P}_{h\perp}\cdot\vec{k}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)-\vec{k}_T\cdot\vec{p}_T}{MM_h} h_1^{\perp} H_1^{\perp}\right]$$

BOER-MULDERS EFFECT

(Implicit sum over quark flavours)

Unpolarized Semi-Inclusive DIS

BOER-MULDERS EFFECT

leading twist

$$F_{UU}^{\cos 2\phi_h} \propto C\left[-\frac{2(\hat{P}_{h\perp}\cdot\vec{k}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)-\vec{k}_T\cdot\vec{p}_T}{MM_h}h_1^{\perp}H_1^{\perp}\right]$$

CAHN EFFECT

next to leading twist

$$F_{UU}^{\cos\phi_h} \propto \frac{2M}{Q}C\left[-\frac{\hat{P}_{h\perp}\cdot\vec{p}_T}{M_h}x\,h_1^{\perp}H_1^{\perp}-\frac{\hat{P}_{h\perp}\cdot\vec{k}_T}{M}x\,f_1D_1+\ldots\right]$$

Interaction dependent terms neglected

(Implicit sum over quark flavours)

Experimental extraction

$$A = 2\langle \cos\phi_h \rangle$$

$$B = 2\langle \cos 2\phi_h \rangle$$

$$n^{EXP} = \int \sigma_0(w)\ [1 + A(w)\cos\phi_h + B(w)\cos 2\phi_h]\ \varepsilon_{acc}(w,\phi_h)\varepsilon_{RAD}(w,\phi_h)\ L\ dw$$

$$w = (x, y, z, P_{h\perp})$$

Experimental extraction

$A = 2\langle \cos \phi_h \rangle$

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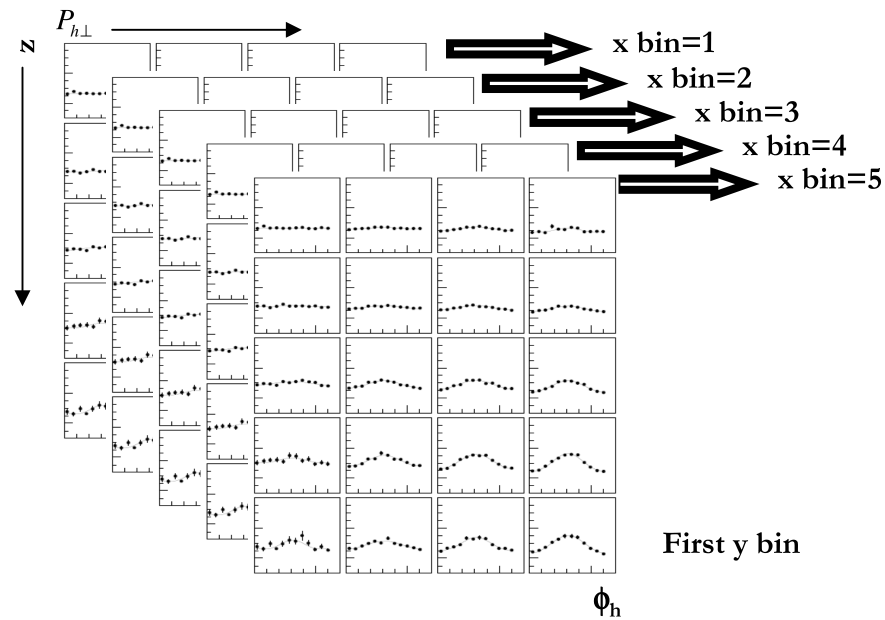
$$n^{EXP} = \int \sigma_0(w) \, [1 + A(w)\cos\phi_h + B(w)\cos 2\phi_h] \, \varepsilon_{acc}(w,\phi_h)\varepsilon_{RAD}(w,\phi_h) \; L \, dw$$

$$w = (x, y, z, P_{h\perp})$$

Multidimensional (W)



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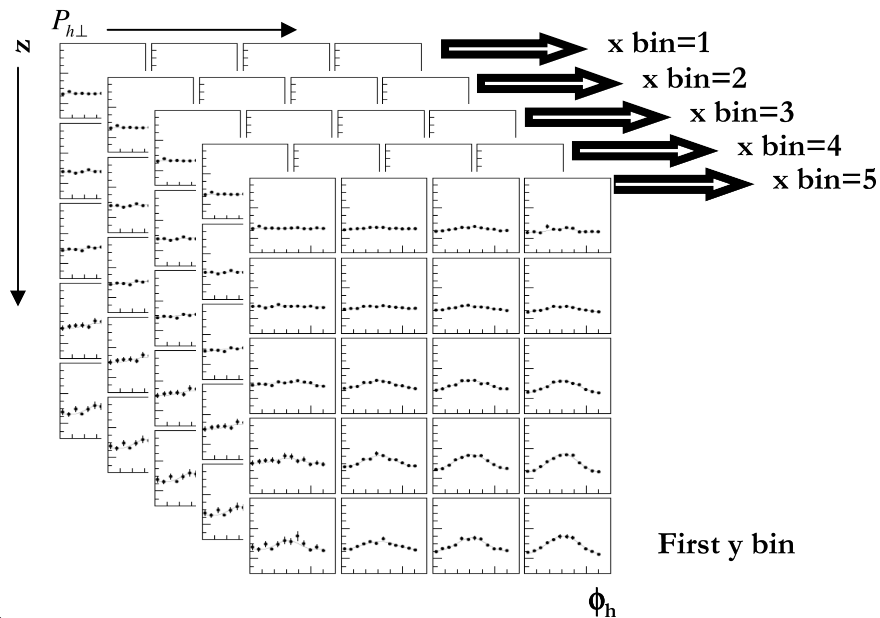
$$w = (x, y, z, P_{h\perp})$$

Multidimensional (w) unfolding procedure



$$n^{EXP} = S\ \ n_{BORN} + n_{Bg}$$

Probability that an event generated with kinematics w is measured with kinematics w'

Includes the events smeared into the acceptance

Experimental extraction

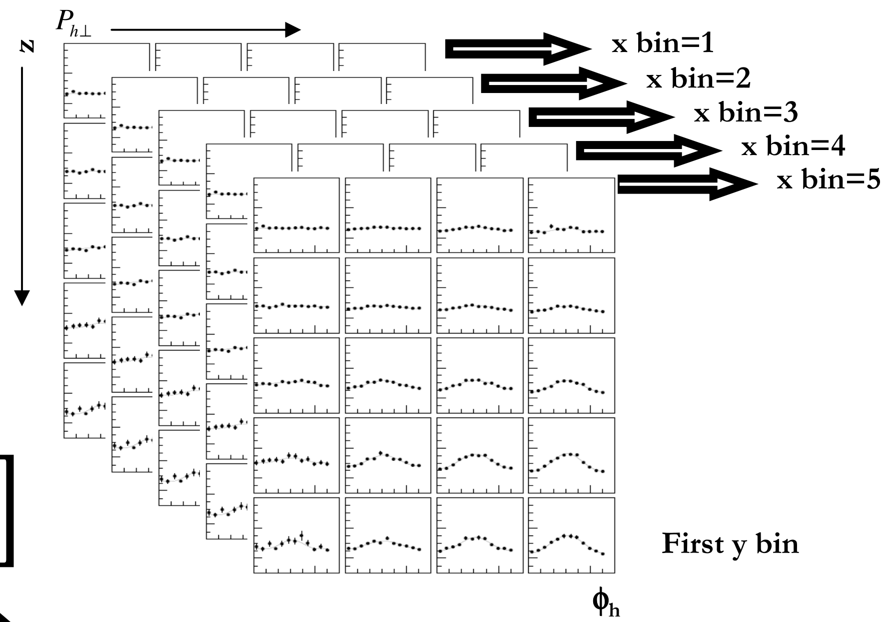
$$A = 2\langle \cos \phi_h \rangle$$

$$B = 2\langle \cos 2\phi_h \rangle$$

$$n^{EXP} = \int \sigma_0(w)\ [1 + A(w)\cos\phi_h + B(w)\cos 2\phi_h]\ \varepsilon_{acc}(w,\phi_h)\varepsilon_{RAD}(w,\phi_h)\ L\ dw$$

$$w = (x, y, z, P_{h\perp})$$

Multidimensional (w) unfolding procedure



$$n_{BORN} = S^{-1}\left[n_{EXP} - n_{Bg}\right]$$

Probability that an event generated with kinematics w is measured with kinematics w'

Includes the events smeared into the acceptance

Experimental extraction

$$A = 2\langle \cos\phi_h \rangle$$

$$B = 2\langle \cos 2\phi_h \rangle$$

$$n^{EXP} = \int \sigma_0(w)\ [1 + A(w)\cos\phi_h + B(w)\cos 2\phi_h]\ \varepsilon_{acc}(w,\phi_h)\varepsilon_{RAD}(w,\phi_h)\ L\, dw$$

$$w = (x, y, z, P_{h\perp})$$

BINNING 400 kinematical bins x 12 ϕ_η-bins							
Variabl e	Bin limits						#
x	0.023	0.042	0.078	0.145	0.27	1	5
y	0.3	0.45	0.6	0.7	0.85		4
z	0.2	0.3	0.45	0.6	0.75	1	5
$P_{h\perp}$	0.05	0.2	0.35	0.5	0.75		4

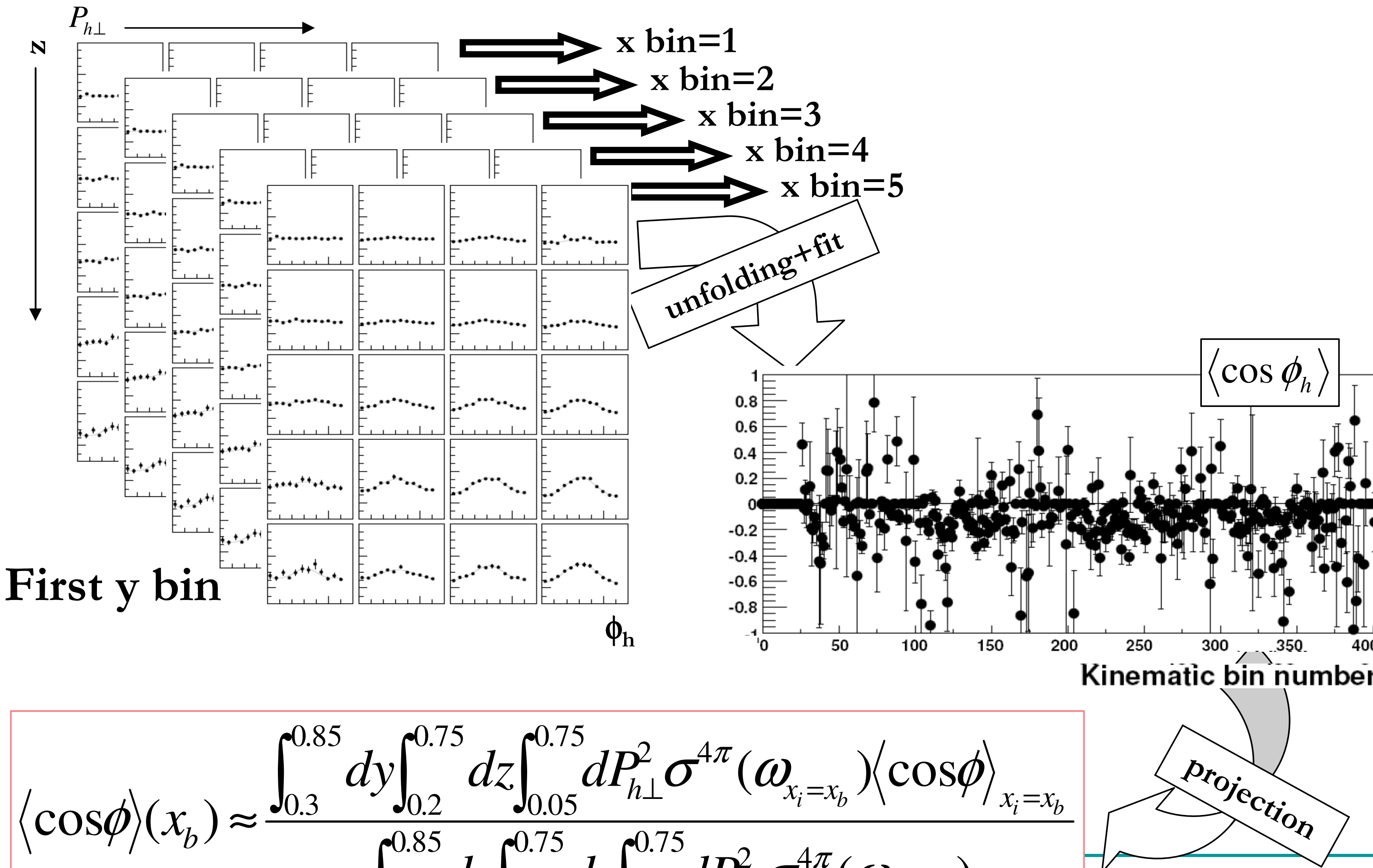
Multidimensional (w) unfolding procedure

$$n_{BORN} = S^{-1}\left[n_{EXP} - n_{Bg}\right]$$

Probability that an event generated with kinematics w is measured with kinematics w'

Includes the events smeared into the acceptance

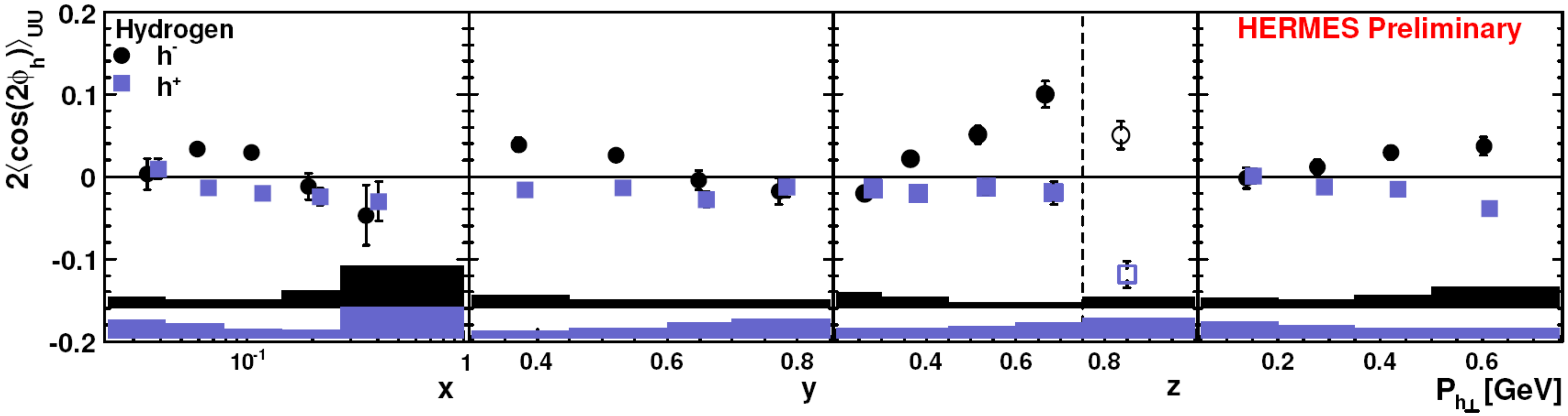
The multi-dimensional analysis



$$\langle\cos\phi\rangle(x_b) \approx \frac{\int_{0.3}^{0.85} dy \int_{0.2}^{0.75} dz \int_{0.05}^{0.75} dP_{h\perp}^2 \, \sigma^{4\pi}(\omega_{x_i=x_b}) \langle\cos\phi\rangle_{x_i=x_b}}{\int_{0.3}^{0.85} dy \int_{0.2}^{0.75} dz \int_{0.05}^{0.75} dP_{h\perp}^2 \, \sigma^{4\pi}(\omega_{x_i=x_b})}$$

Hydrogen data: cos2ϕ_h

$$F_{UU}^{\cos 2\phi_h} \propto C\left[-h_1^{\perp} H_1^{\perp}\right]$$



$$H_1^{\perp,u\to\pi^-} \approx -H_1^{\perp,u\to\pi^+}$$

Hydrogen data: cos2ϕ_h

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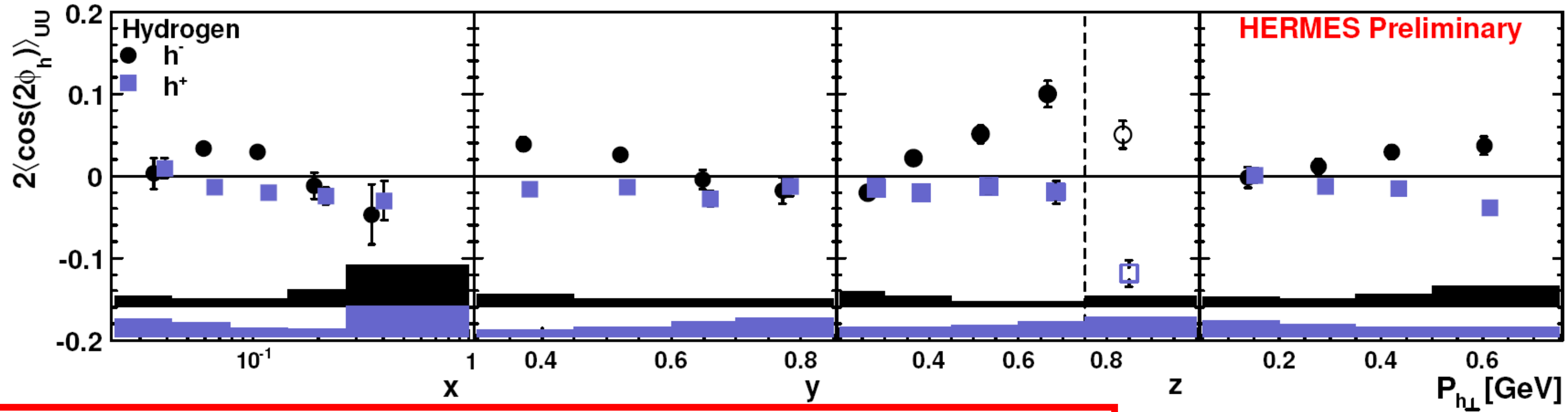
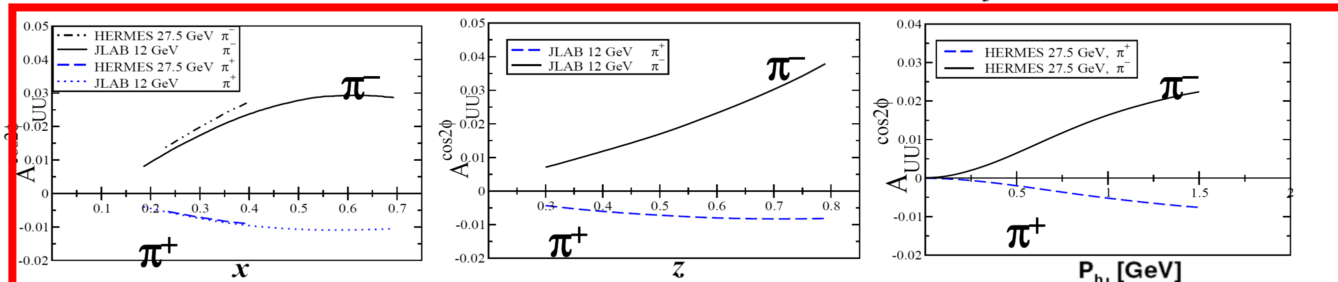
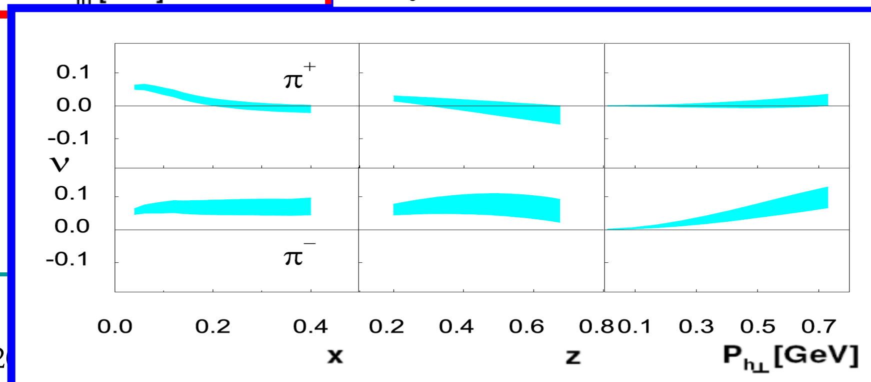




B. Zhang et al.,
Phys. Rev. D78:034035, 2008

L. P. Gamberg and G. R. Goldstein,
Phys. Rev. D77:094016, 2008



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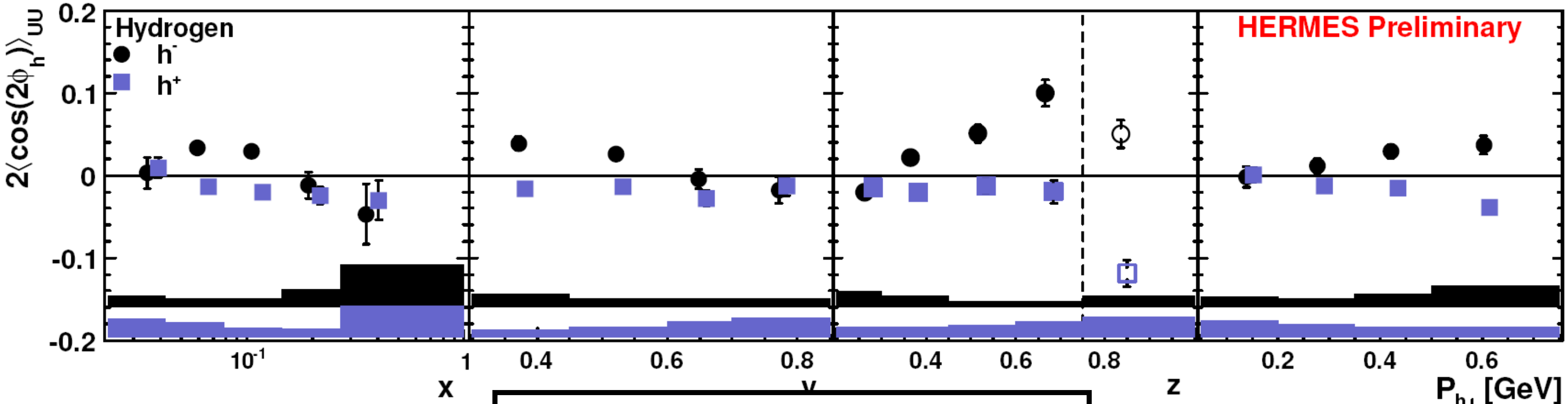
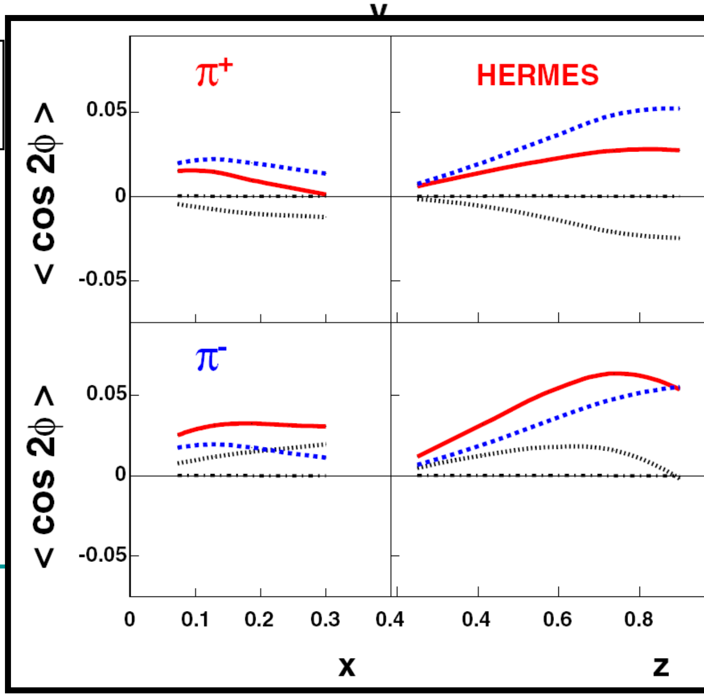
$$F_{UU}^{\cos 2\phi_h} \propto C\left[-h_1^{\perp} H_1^{\perp}\right]$$



V. Barone et al.
Phys.Rev. D78:045022, 2008



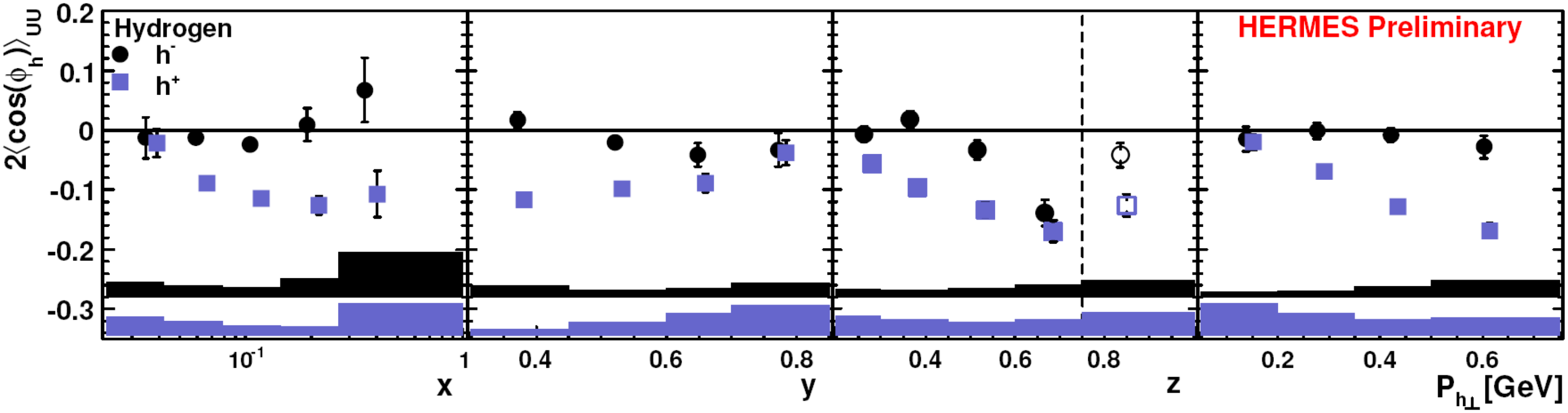
All contributions

Boer-Mulders

Cahn (twist 4)

Hydrogen data: cosϕ_h

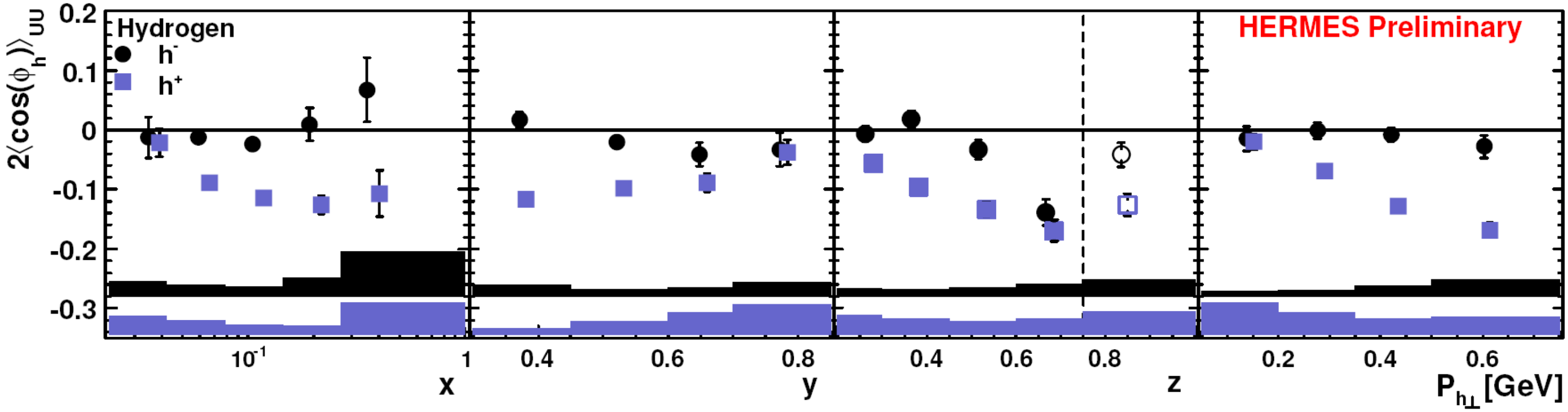
$$F_{UU}^{\cos\phi_h} = \frac{2M}{Q} C\left[-\frac{\hat{P}_{h\perp}\cdot\vec{p}_T}{M_h} x\, h_1^{\perp} H_1^{\perp} - \frac{\hat{P}_{h\perp}\cdot\vec{k}_T}{M} x\, f_1 D_1 + \ldots \right]$$

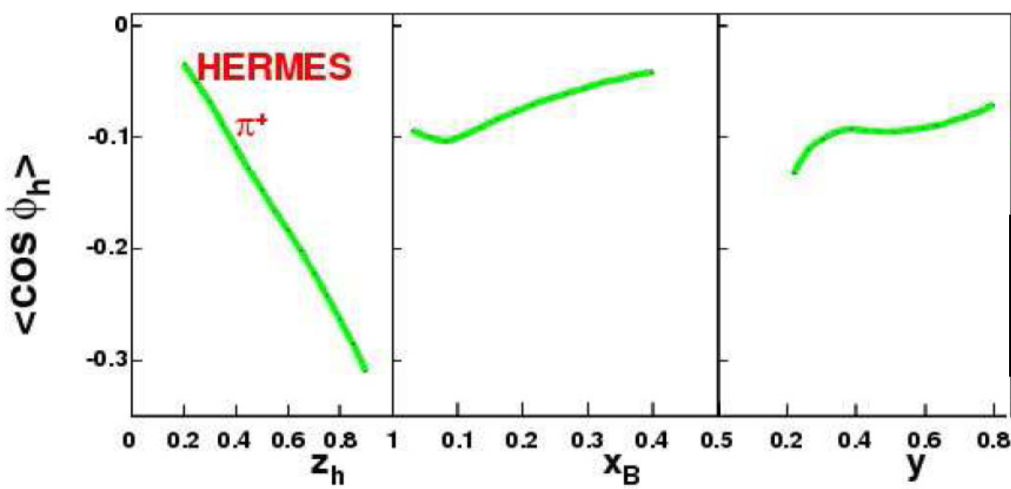


$$H_1^{\perp,u\to\pi^-} \approx -H_1^{\perp,u\to\pi^+}$$

Hydrogen data: $\cos\phi_h$

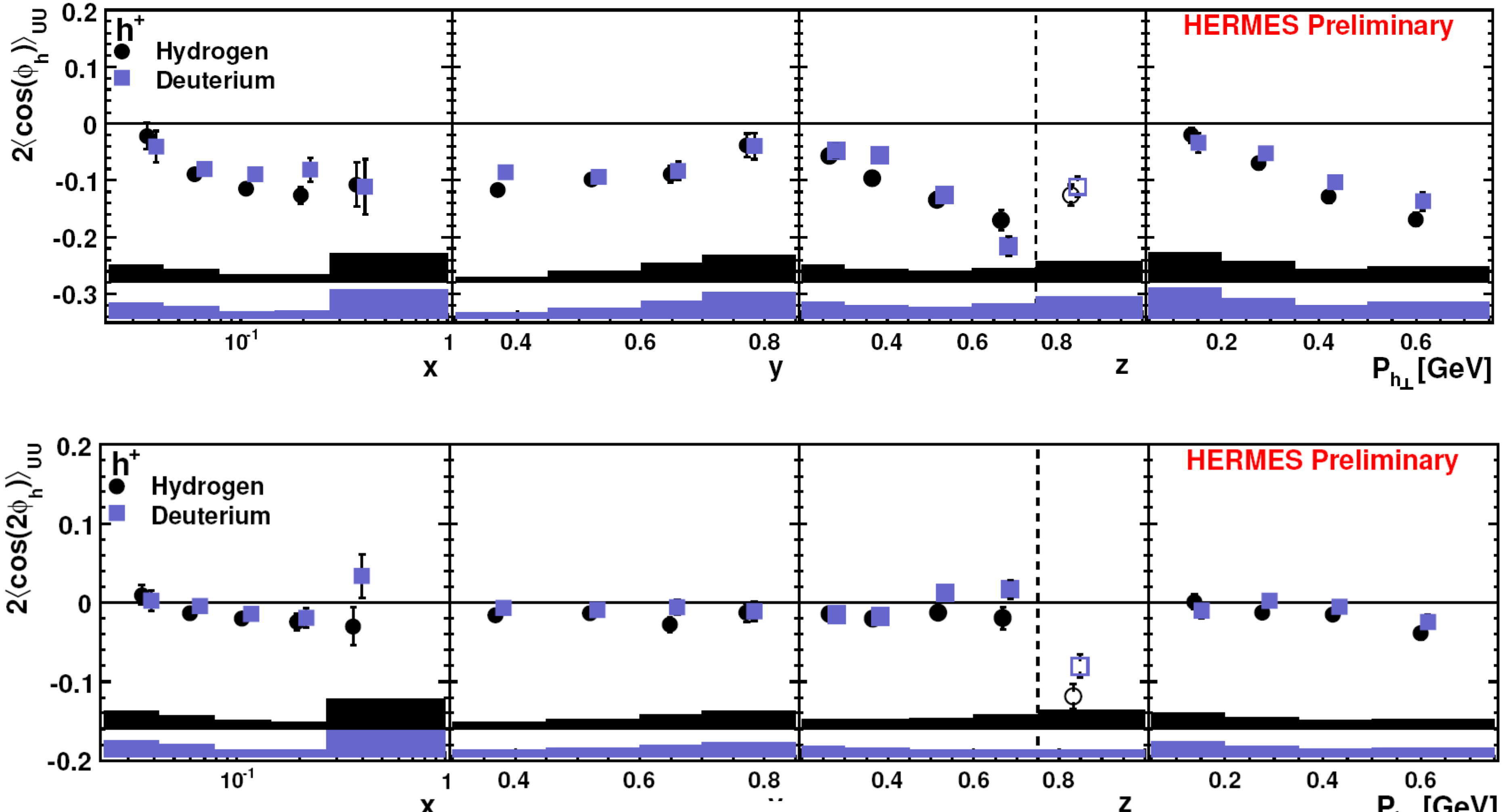
$$F_{UU}^{\cos\phi_h} = \frac{2M}{Q} C\left[-\frac{\hat{P}_{h\perp}\cdot\vec{p}_T}{M_h}\, x\, h_1^{\perp} H_1^{\perp} - \frac{\hat{P}_{h\perp}\cdot\vec{k}_T}{M}\, x\, f_1 D_1 + \ldots \right]$$





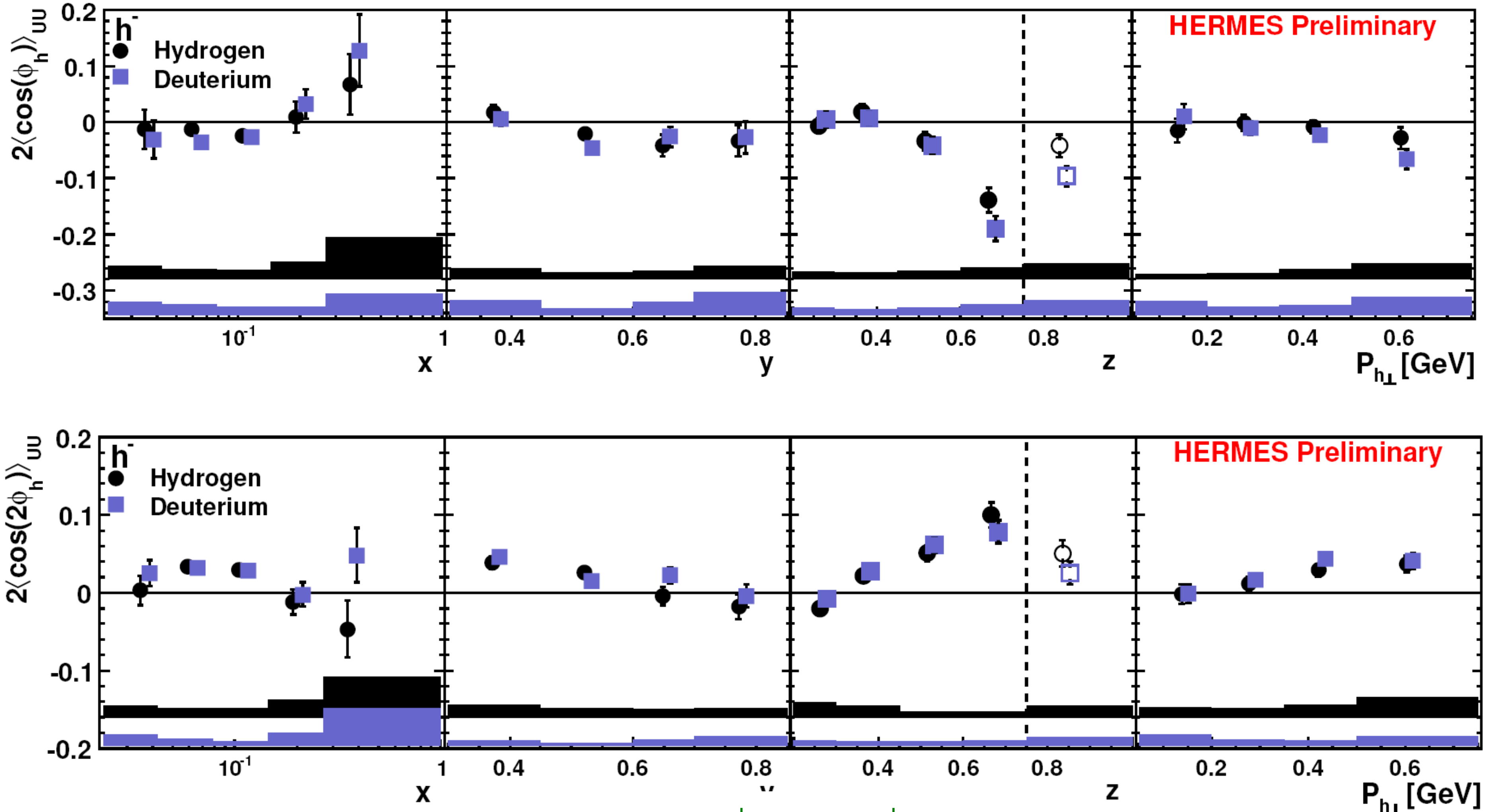
M. Anselmino et al.,
Phys. Rev. D71:074006, 2005
Eur. Phys. J. A31:373, 2007

Hydrogen vs. Deuterium data h^+



$h_{1,u}^{\perp} \approx h_{1,d}^{\perp}$

Hydrogen vs. Deuterium data h^-



$$h_{1,u}^{\perp} \approx h_{1,d}^{\perp}$$

Semi-Inclusive DIS cross section

$$\frac{d^5\sigma}{dx\ dy\ dz\ d\phi_h dP_{h\perp}^2} = \frac{\alpha^2}{xyQ^2}\left(\frac{y^2}{2(1-\varepsilon)}\right)\left(1+\frac{\gamma^2}{2x}\right)\Big\{ F_{UU,T} + \varepsilon\ F_{UU,L}$$

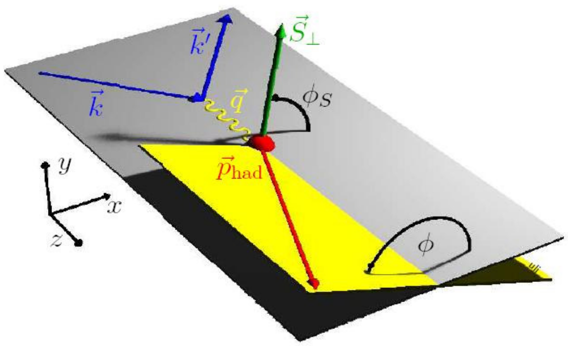
$$+\sqrt{2\varepsilon(1+\varepsilon)}\cos\phi_h F_{UU}^{\cos\phi_h} + \varepsilon\cos 2\phi_h\ \ F_{UU}^{\cos 2\phi_h}$$

$$+\left|S_T\right|\ \Big[\ \sin(\phi_h-\phi_S)\left(F_{UT,T}^{\sin(\phi_h-\phi_S)} + \varepsilon\ F_{UT,L}^{\sin(\phi_h-\phi_S)}\right)$$

$$+\varepsilon\sin(\phi_h+\phi_S) F_{UT}^{\sin(\phi_h+\phi_S)}$$

$$+\ \sqrt{2\varepsilon(1+\varepsilon)}\sin\phi_S F_{UT}^{\sin\phi_S} + \varepsilon\sin(3\phi_h-\phi_S) F_{UT}^{\sin(3\phi_h-\phi_S)}$$

$$+\sqrt{2\varepsilon(1+\varepsilon)}\sin(2\phi_h-\phi_S) F_{UT,L}^{\sin(2\phi_h-\phi_S)}\Big]\Big\}$$



$$F_{...} = F_{...}(x, y, z, P_{h\perp})$$

Leading twist expansion

Distribution Functions (DF)			
N / q	U	L	T
U	f_1		$h_1^{\perp}$
L		g_1	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	$h_1, h_{1T}^{\perp}$

Fragmentation Functions (FF)	
q/h	U
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h_1 = **Transversity function**

Fragmentation Functions (FF)	
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Leading twist expansion

Distribution Functions (DF)			
N / q	U	L	T
U	f_1		$h_1^{\perp}$
L		g_1	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	$h_1, h_{1T}^{\perp}$

h_1 = Transversity function

integrated over $P_{h_\perp}$

Distribution Functions (DF)			
N / q	U	L	T
U	f_1		
L		g_1	
T			h_1

Fragmentation Functions (FF)	
q/h	U
U	D_1
T	$H_1^{\perp}$

Leading twist expansion

Distribution Functions (DF)			
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Fragmentation Functions (FF)	
q/h	U
U	D_1
T	$H_1^{\perp}$

h_1 = **Transversity function**

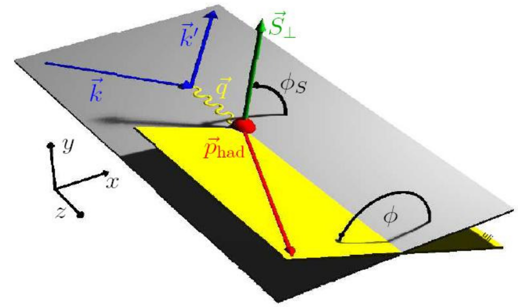
$$C\left[h_1 H_1^{\perp}\right]$$

chiral-odd DF | **chiral-odd FF**

CHIRAL-EVEN!

Semi Inclusive DIS on transversely polarized target

$$A_{UT}^{h} = \frac{\sigma_h^{\Downarrow} - \sigma_h^{\Uparrow}}{\sigma_h^{\Downarrow} + \sigma_h^{\Uparrow}}$$

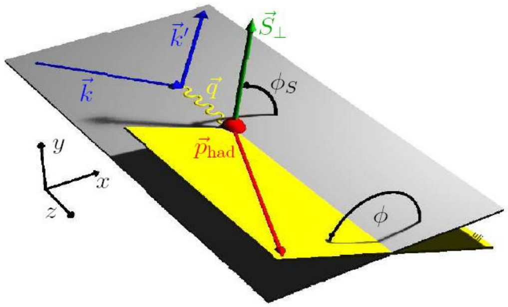


$$A_{UT}^{h} \propto \frac{2|S_T|}{e^2[f_1 D_1]} \left\{ \sin(\phi_h + \phi_S) e^2 C \left[\frac{(\vec{k}_T \cdot \hat{P}_{h\perp})}{M_h} h_1 H_1^{\perp} \right] \right.$$

Collins effect

Semi Inclusive DIS on transversely polarized target

$$A_{UT}^{h} = \frac{\sigma_h^{\Downarrow} - \sigma_h^{\Uparrow}}{\sigma_h^{\Downarrow} + \sigma_h^{\Uparrow}}$$



$$A_{UT}^{h} \propto \frac{2|S_T|}{e^2[f_1 D_1]} \left\{ \sin(\phi_h + \phi_S) e^2 C \left[\frac{(\vec{k}_T \cdot \hat{P}_{h\perp})}{M_h} h_1 H_1^{\perp} \right] + \sin(\phi_h - \phi_S) e^2 C \left[\frac{(\vec{p}_T \cdot \hat{P}_{h\perp})}{M} f_{1T}^{\perp} D_1 \right] \right.$$

Collins effect

Sivers effect

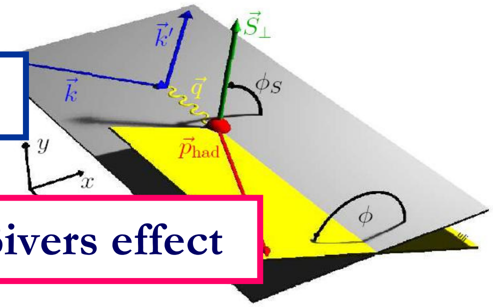
Leading twist expansion

Distribution Functions (DF)			
N / q	U	L	T
U	f_1		$h_1^{\perp}$
L		g_1	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	$h_1, h_{1T}^{\perp}$

a non-zero Sivers function requires a **non-vanishing quark orbital angular momentum** inside the nucleon

The Sivers function: describes the correlations between the transverse polarization of the nucleon and the transverse momentum of the struck quark
→ **spin-orbit structure** of the nucleon

Semi Inclusive DIS on transversely polarized target



$$A_{UT}^h \propto \frac{2|S_T|}{e^2[f_1 D_1]}\Bigg\{ \sin(\phi_h+\phi_S)\, e^2 C\left[\frac{(\vec{k}_T\cdot\hat{P}_{h\perp})}{M_h} h_1 H_1^\perp\right]$$

Collins effect

$$+\sin(\phi_h-\phi_S)\, e^2 C\left[\frac{(\vec{p}_T\cdot\hat{P}_{h\perp})}{M} f_{1T}^\perp D_1\right]$$

Sivers effect

$$+\sin(3\phi_h-\phi_S)\, e^2 C\left[\frac{2(\hat{P}_{h\perp}\cdot\vec{k}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)-p_T^2(\hat{P}_{h\perp}\cdot\vec{k}_T)-4(\hat{P}_{h\perp}\cdot\vec{k}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)^2}{2M^2M_h} h_{1T}^\perp H_1^\perp\right]$$

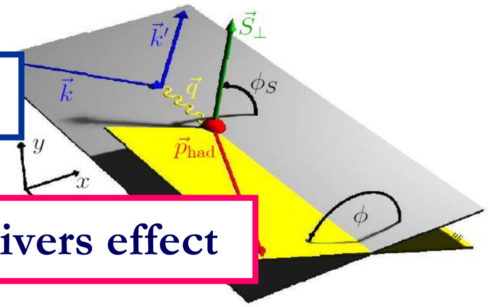
$$+\sin(2\phi_h+\phi_S)\, e^2 C\left[-\frac{2(\hat{P}_{h\perp}\cdot\vec{k}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)-\vec{p}_T\cdot\vec{k}_T}{MM_h} h_{1L}^\perp H_1^\perp\right]$$

Leading-Twist

Semi Inclusive DIS on transversely polarized target

$$A_{UT}^{h} \propto \frac{2|S_T|}{e^2[f_1 D_1]}\Big\{\sin(\phi_h+\phi_S)\, e^2 C\left[\frac{(\vec{k}_T\cdot\hat{P}_{h\perp})}{M_h} h_1 H_1^{\perp}\right]$$

Collins effect



$$+\sin(\phi_h-\phi_S)\, e^2 C\left[\frac{(\vec{p}_T\cdot\hat{P}_{h\perp})}{M} f_{1T}^{\perp} D_1\right]$$

Sivers effect

$$+\sin(3\phi_h-\phi_S)\, e^2 C\left[\frac{2(\hat{P}_{h\perp}\cdot\vec{k}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)-p_T^2(\hat{P}_{h\perp}\cdot\vec{k}_T)-4(\hat{P}_{h\perp}\cdot\vec{k}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)^2}{2M^2 M_h} h_{1T}^{\perp} H_1^{\perp}\right]$$

$$+\sin(2\phi_h+\phi_S)\, e^2 C\left[-\frac{2(\hat{P}_{h\perp}\cdot\vec{k}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)-\vec{p}_T\cdot\vec{k}_T}{M M_h} h_{1L}^{\perp} H_1^{\perp}\right]\Big\}$$

Leading-Tw

Pretzelosity

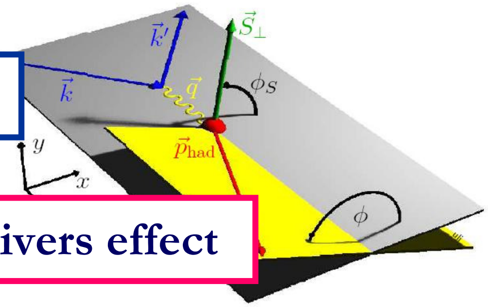
→ **directly related to quark orbital angular momentum**

→ **measures the deviation of nucleon shape from sphere**

Semi Inclusive DIS on transversely polarized target

$$A_{UT}^{h} \propto \frac{2|S_T|}{e^2[f_1 D_1]}\Bigg\{\sin(\phi_h+\phi_S)\, e^2 C\left[\frac{(\vec{k}_T\cdot\hat{P}_{h\perp})}{M_h} h_1 H_1^{\perp}\right]$$

Collins effect



$$+\sin(\phi_h-\phi_S)\, e^2 C\left[\frac{(\vec{p}_T\cdot\hat{P}_{h\perp})}{M} f_{1T}^{\perp} D_1\right]$$

Sivers effect

$$+\sin(3\phi_h-\phi_S)\, e^2 C\left[\frac{2(\hat{P}_{h\perp}\cdot\vec{k}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)-p_T^2(\hat{P}_{h\perp}\cdot\vec{k}_T)-4(\hat{P}_{h\perp}\cdot\vec{k}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)^2}{2M^2M_h} h_{1T}^{\perp} H_1^{\perp}\right]$$

$$+\sin(2\phi_h+\phi_S)\, e^2 C\left[-\frac{2(\hat{P}_{h\perp}\cdot\vec{k}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)-\vec{p}_T\cdot\vec{k}_T}{MM_h} h_{1L}^{\perp} H_1^{\perp}\right]$$

Leading-Twist

$$+\sin(2\phi_h-\phi_S)\, e^2 \frac{2M}{Q} C\Bigg\{\frac{2(\vec{p}_T\cdot\hat{P}_{h\perp})^2-p_T^2}{2M^2}\left(x f_T^{\perp} D_1-\frac{M_h}{Mz} h_{1T}^{\perp}\tilde{H}\right)-$$

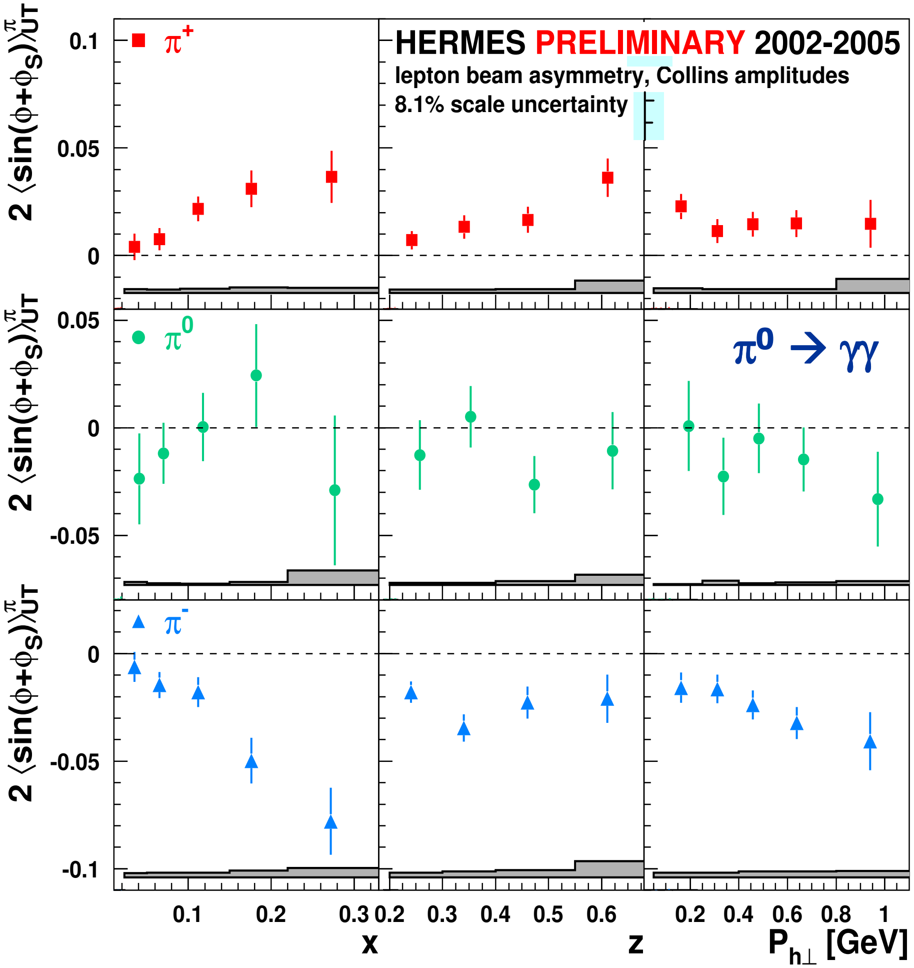
Twist-3

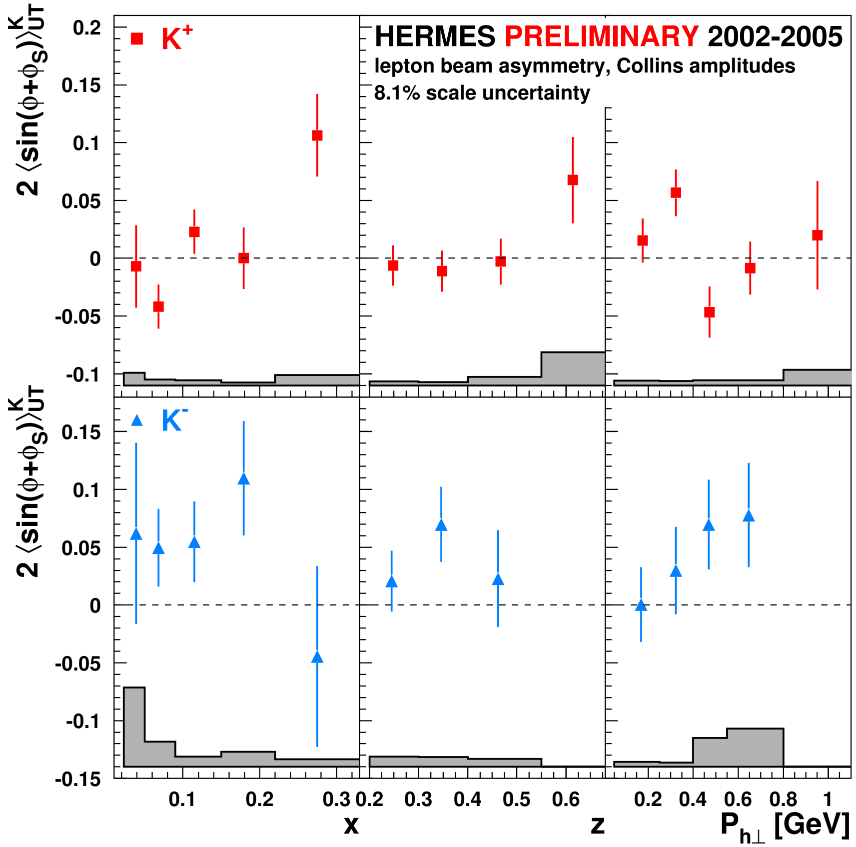
$$\frac{2(\vec{p}_T\cdot\hat{P}_{h\perp})(\vec{k}_T\cdot\hat{P}_{h\perp})-\vec{p}_T\cdot\vec{k}_T}{2MM_h}\left[\left(x h_T + x h_T^{\perp}\right)H_1^{\perp}-\frac{M_h}{Mz}\left(f_{1T}^{\perp}\tilde{D}^{\perp}-g_{1T}\tilde{G}^{\perp}\right)\right]\Bigg\}$$

$$+\sin\phi_S\, e^2 \frac{2M}{Q} C\Bigg\{x f_T D_1-\frac{M_h}{Mz} h_1 \tilde{H}-\frac{\vec{p}_T\cdot\vec{k}_T}{2MM_h}\left[\left(x h_T + x h_T^{\perp}\right)H_1^{\perp}+\frac{M_h}{Mz}\left(f_{1T}^{\perp}\tilde{D}^{\perp}-g_{1T}\tilde{G}^{\perp}\right)\right]\Bigg\}\Bigg\}$$

Collins amplitudes

$$\propto C\left[h_1 H_1^{\perp}\right]$$

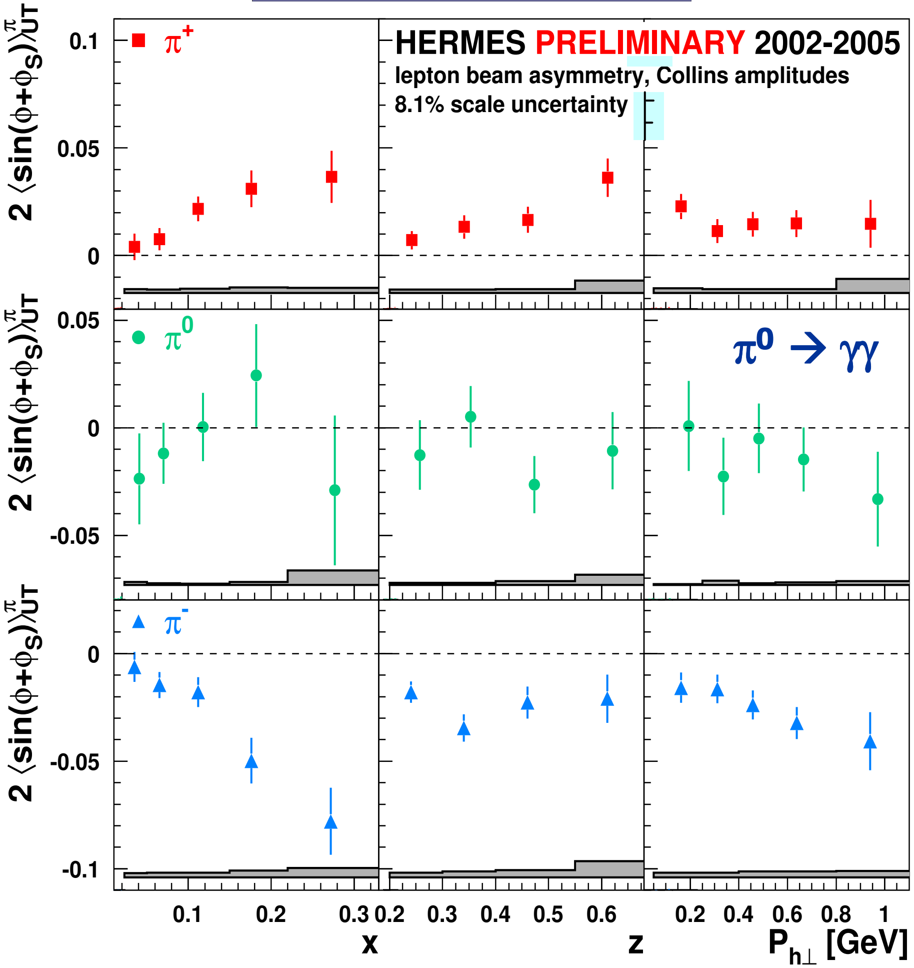


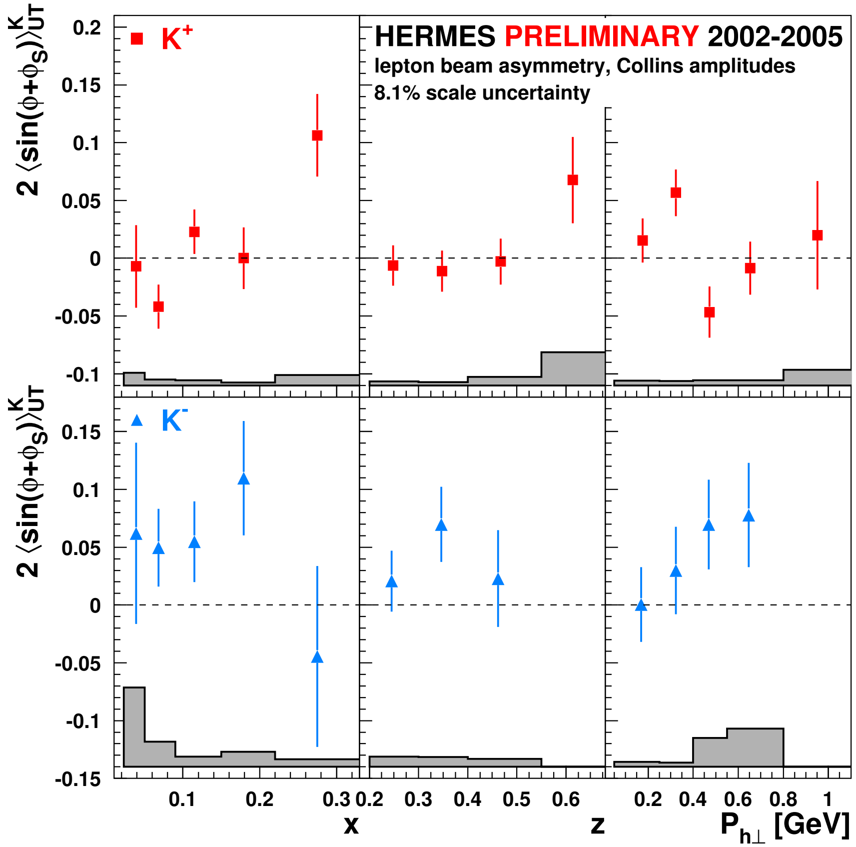


Collins amplitudes

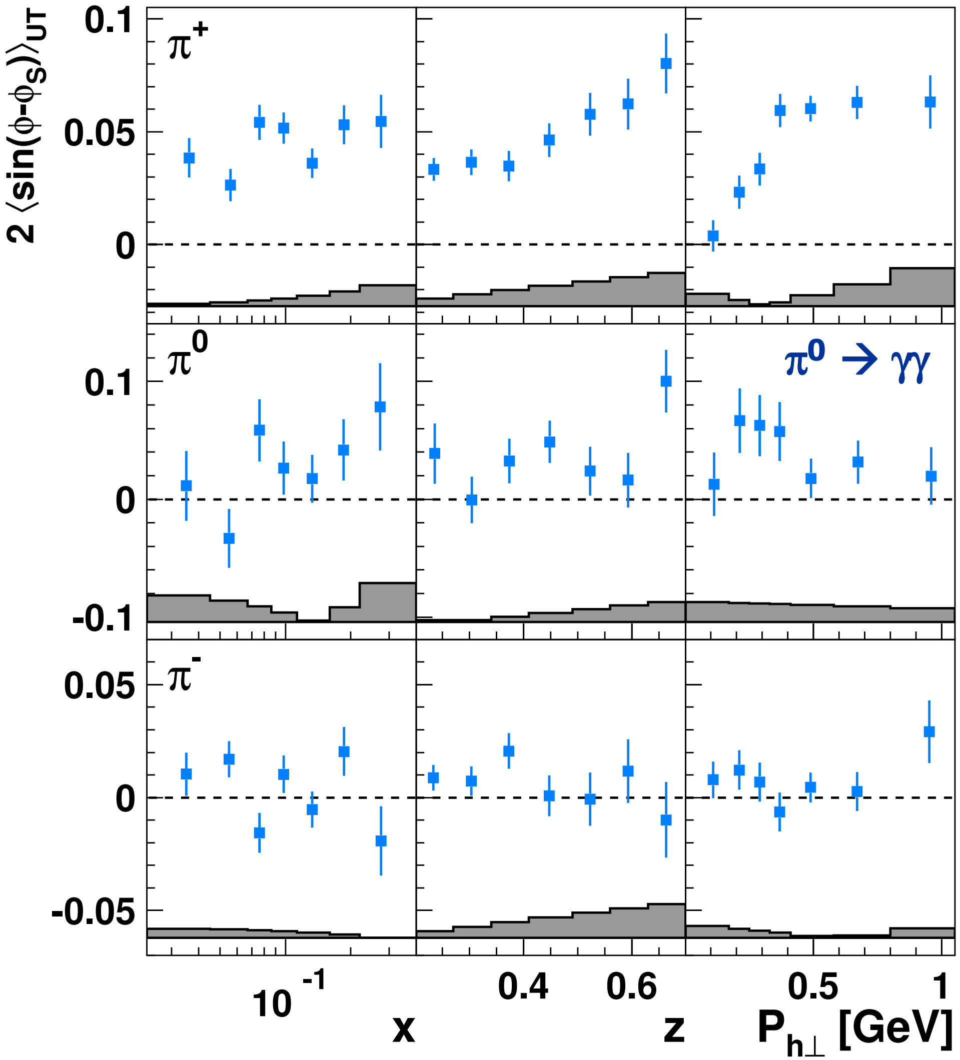
$$H_1^{\perp,unfav} \approx -H_1^{\perp,fav}$$

$$\propto C\left[h_1 H_1^{\perp}\right]$$





Sivers amplitudes for pions



$$\propto C\left[f_{1T}^{\perp} D_1\right]$$

- → Large positive for π^+
- → Consistent with zero for π^-
- → Slightly positive for π^0

Final results:

A. Airapetian et al., arXiv:0906.3918

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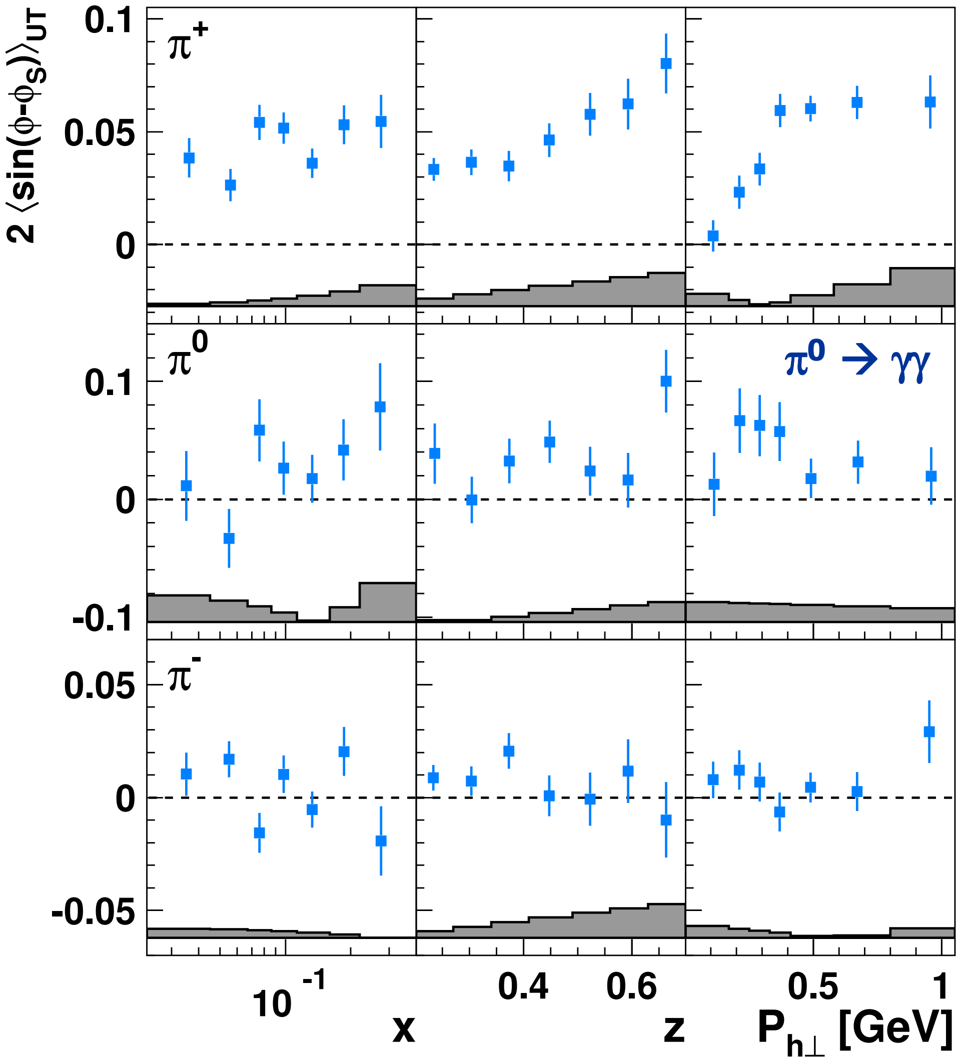
$$\propto C\left[f_{1T}^{\perp} D_1\right]$$



- → Large positive for π^+
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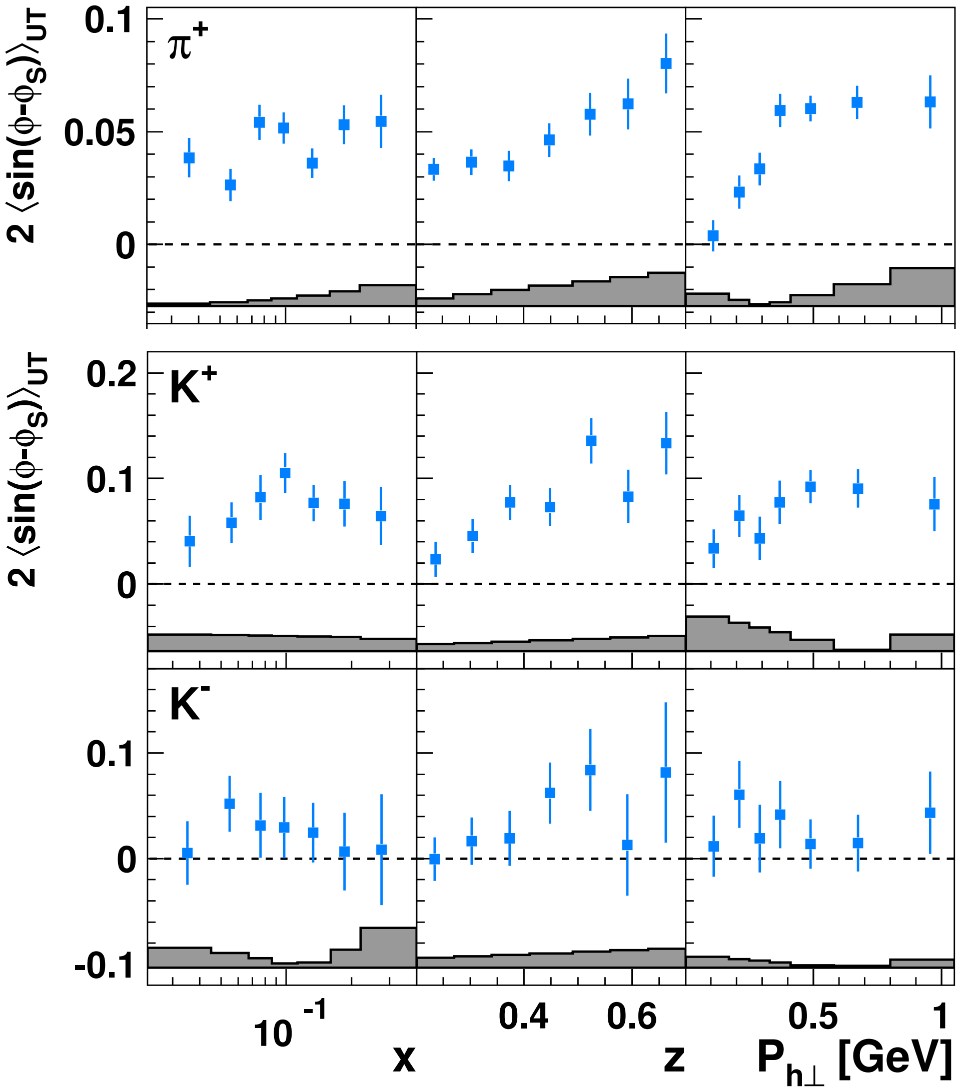
Non zero quark orbital angular momentum !

Final results:

A. Airapetian et al., arXiv:0906.3918

Sivers amplitudes for charged kaons



$$\propto C\left[f_{1T}^{\perp} D_1\right]$$

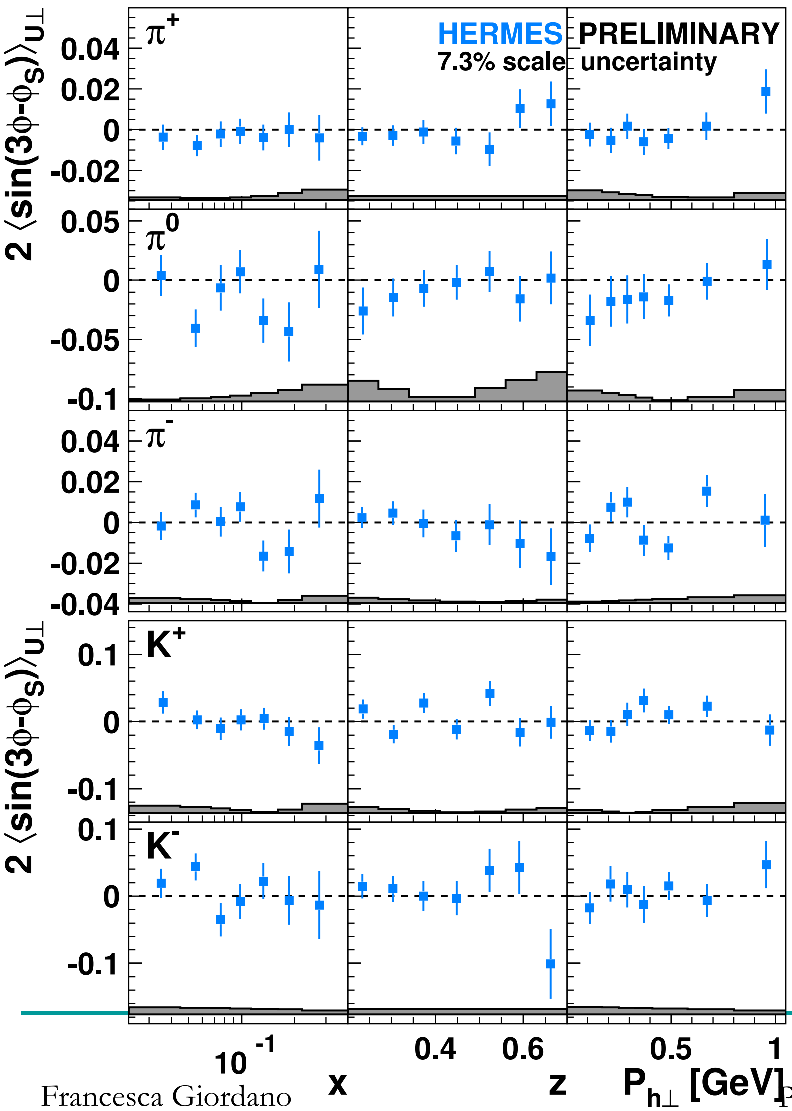
- → **Large positive for K^+**
- → **Consistent with zero for K^-**

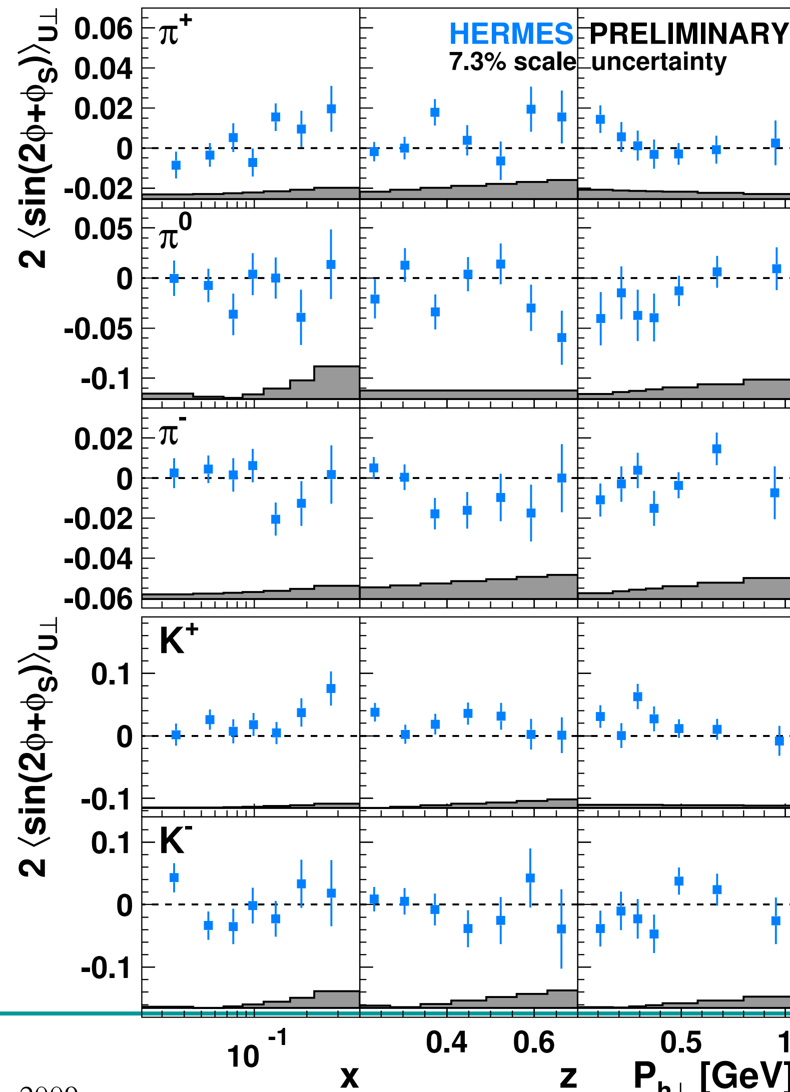
Final results:

A. Airapetian et al., arXiv:0906.3918

Additional Twist-2 contributions:

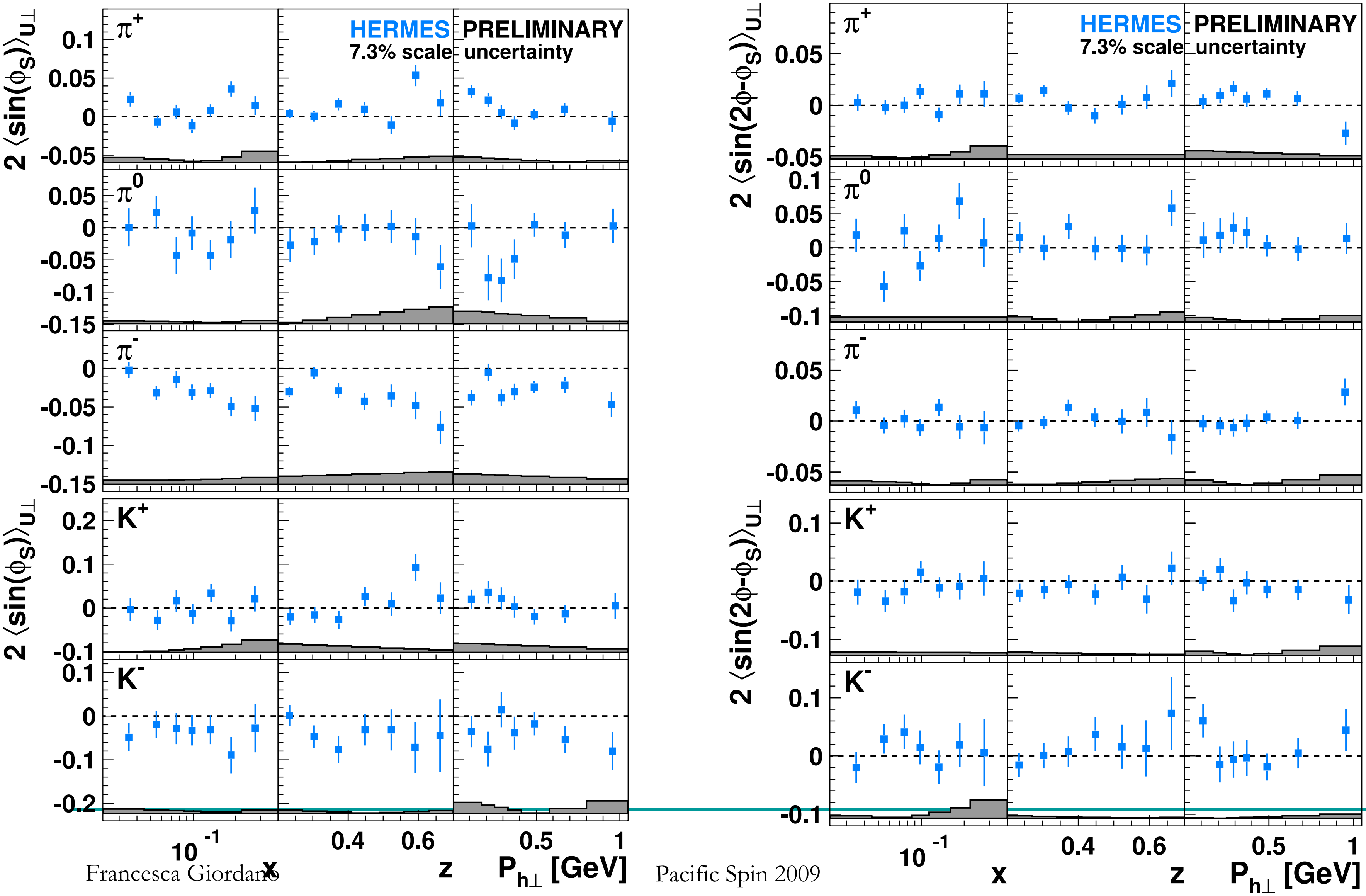
$\sin(3\phi_h - \phi_S) \quad \propto C\left[h_{1T}^{\perp} H_1^{\perp}\right]$ $\qquad$ $\sin(2\phi_h + \phi_S) \quad \propto C\left[h_{1L}^{\perp} H_1^{\perp}\right]$





Additional Twist-3 contributions:

$\sin\phi_S$ $\sin(2\phi_h-\phi_S)$



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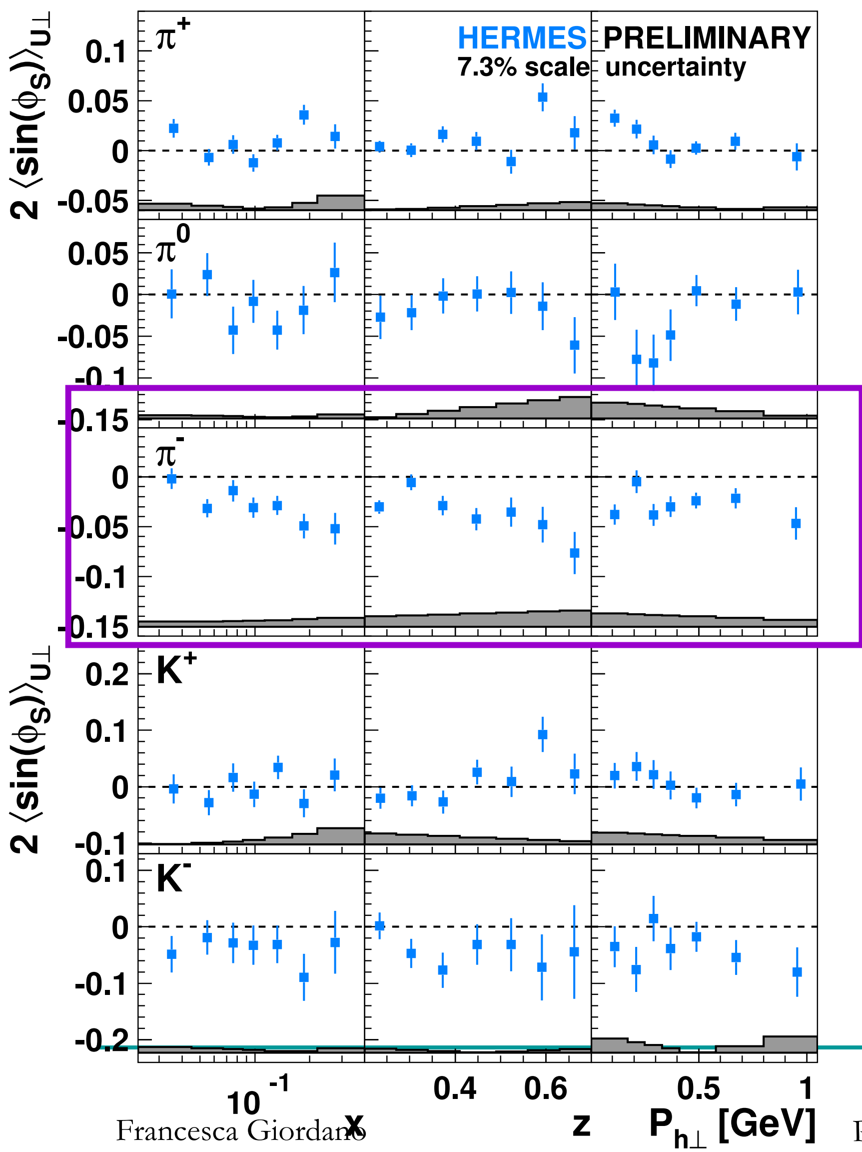
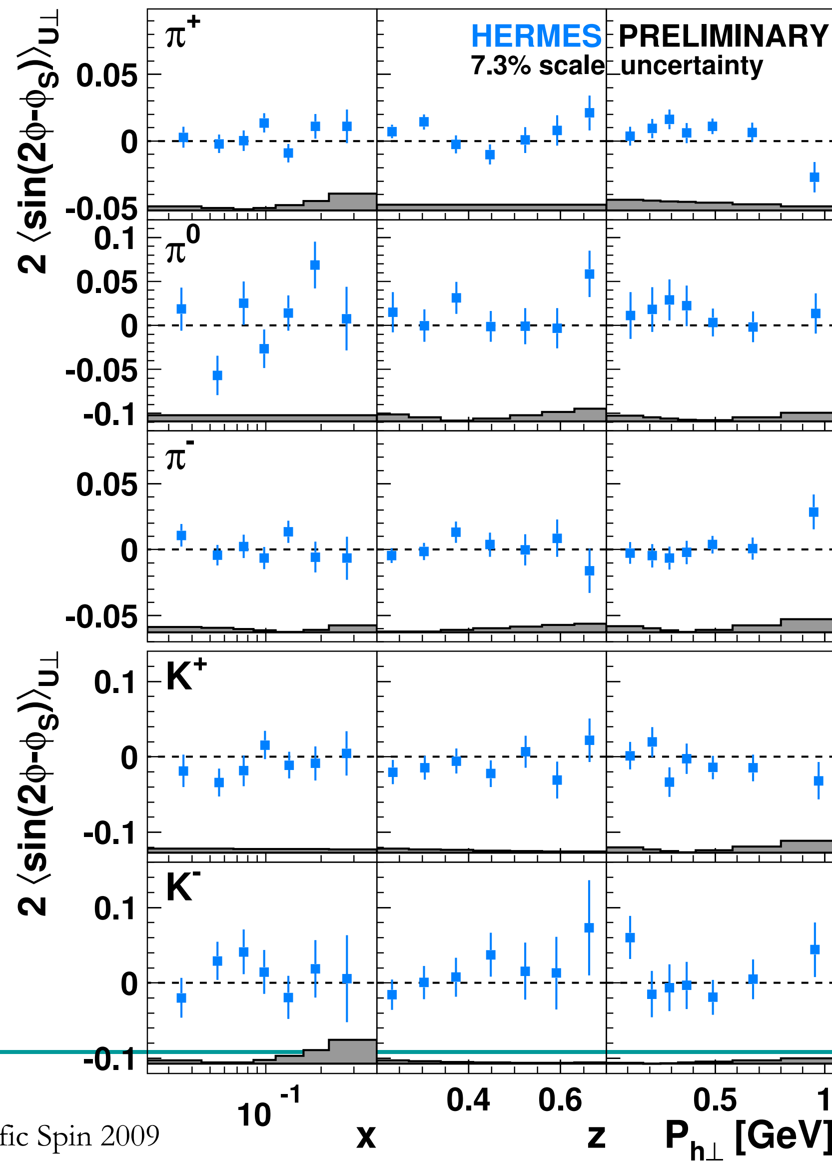
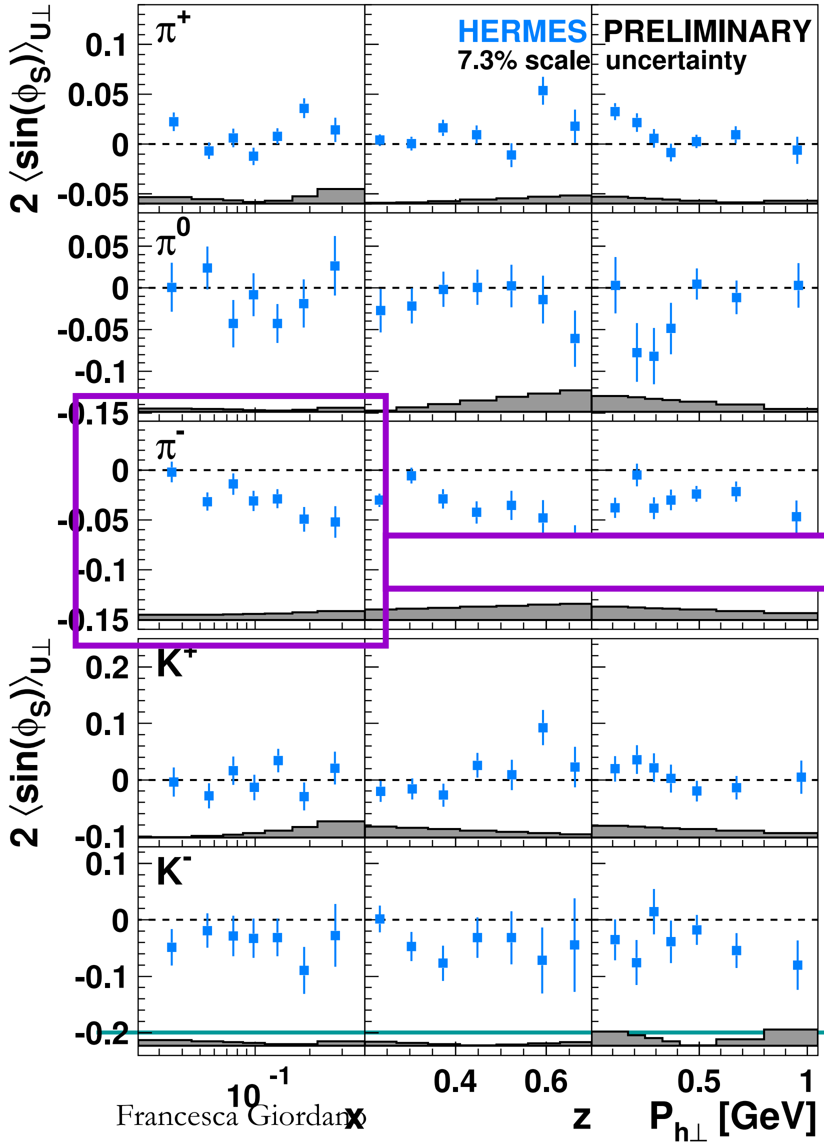


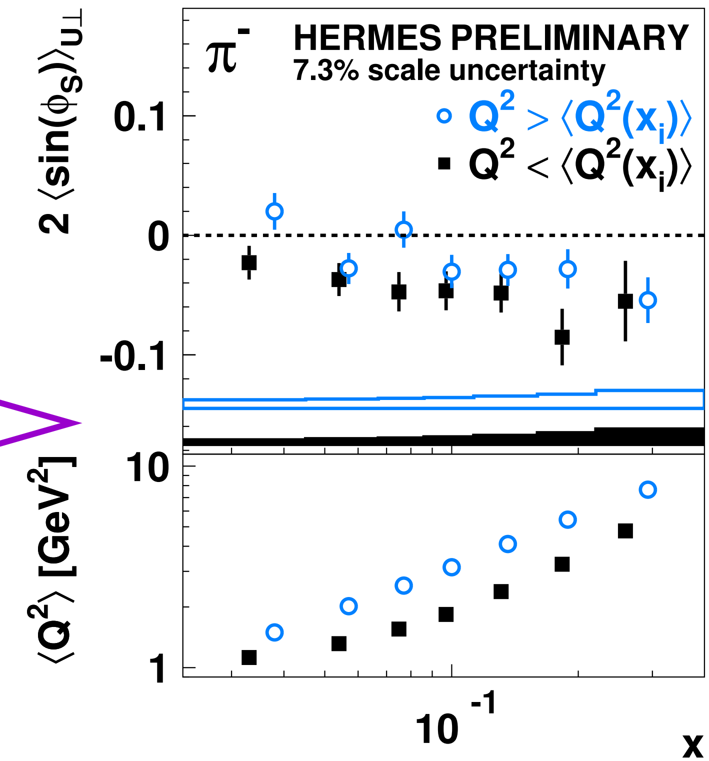
$\sin(2\phi_h-\phi_S)$



Additional Twist-3 contributions:

$\sin\phi_S$





Summary

SIDIS over Unpolarized targets:

- **Negative <cosϕ_h> moments are extracted for positive and negative hadrons, with a larger absolute value for the positive ones**
- **The results for the <cos2ϕ_h> moments are negative for the positive hadrons and positive for the negative hadrons:**

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Summary

SIDIS over Unpolarized targets:

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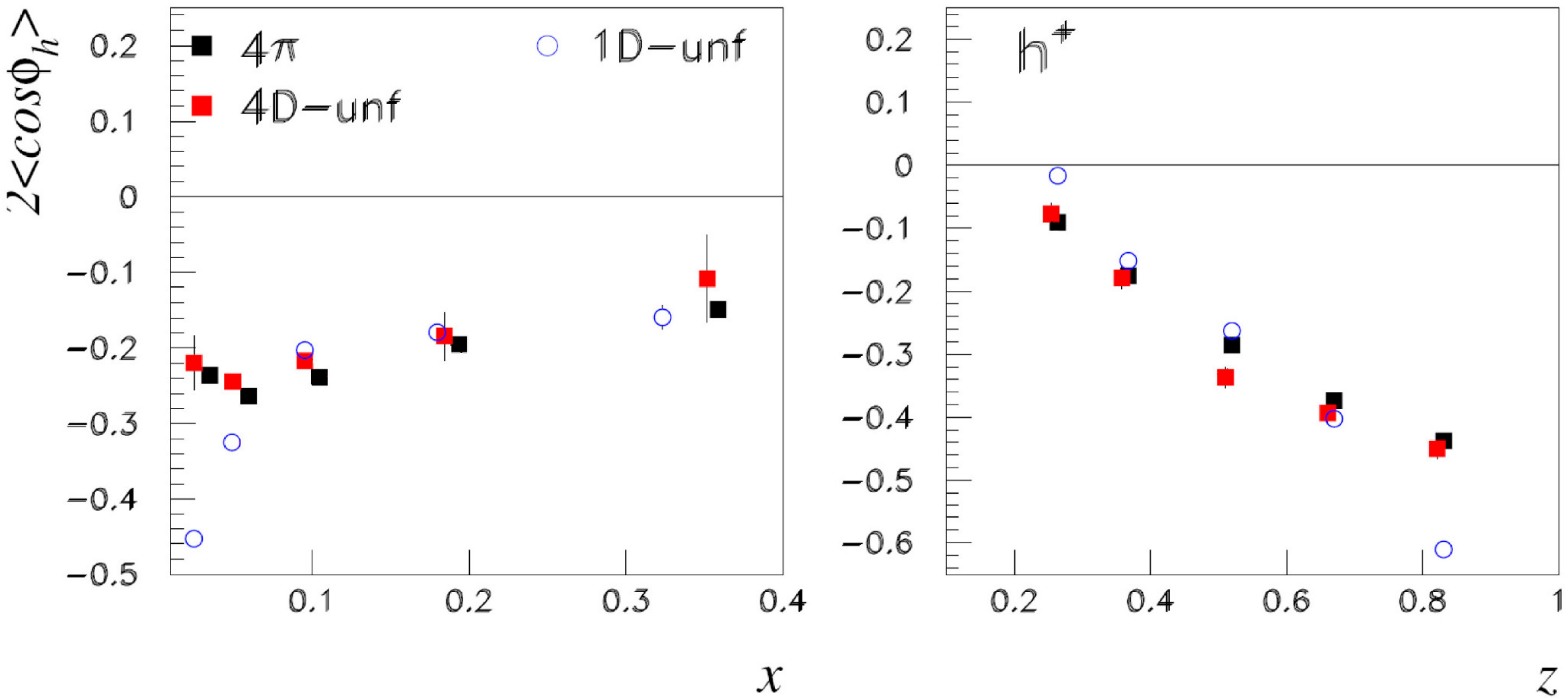
  ➡ Evidence of a non-zero Boer-Mulders function

SIDIS over Transversely polarized target:

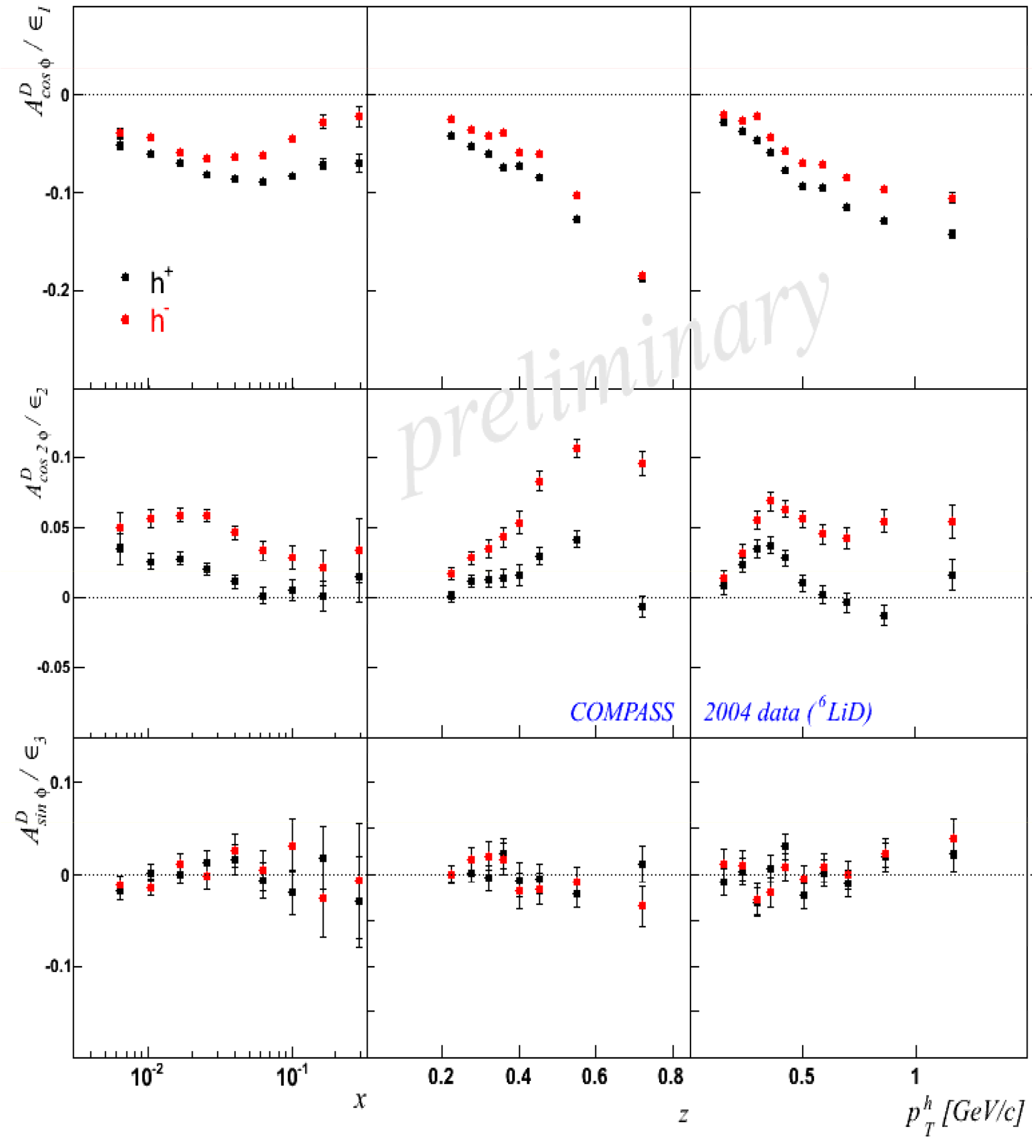
- First evidence of a significant SSA Collins amplitudes for π-mesons:
  ➡ allowed the first extraction of the transversity function!
- Significant SSA Sivers amplitudes for π^+ and K^+:
  ➡ non-zero quark orbital angular momenta!
- Additional sine contributions to A_{UT} found to be consistent with zero, except the sizable negative sinϕ_S ampltudes for π^-

Why a multi-dimensional analysis?

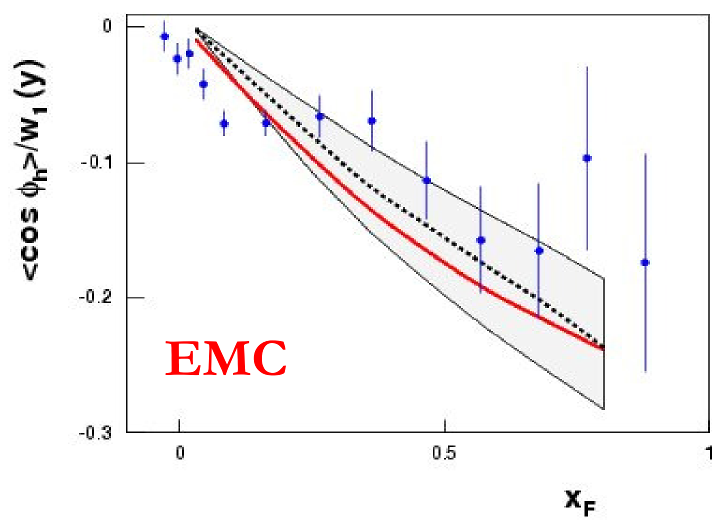


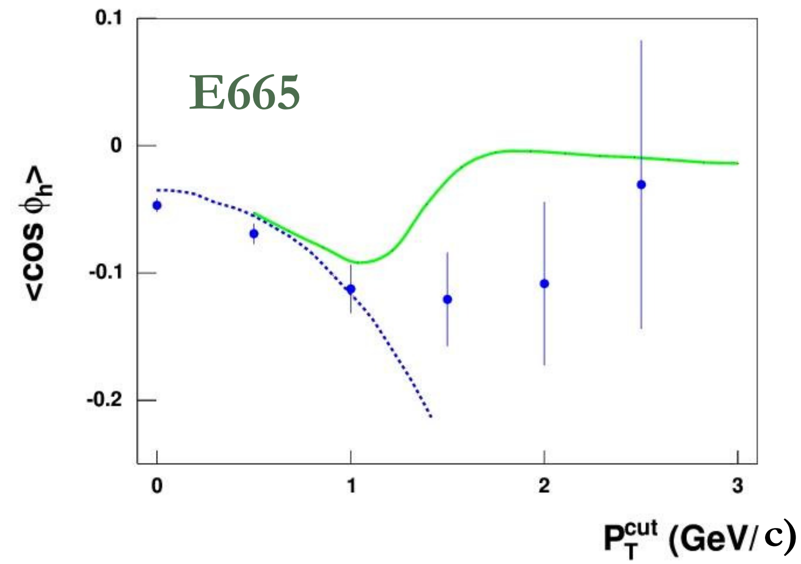
4D ➡ **binned in** $(x, y, z, P_{h\perp})$

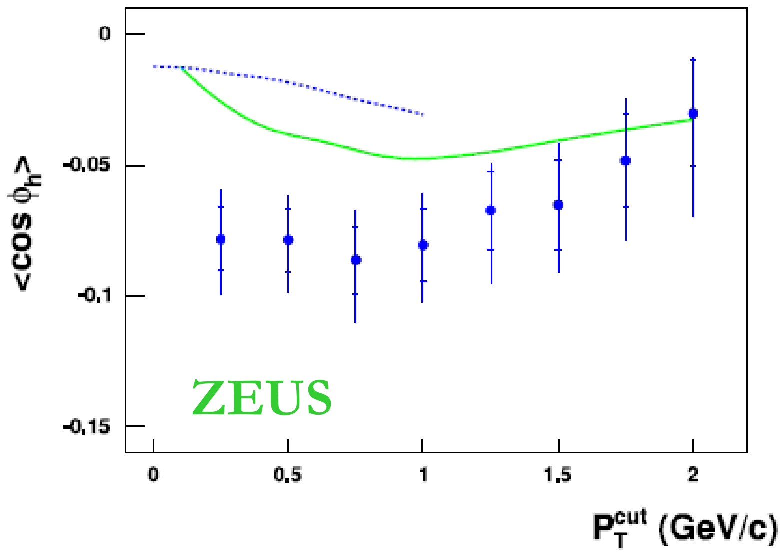
Compass results



Experimental status: $\langle \cos \phi_h \rangle$

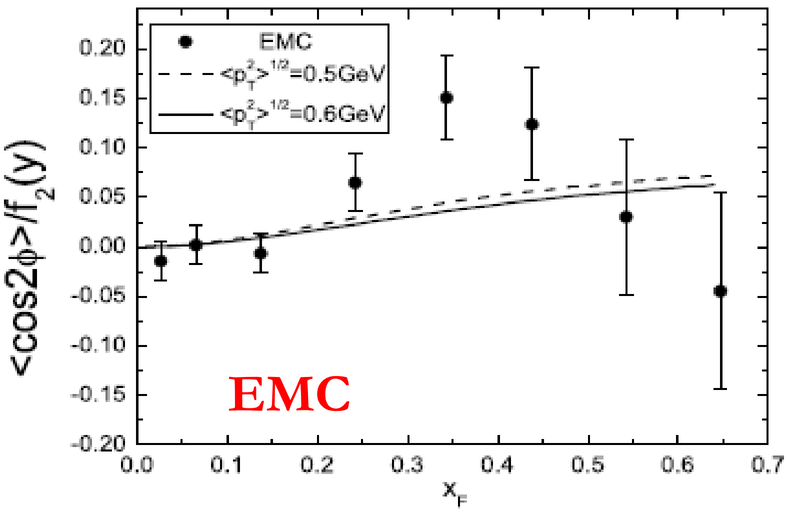


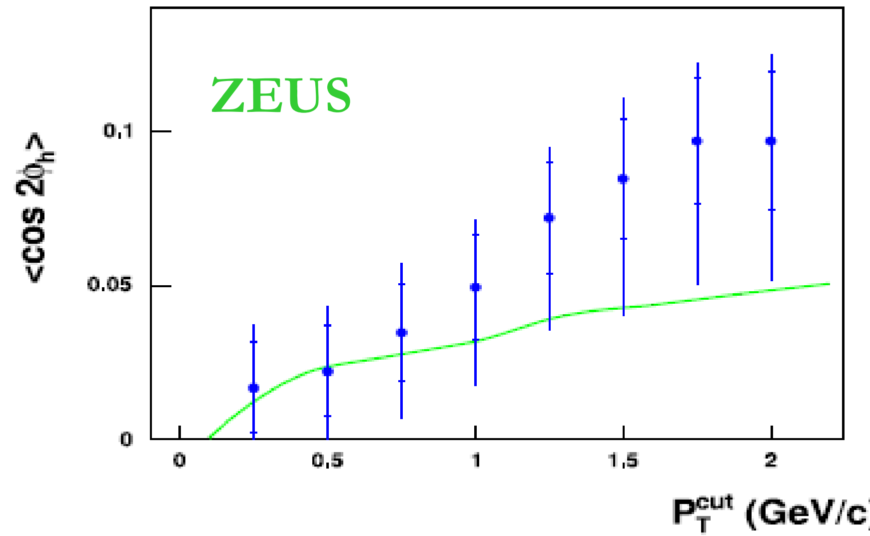




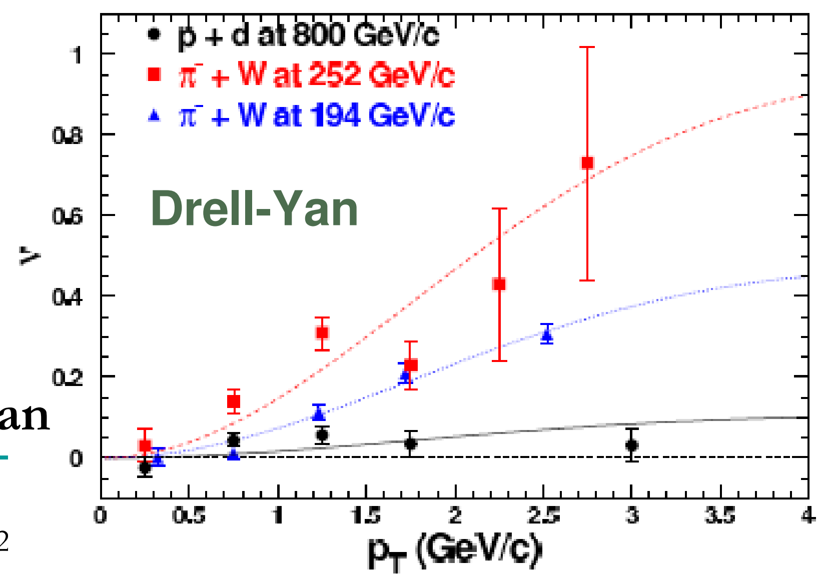
- Negative results in all the existing measurements
- No distinction between hadron type or charge

Experimental status: $\langle \cos 2\phi_h \rangle$





- Positive results in all the existing measurements
- No distinction between hadron type or charge (in SIDIS experiments)
- Indication of small Boer-Mulders function for the sea quark (from Drell-Yan experiments)



Vector meson contamination