Transverse structure of the nucleon at COMPASS

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On behalf of the COMPASS Collaboration

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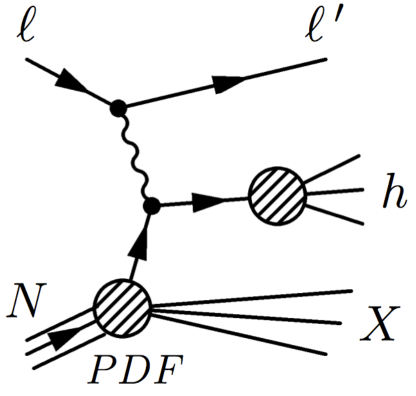
Semi-Inclusive DIS

$$\boxed{\ell N \to \ell' h (X)}$$



DIS with (at least) a hadron detected in the final state

Powerful tool to study spin & momentum structure of nucleon

- Access PDFs and FFs
- Allows flavor & charge separation of FFs
- Covers "relatively" wide range in energy scale (Q^2)
- Relevant for spin physics kinematics
- Sensitive to FF modification in nuclear medium

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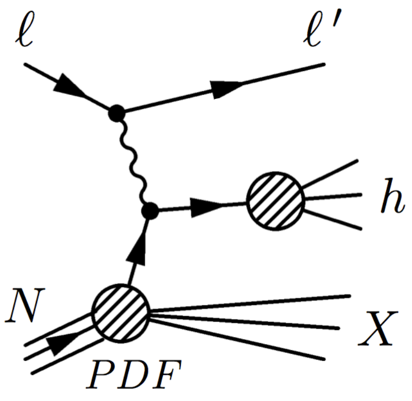

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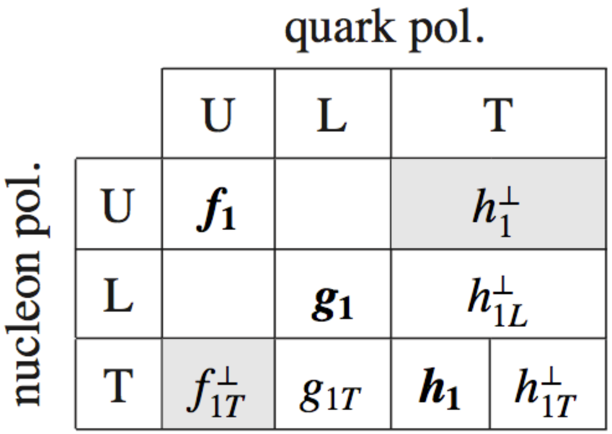
At Leading twist:



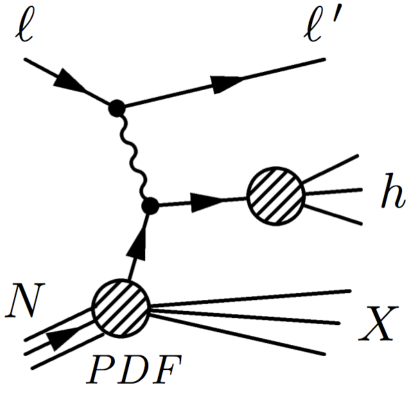
quark pol.

nucleon pol.	U	L	T	
U	$\boldsymbol{f_1}$		$h_1^\perp$	
L		$\boldsymbol{g_1}$	$h_{1L}^\perp$	
T	$f_{1T}^\perp$	g_{1T}	$\boldsymbol{h_1}$	$h_{1T}^\perp$

- 8 intrinsic-transverse-momentum (k_T) dependent PDFs
- Azimuthal asymmetries with different angular modulations in the hadron and spin azimuthal angles, φ_h and φ_s

Semi-inclusive DIS

$$\boxed{\ell N \to \ell' h (X)}$$



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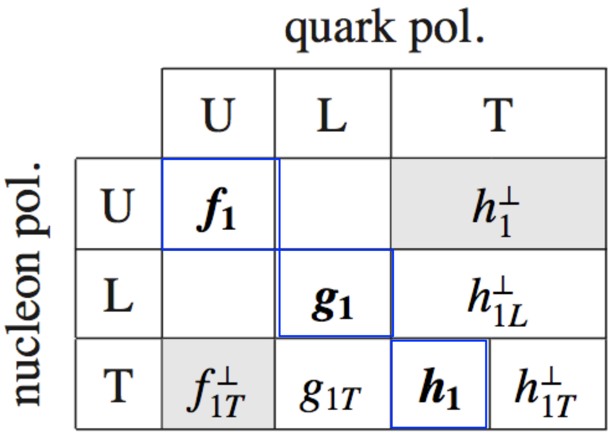
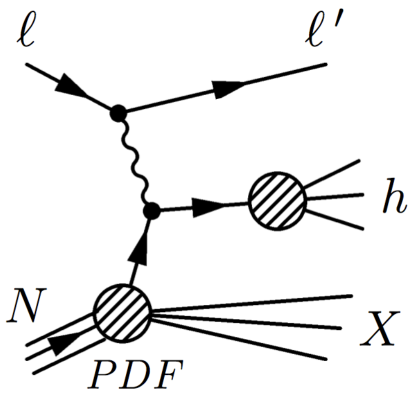


nucleon pol. \ quark pol.	U	L	T	
U	f_1		$h_1^\perp$	
L		g_1	$h_{1L}^\perp$	
T	$f_{1T}^\perp$	g_{1T}	h_1	$h_{1T}^\perp$

- 8 intrinsic-transverse-momentum (k_T) dependent PDFs
- Azimuthal asymmetries with different angular modulations in the hadron and spin azimuthal angles, φ_h and φ_s
- Vanish upon integration over k_T except f_1, g_1, and h_1

Semi-inclusive DIS

$\boxed{\ell N \rightarrow \ell' h (X)}$



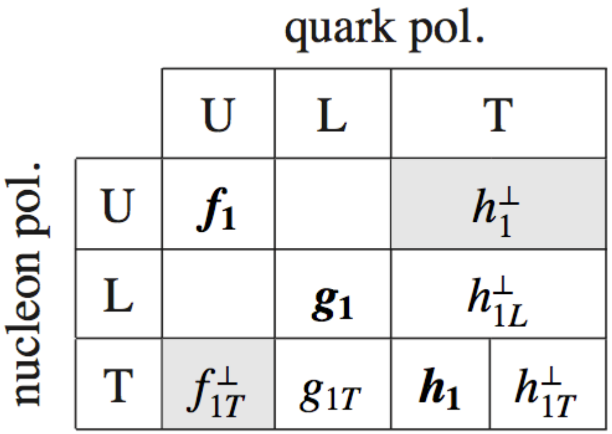
DIS with (at least) a hadron detected in the final state

Powerful tool to study spin & momentum structure of nucleon

- Access PDFs and FFs
- Allows flavor & charge separation of FFs
- Covers "relatively" wide range in energy scale (Q^2)
- Relevant for spin physics kinematics
- Sensitive to FF modification in nuclear medium

At Leading twist:

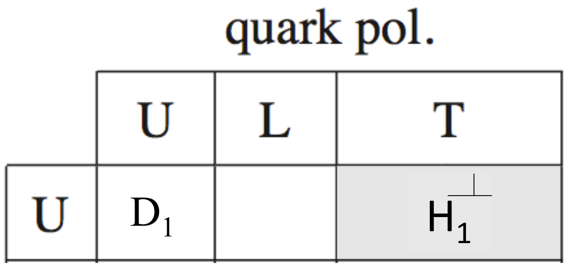
8 TMD PDFs



quark pol.

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

2 TMD FFs



quark pol.

	U	L	T
U	D_1		$H_1^\perp$

Unpolarized PDFs & FF

TMD PDFs & FFs

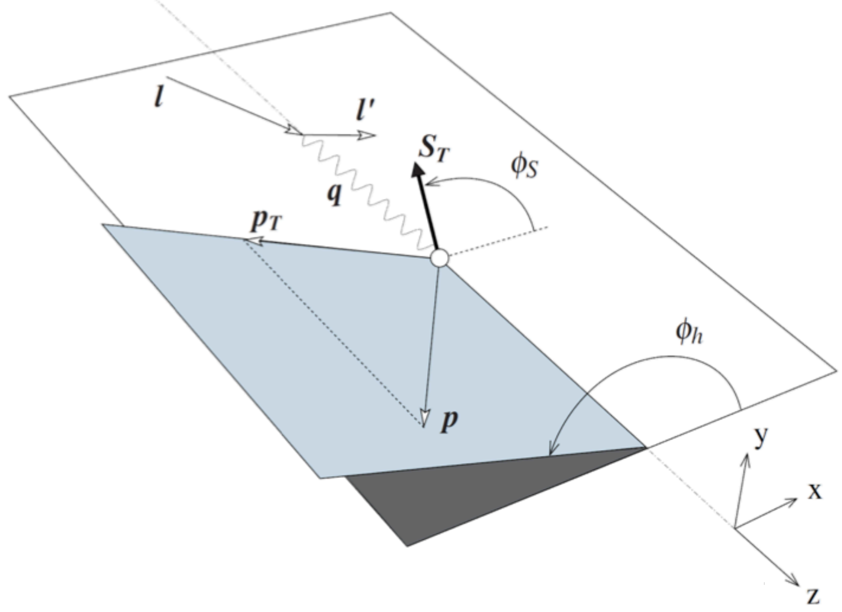
SIDIS cross section

$$\frac{d\sigma}{dxdydzdP_{hT}^2d\varphi_h d\varphi_S} =$$

$$\left[\frac{\alpha}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right](F_{UU,T}+\varepsilon F_{UU,L})\times$$

$$\left(\begin{array}{l}
1+\cos\varphi_h\sqrt{2\varepsilon(1+\varepsilon)}A_{UU}^{\cos\varphi_h}+\cos(2\varphi_h)\varepsilon A_{UU}^{\cos(2\varphi_h)}+\\
\lambda\sin\varphi_h\sqrt{2\varepsilon(1-\varepsilon)}A_{LU}^{\sin\varphi_h}+\\
S_L\left[\sqrt{2\varepsilon(1+\varepsilon)}\sin\varphi_h A_{UL}^{\sin\varphi_h}+\sin(2\varphi_h)\varepsilon A_{UL}^{\sin 2\varphi_h}\right]+\\
S_L\lambda\left[\sqrt{(1-\varepsilon^2)}A_{LL}+\sqrt{2\varepsilon(1-\varepsilon)}\cos\varphi_h A_{LL}^{\cos\varphi_h}\right]+\\
S_T\left[\begin{array}{l}
\sin\varphi_S\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+\\
\sin(\varphi_h-\varphi_S)\left(A_{UT}^{\sin(\varphi_h-\varphi_S)}\right)+\\
\sin(\varphi_h+\varphi_S)\left(\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}\right)+\\
\sin(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}\right)+\\
\sin(3\varphi_h-\varphi_S)\left(\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right)
\end{array}\right]+\\
S_T\lambda\left[\begin{array}{l}
\cos\varphi_S\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+\\
\cos(\varphi_h-\varphi_S)\left(\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}\right)+\\
\cos(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)
\end{array}\right]
\end{array}\right)$$

18 structure functions



Q^2	$= -q^2$: photon virtuality
x	$= Q^2/2M\nu$: Bjorken variable
y	$= (E_\mu - E_{\mu'})/E_\mu$
z	hadron fractional energy
p_T	hadron transverse momentum
Φ_h	hadron azimuthal angle

SIDIS cross section

$$\frac{d\sigma}{dxdydzdP_{hT}^2d\varphi_hd\varphi_S} =$$

$$\left[\frac{\alpha}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right](F_{UU,T}+\varepsilon F_{UU,L})\times$$

$$\left(\begin{aligned}
&1+\cos\varphi_h\sqrt{2\varepsilon(1+\varepsilon)}A_{UU}^{\cos\varphi_h}+\cos(2\varphi_h)\varepsilon A_{UU}^{\cos(2\varphi_h)}+\\
&\lambda\sin\varphi_h\sqrt{2\varepsilon(1-\varepsilon)}A_{LU}^{\sin\varphi_h}+\\
&S_L\left[\sqrt{2\varepsilon(1+\varepsilon)}\sin\varphi_h A_{UL}^{\sin\varphi_h}+\sin(2\varphi_h)\varepsilon A_{UL}^{\sin 2\varphi_h}\right]+\\
&S_L\lambda\left[\sqrt{(1-\varepsilon^2)}A_{LL}+\sqrt{2\varepsilon(1-\varepsilon)}\cos\varphi_h A_{LL}^{\cos\varphi_h}\right]+\\
&S_T\left[\begin{aligned}
&\sin\varphi_S\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+\\
&\sin(\varphi_h-\varphi_S)\left(A_{UT}^{\sin(\varphi_h-\varphi_S)}\right)+\\
&\sin(\varphi_h+\varphi_S)\left(\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}\right)+\\
&\sin(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}\right)+\\
&\sin(3\varphi_h-\varphi_S)\left(\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right)
\end{aligned}\right]+\\
&S_T\lambda\left[\begin{aligned}
&\cos\varphi_S\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+\\
&\cos(\varphi_h-\varphi_S)\left(\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}\right)+\\
&\cos(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)
\end{aligned}\right]
\end{aligned}\right)$$

Unpolarized target

Longitudinally polarized target

Transversely polarized target

SIDIS cross section

$$\frac{d\sigma}{dxdydzdP_{hT}^2d\varphi_h d\varphi_S} =$$

$$\left[\frac{\alpha}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right]\left(F_{UU,T}+\varepsilon F_{UU,L}\right)\times$$

$$\Bigg(1+\cos\varphi_h\sqrt{2\varepsilon(1+\varepsilon)}A_{UU}^{\cos\varphi_h}+\cos(2\varphi_h)\varepsilon A_{UU}^{\cos(2\varphi_h)}+$$
$$\lambda\sin\varphi_h\sqrt{2\varepsilon(1-\varepsilon)}A_{LU}^{\sin\varphi_h}+$$

Unpolarized target

$$S_L\left[\sqrt{2\varepsilon(1+\varepsilon)}\sin\varphi_h A_{UL}^{\sin\varphi_h}+\sin(2\varphi_h)\varepsilon A_{UL}^{\sin 2\varphi_h}\right]+$$
$$S_L\lambda\left[\sqrt{(1-\varepsilon^2)}A_{LL}+\sqrt{2\varepsilon(1-\varepsilon)}\cos\varphi_h A_{LL}^{\cos\varphi_h}\right]+$$

Longitudinally polarized target

$$S_T\left[\begin{array}{l}\sin\varphi_S\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+\\ \sin(\varphi_h-\varphi_S)\left(A_{UT}^{\sin(\varphi_h-\varphi_S)}\right)+\\ \sin(\varphi_h+\varphi_S)\left(\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}\right)+\\ \sin(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}\right)+\\ \sin(3\varphi_h-\varphi_S)\left(\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right)\end{array}\right]+$$

Transversely polarized target

SSA

DSA

$$S_T\lambda\left[\begin{array}{l}\cos\varphi_S\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+\\ \cos(\varphi_h-\varphi_S)\left(\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}\right)+\\ \cos(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)\end{array}\right]\Bigg)$$

SIDIS cross section

$$\frac{d\sigma}{dxdydzdP_{hT}^2d\varphi_h d\varphi_S} =$$

$$\left[\frac{\alpha}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right](F_{UU,T}+\varepsilon F_{UU,L})\times$$

$$\left(\begin{array}{l}
1+\cos\varphi_h\sqrt{2\varepsilon(1+\varepsilon)}A_{UU}^{\cos\varphi_h}+\cos(2\varphi_h)\varepsilon A_{UU}^{\cos(2\varphi_h)}+ \\
\lambda\sin\varphi_h\sqrt{2\varepsilon(1-\varepsilon)}A_{LU}^{\sin\varphi_h}+ \\
S_L\left[\sqrt{2\varepsilon(1+\varepsilon)}\sin\varphi_h A_{UL}^{\sin\varphi_h}+\sin(2\varphi_h)\varepsilon A_{UL}^{\sin 2\varphi_h}\right]+ \\
S_L\lambda\left[\sqrt{(1-\varepsilon^2)}A_{LL}+\sqrt{2\varepsilon(1-\varepsilon)}\cos\varphi_h A_{LL}^{\cos\varphi_h}\right]+ \\
S_T\left[\begin{array}{l}
\sin\varphi_S\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+ \\
\sin(\varphi_h-\varphi_S)\left(A_{UT}^{\sin(\varphi_h-\varphi_S)}\right)+ \\
\sin(\varphi_h+\varphi_S)\left(\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}\right)+ \\
\sin(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}\right)+ \\
\sin(3\varphi_h-\varphi_S)\left(\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right)
\end{array}\right]+ \\
S_T\lambda\left[\begin{array}{l}
\cos\varphi_S\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+ \\
\cos(\varphi_h-\varphi_S)\left(\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}\right)+ \\
\cos(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)
\end{array}\right]
\end{array}\right)$$

Unpolarized target

Longitudinally polarized target

Transversely polarized target

SSA

DSA

Measured at COMPASS !
subject of this talk

SIDIS cross section – Collins

$$\frac{d\sigma}{dxdydzdP_{hT}^2 d\varphi_h d\varphi_S} =$$

$$\left[\frac{\alpha}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right](F_{UU,T}+\varepsilon F_{UU,L})\times$$

$$\left(\begin{array}{l}
1+\cos\varphi_h\sqrt{2\varepsilon(1+\varepsilon)}A_{UU}^{\cos\varphi_h}+\cos(2\varphi_h)\varepsilon A_{UU}^{\cos(2\varphi_h)}+ \\
\lambda\sin\varphi_h\sqrt{2\varepsilon(1-\varepsilon)}A_{LU}^{\sin\varphi_h}+ \\
S_L\left[\sqrt{2\varepsilon(1+\varepsilon)}\sin\varphi_h A_{UL}^{\sin\varphi_h}+\sin(2\varphi_h)\varepsilon A_{UL}^{\sin 2\varphi_h}\right]+ \\
S_L\lambda\left[\sqrt{(1-\varepsilon^2)}A_{LL}+\sqrt{2\varepsilon(1-\varepsilon)}\cos\varphi_h A_{LL}^{\cos\varphi_h}\right]+ \\
S_T\left[\begin{array}{l}
\sin\varphi_S\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+ \\
\sin(\varphi_h-\varphi_S)\left(A_{UT}^{\sin(\varphi_h-\varphi_S)}\right)+ \\
\sin(\varphi_h+\varphi_S)\left(\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}\right)+ \\
\sin(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}\right)+ \\
\sin(3\varphi_h-\varphi_S)\left(\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right)
\end{array}\right]+ \\
S_T\lambda\left[\begin{array}{l}
\cos\varphi_S\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+ \\
\cos(\varphi_h-\varphi_S)\left(\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}\right)+ \\
\cos(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)
\end{array}\right]
\end{array}\right)$$

TMD polarized F

$$A_{UT}^{\sin(\varphi_h+\varphi_S)} \propto \boldsymbol{h_1^q} \otimes \boldsymbol{H_{1q}^{\perp h}}$$

Transversity function

Correlation between nucleon transverse spin and transverse polarization of quarks

SIDIS cross section – Collins & Sivers

$$\frac{d\sigma}{dx\,dy\,dz\,dP_{hT}^2\,d\varphi_h\,d\varphi_S} =$$

$$\left[\frac{\alpha}{xyQ^2}\,\frac{y^2}{2\,(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right](F_{UU,T}+\varepsilon F_{UU,L})\times$$

$$\left(\begin{array}{l}
1+\cos\varphi_h\sqrt{2\varepsilon\,(1+\varepsilon)}A_{UU}^{\cos\varphi_h}+\cos\,(2\varphi_h)\varepsilon A_{UU}^{\cos\,(2\varphi_h)}+\\
\lambda\sin\varphi_h\sqrt{2\varepsilon\,(1-\varepsilon)}A_{LU}^{\sin\varphi_h}+\\
S_L\quad\left[\sqrt{2\varepsilon\,(1+\varepsilon)}\sin\varphi_h A_{UL}^{\sin\varphi_h}+\sin\,(2\varphi_h)\varepsilon A_{UL}^{\sin 2\varphi_h}\right]+\\
S_L\lambda\left[\sqrt{(1-\varepsilon^2)}A_{LL}+\sqrt{2\varepsilon\,(1-\varepsilon)}\cos\varphi_h A_{LL}^{\cos\varphi_h}\right]+\\
S_T\left[\begin{array}{l}
\sin\varphi_S\left(\sqrt{2\varepsilon\,(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+\\
\sin\,(\varphi_h-\varphi_S)\left(A_{UT}^{\sin(\varphi_h-\varphi_S)}\right)+\\
\sin\,(\varphi_h+\varphi_S)\left(\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}\right)+\\
\sin\,(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon\,(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}\right)+\\
\sin\,(3\varphi_h-\varphi_S)\left(\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right)
\end{array}\right]+\\
S_T\lambda\left[\begin{array}{l}
\cos\varphi_S\left(\sqrt{2\varepsilon\,(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+\\
\cos\,(\varphi_h-\varphi_S)\left(\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}\right)+\\
\cos\,(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon\,(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)
\end{array}\right]
\end{array}\right)$$

Correlation between nucleon transverse spin and quark transverse momentum

Unpolarized FF

$$A_{UT}^{\sin(\varphi_h-\varphi_S)}\propto \mathbf{f_{1T}^{\perp q}}\otimes\mathbf{D_{1q}^{h}}$$

Sivers function

TMD polarized F

$$A_{UT}^{\sin(\varphi_h+\varphi_S)}\propto h_1^{\mathbf{q}}\otimes H_{\mathbf{1q}}^{\perp\mathbf{h}}$$

Transversity function

Correlation between nucleon transverse spin and transverse polarization of quarks

SIDIS cross section – TMD PDFs

$$\frac{d\sigma}{dxdydzdP_{hT}^2d\varphi_h d\varphi_S} =$$

$$\left[\frac{\alpha}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right](F_{UU,T}+\varepsilon F_{UU,L})\times$$

$$\left(\begin{array}{ll}
\multicolumn{2}{l}{1+\cos\varphi_h\sqrt{2\varepsilon(1+\varepsilon)}A_{UU}^{\cos\varphi_h}+\cos(2\varphi_h)\varepsilon A_{UU}^{\cos(2\varphi_h)}+} \\
\multicolumn{2}{l}{\lambda\sin\varphi_h\sqrt{2\varepsilon(1-\varepsilon)}A_{LU}^{\sin\varphi_h}+} \\
S_L & \left[\sqrt{2\varepsilon(1+\varepsilon)}\sin\varphi_h A_{UL}^{\sin\varphi_h}+\sin(2\varphi_h)\varepsilon A_{UL}^{\sin 2\varphi_h}\right]+ \\
S_L\lambda & \left[\sqrt{(1-\varepsilon^2)}A_{LL}+\sqrt{2\varepsilon(1-\varepsilon)}\cos\varphi_h A_{LL}^{\cos\varphi_h}\right]+ \\
S_T & \left[\begin{array}{l}
\sin\varphi_S\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+ \\
\sin(\varphi_h-\varphi_S)\left(A_{UT}^{\sin(\varphi_h-\varphi_S)}\right)+ \\
\sin(\varphi_h+\varphi_S)\left(\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}\right)+ \\
\sin(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}\right)+ \\
\sin(3\varphi_h-\varphi_S)\left(\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right)
\end{array}\right]+ \\
S_T\lambda & \left[\begin{array}{l}
\cos\varphi_S\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+ \\
\cos(\varphi_h-\varphi_S)\left(\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}\right)+ \\
\cos(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)
\end{array}\right]
\end{array}\right)$$

$$A_{UU}^{\cos\phi_h}\propto Q^{-1}\left(f_1^q\otimes D_{1q}^h-h_1^{\perp q}\otimes H_{1q}^{\perp h}+\cdots\right)$$

$$A_{UU}^{\cos 2\phi_h}\propto h_1^{\perp q}\otimes H_{1q}^{\perp h}+Q^{-1}\left(f_1^q\otimes D_{1q}^h+\cdots\right)$$

$$A_{UT}^{\sin(\varphi_h-\varphi_S)}\propto f_{1T}^{\perp q}\otimes D_{1q}^h$$

$$A_{UT}^{\sin(\varphi_h+\varphi_S)}\propto h_1^q\otimes H_{1q}^{\perp h}$$

$$A_{UT}^{3(\varphi_h-\varphi_S)}\propto h_{1T}^{\perp q}\otimes H_{1q}^{\perp h}$$

$$A_{UT}^{\sin\varphi_S}\propto Q^{-1}\left(h_1^q\otimes H_{1q}^{\perp h}+f_{1T}\otimes D_{1q}^h+\cdots\right)$$

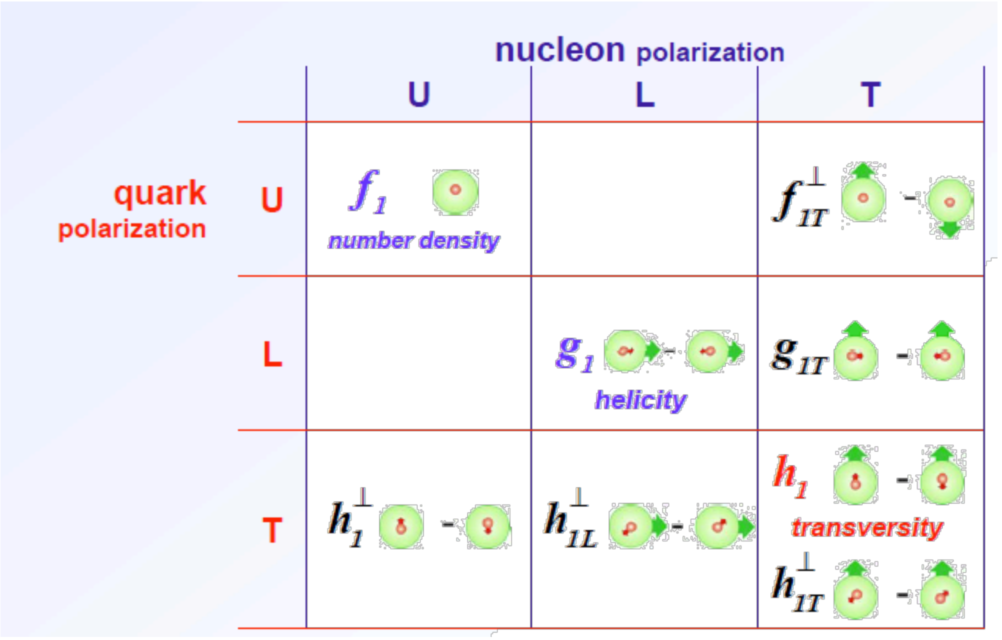
$$A_{UT}^{\sin(2\varphi_h-\varphi_S)}\propto Q^{-1}\left(h_{1T}^{\perp q}\otimes H_{1q}^{\perp h}+f_{1T}^{\perp h}\otimes D_{1q}^h+\cdots\right)$$

$$A_{LT}^{\cos(\varphi_h-\varphi_S)}\propto g_{1T}^q\otimes D_{1q}^h$$

$$A_{LT}^{\cos\varphi_S}\propto Q^{-1}\left(g_{1T}^q\otimes D_{1q}^h+\cdots\right)$$

$$A_{LT}^{\cos(2\varphi_h-\varphi_S)}\propto Q^{-1}\left(g_{1T}^q\otimes D_{1q}^h\right)$$

Ttransverse Momentum Dependent PDFs



		nucleon polarization		
		U	L	T
quark polarization	U	f_1 number density		$f_{1T}^{\perp}$
	L		g_1 helicity	g_{1T}
	T	$h_1^{\perp}$	$h_{1L}^{\perp}$	h_1 transversity $h_{1T}^{\perp}$

- Can only be assessed in experimental data (measured asymmetries)

- More asymmetries, measured by different experiments in different reactions, at different energies and kinematical ranges expected in the near future towards a global analysis

$$A_{UU}^{\cos\phi_h} \propto Q^{-1}\left(f_1^q \otimes D_{1q}^h - h_1^{\perp q} \otimes H_{1q}^{\perp h} + \cdots\right)$$

$$A_{UU}^{\cos 2\phi_h} \propto h_1^{\perp q} \otimes H_{1q}^{\perp h} + Q^{-1}\left(f_1^q \otimes D_{1q}^h + \cdots\right)$$

$$A_{UT}^{\sin(\varphi_h - \varphi_S)} \propto f_{1T}^{\perp q} \otimes D_{1q}^h$$

$$A_{UT}^{\sin(\varphi_h + \varphi_S)} \propto h_1^q \otimes H_{1q}^{\perp h}$$

$$A_{UT}^{3(\varphi_h - \varphi_S)} \propto h_{1T}^{\perp q} \otimes H_{1q}^{\perp h}$$

$$A_{UT}^{\sin\varphi_S} \propto Q^{-1}\left(h_1^q \otimes H_{1q}^{\perp h} + f_{1T} \otimes D_{1q}^h + \cdots\right)$$

$$A_{UT}^{\sin(2\varphi_h - \varphi_S)} \propto Q^{-1}\left(h_{1T}^{\perp q} \otimes H_{1q}^{\perp h} + f_{1T}^{\perp h} \otimes D_{1q}^h + \cdots\right)$$

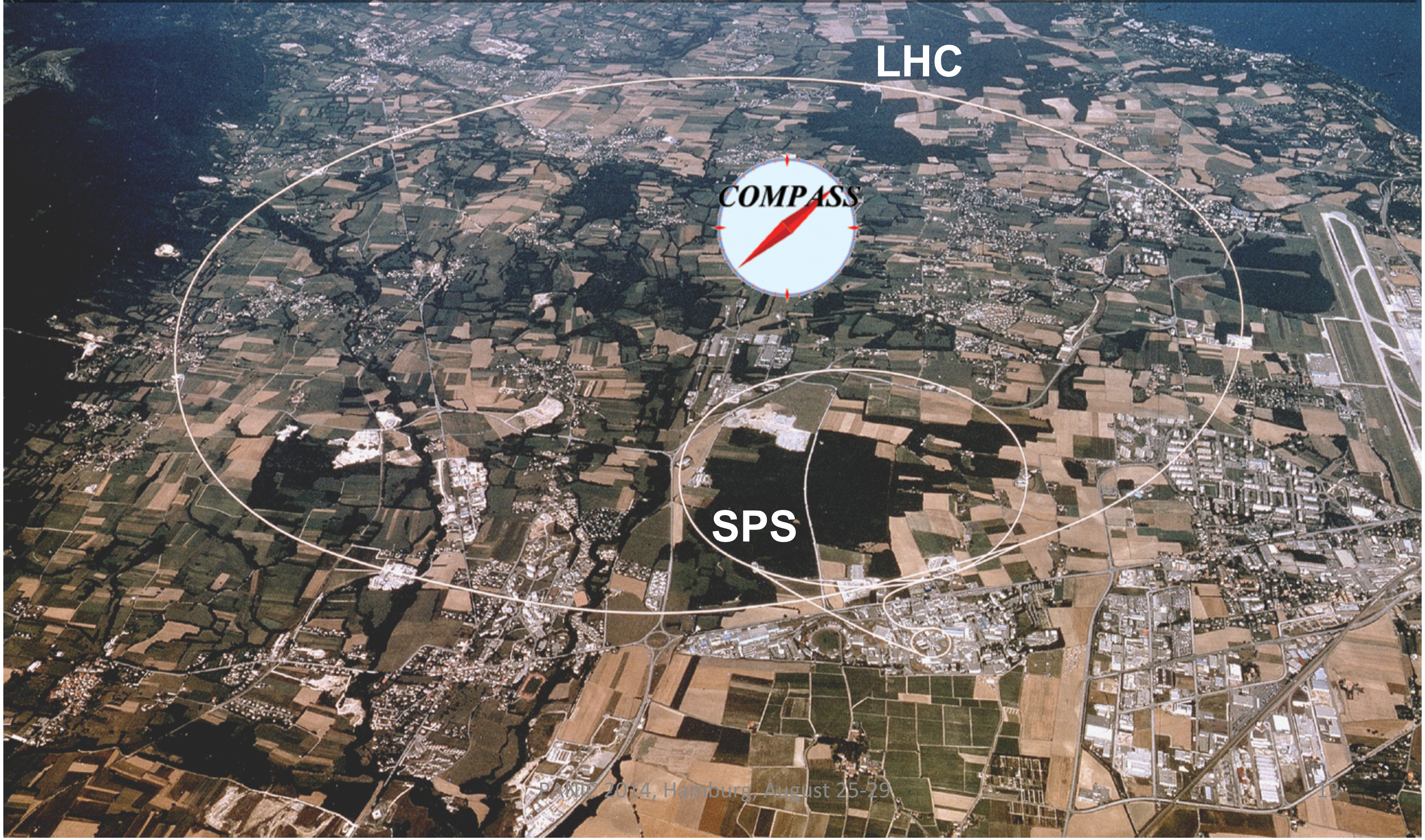
$$A_{LT}^{\cos(\varphi_h - \varphi_S)} \propto g_{1T}^q \otimes D_{1q}^h$$

$$A_{LT}^{\cos\varphi_S} \propto Q^{-1}\left(g_{1T}^q \otimes D_{1q}^h + \cdots\right)$$

$$A_{LT}^{\cos(2\varphi_h - \varphi_S)} \propto Q^{-1}\left(g_{1T}^q \otimes D_{1q}^h\right)$$

COMPASS:

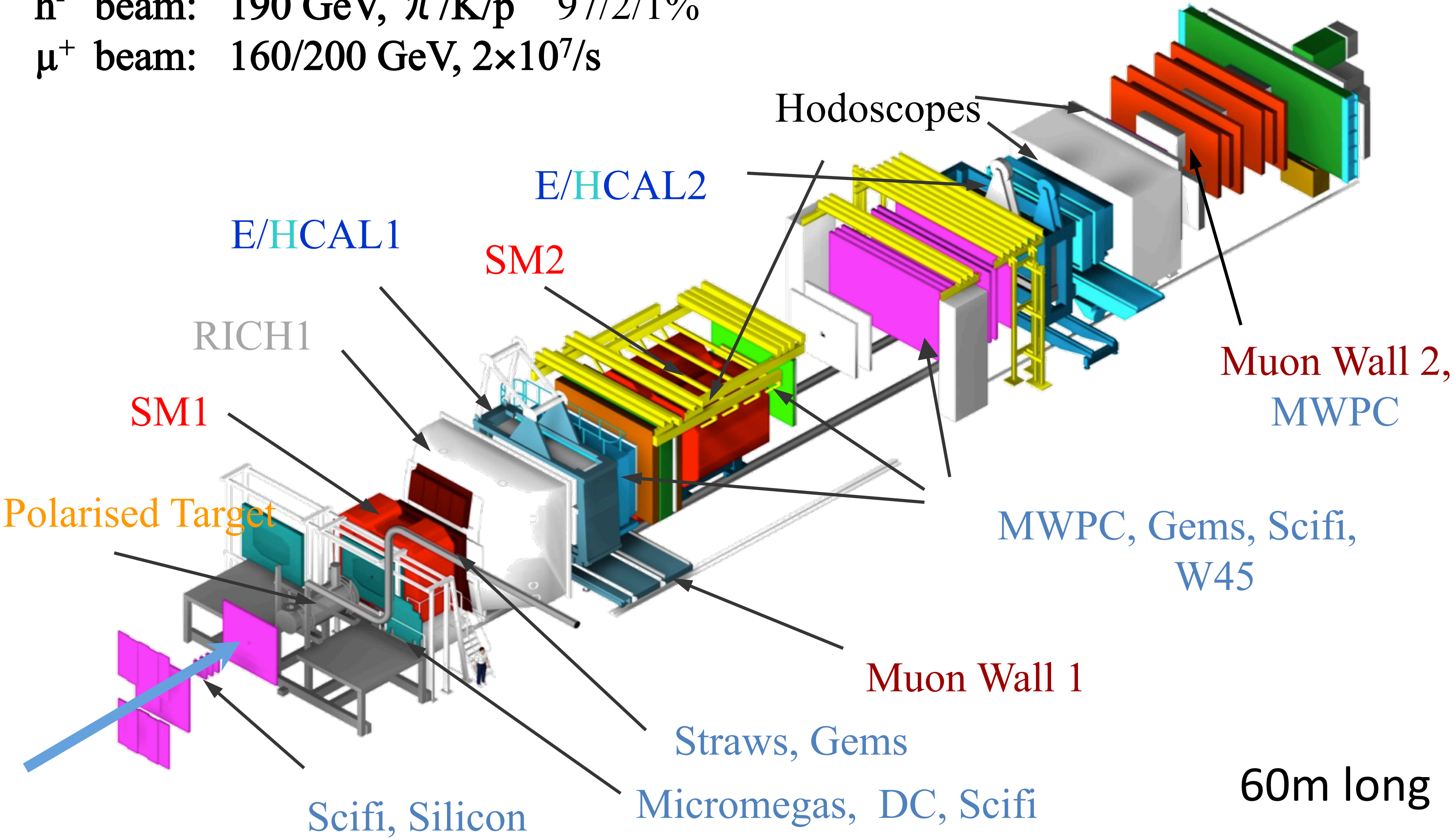
COmmon Muon and Proton Apparatus for Structure and Spectroscopy"



COMPASS spectrometer

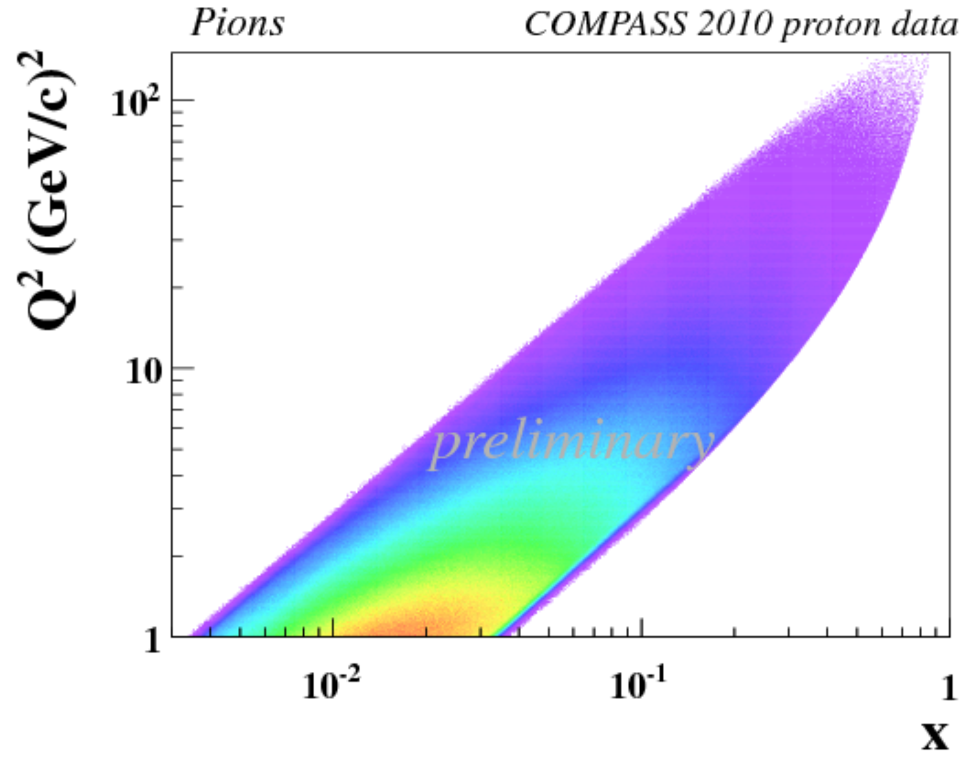
h^+ beam: 190 GeV, p/ π /K 75/24/1%
h^- beam: 190 GeV, π /K/p 97/2/1%
μ^+ beam: 160/200 GeV, 2×10^7/s

Data taking since 2002



60m long

COMPASS 2010 data: x vs. Q^2



COMPASS **proton 2010**

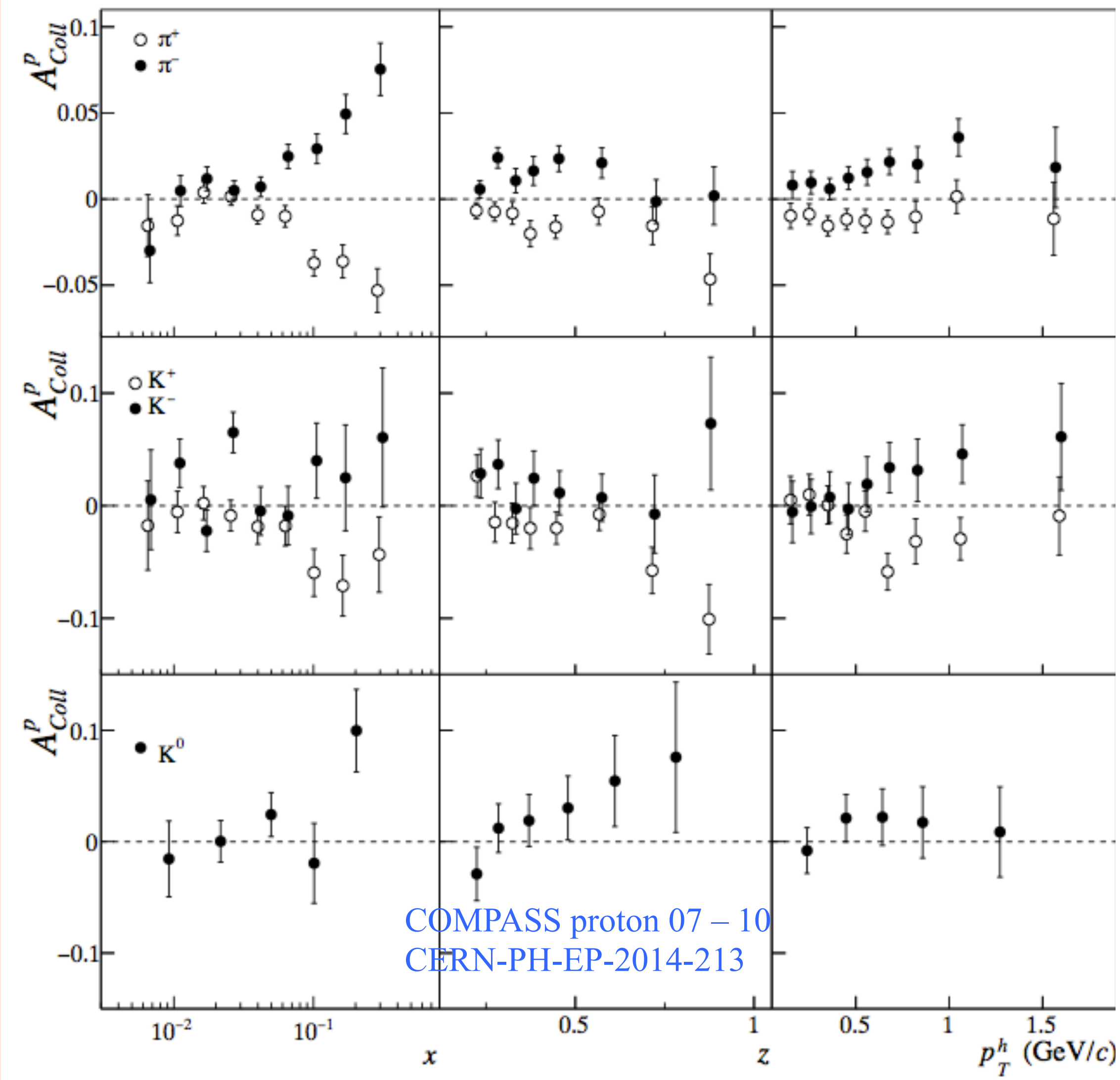
$Q^2 > 1$ (GeV/c)^2, $W > 5$ GeV, $0.1 < y < 0.9$, $z > 0.1$, $p_T > 0.1$ GeV

Asymmetries measured vs. x, z, p_T independently

SIDIS cross section – Collins asymmetries

$$\frac{d\sigma}{dxdydzdP_{hT}^2d\varphi_h d\varphi_S} = \left[\frac{\alpha}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right](F_{UU,T}+\varepsilon F_{UU,L})\times$$

$$\left(\begin{array}{ll} \cdots + & \\ S_T & \left[\begin{array}{l} \sin\varphi_S\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+ \\ \sin(\varphi_h-\varphi_S)\left(A_{UT}^{\sin(\varphi_h-\varphi_S)}\right)+ \\ \sin(\varphi_h+\varphi_S)\left(\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}\right)+ \\ \sin(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}\right)+ \\ \sin(3\varphi_h-\varphi_S)\left(\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right) \end{array}\right] + \\ S_T\lambda & \left[\begin{array}{l} \cos\varphi_S\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+ \\ \cos(\varphi_h-\varphi_S)\left(\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}\right)+ \\ \cos(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right) \end{array}\right] \end{array}\right)$$



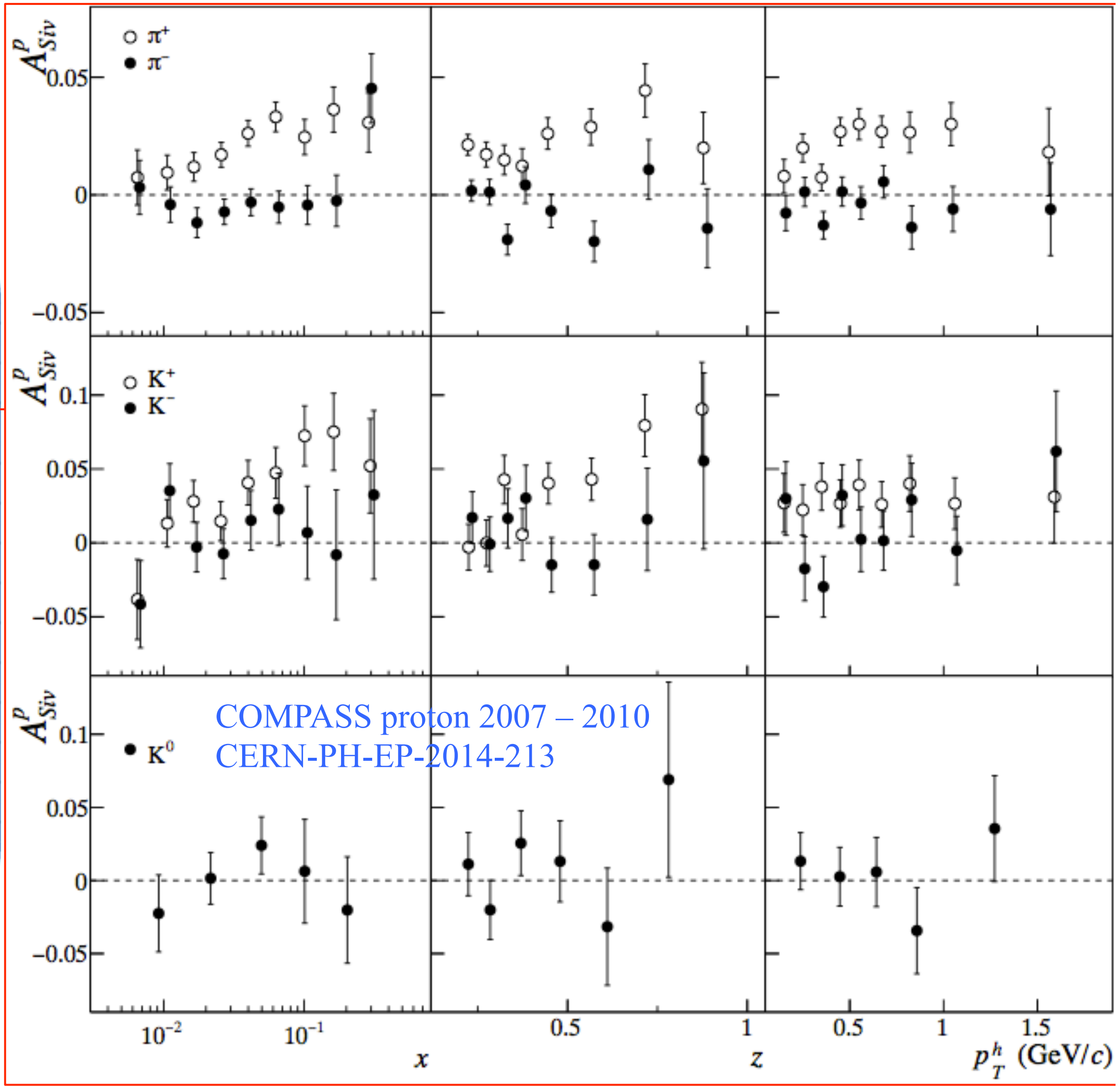
COMPASS proton 07 – 10
CERN-PH-EP-2014-213

- Asymmetries compatible with zero at small x
- Significant signal in the valence region with opposite sign for $\pi^\pm$
- Small signal with opposite signs for K^+ & K^-

SIDIS cross section – Sivers asymmetries

$$\frac{d\sigma}{dxdydzdP_{hT}^2d\varphi_hd\varphi_S} = \left[\frac{\alpha}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right](F_{UU,T}+\varepsilon F_{UU,L}) \times$$

$$\left(\begin{array}{l} \cdots + \\ S_T \left[\begin{array}{l} \sin\varphi_S\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+ \\ \sin(\varphi_h-\varphi_S)\left(A_{UT}^{\sin(\varphi_h-\varphi_S)}\right)+ \longleftarrow \\ \sin(\varphi_h+\varphi_S)\left(\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}\right)+ \\ \sin(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}\right)+ \\ \sin(3\varphi_h-\varphi_S)\left(\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right) \end{array}\right] + \\ S_T\lambda \left[\begin{array}{l} \cos\varphi_S\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+ \\ \cos(\varphi_h-\varphi_S)\left(\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}\right)+ \\ \cos(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right) \end{array}\right] \end{array}\right)$$



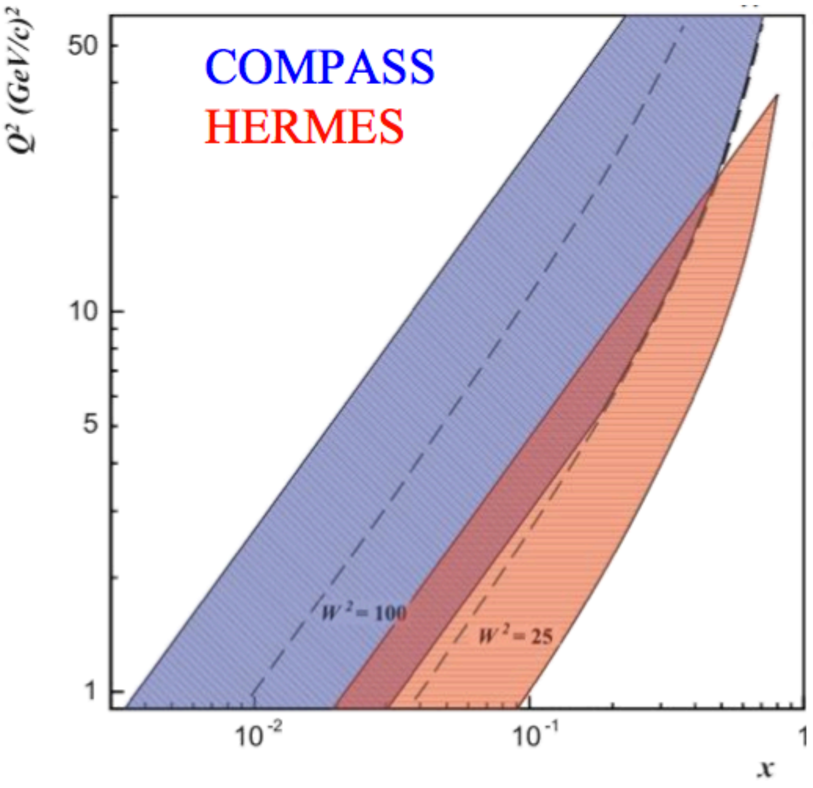
COMPASS proton 2007 – 2010
CERN-PH-EP-2014-213

- Large signal for h^+ over all x, compatible with zero for h^-
- Increasing signal vs. z
- Linear p_T^h dependence at small p_T^h, constant for large p_T

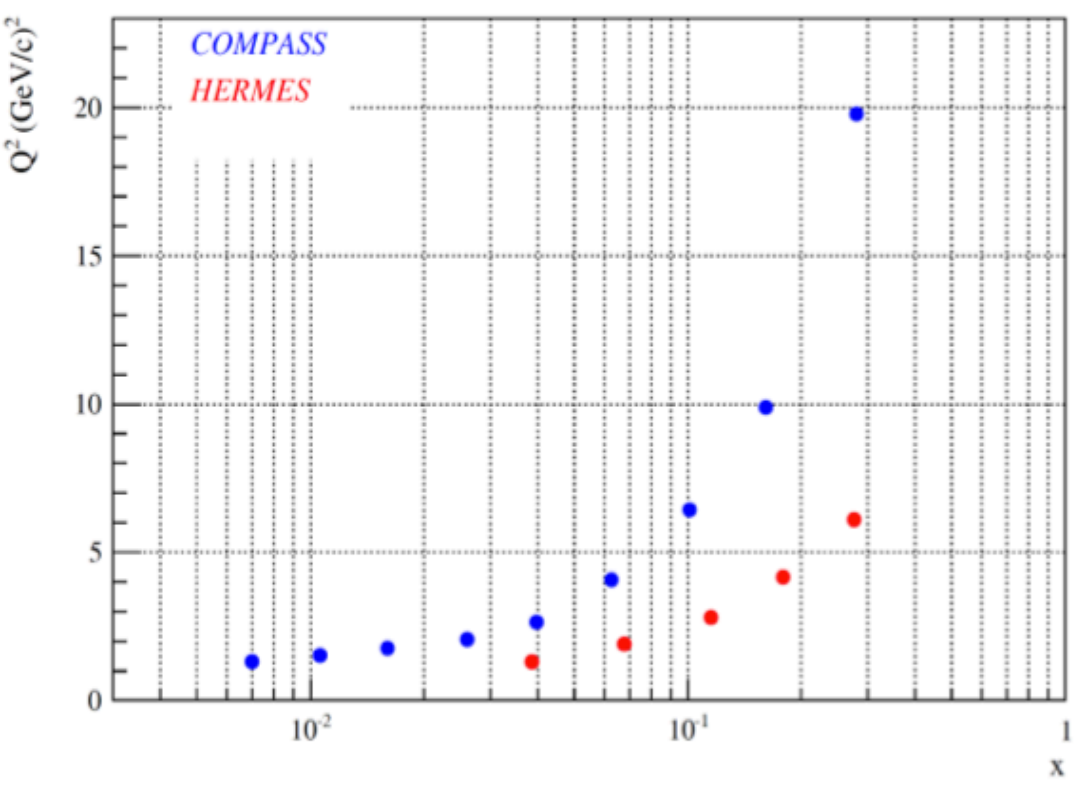
COMPASS vs. HERMES

- Fixed target experiments
- COMPASS still running, HERMES ended
- Larger kinematic coverage by COMPASS (low/large x)

x vs. Q^2

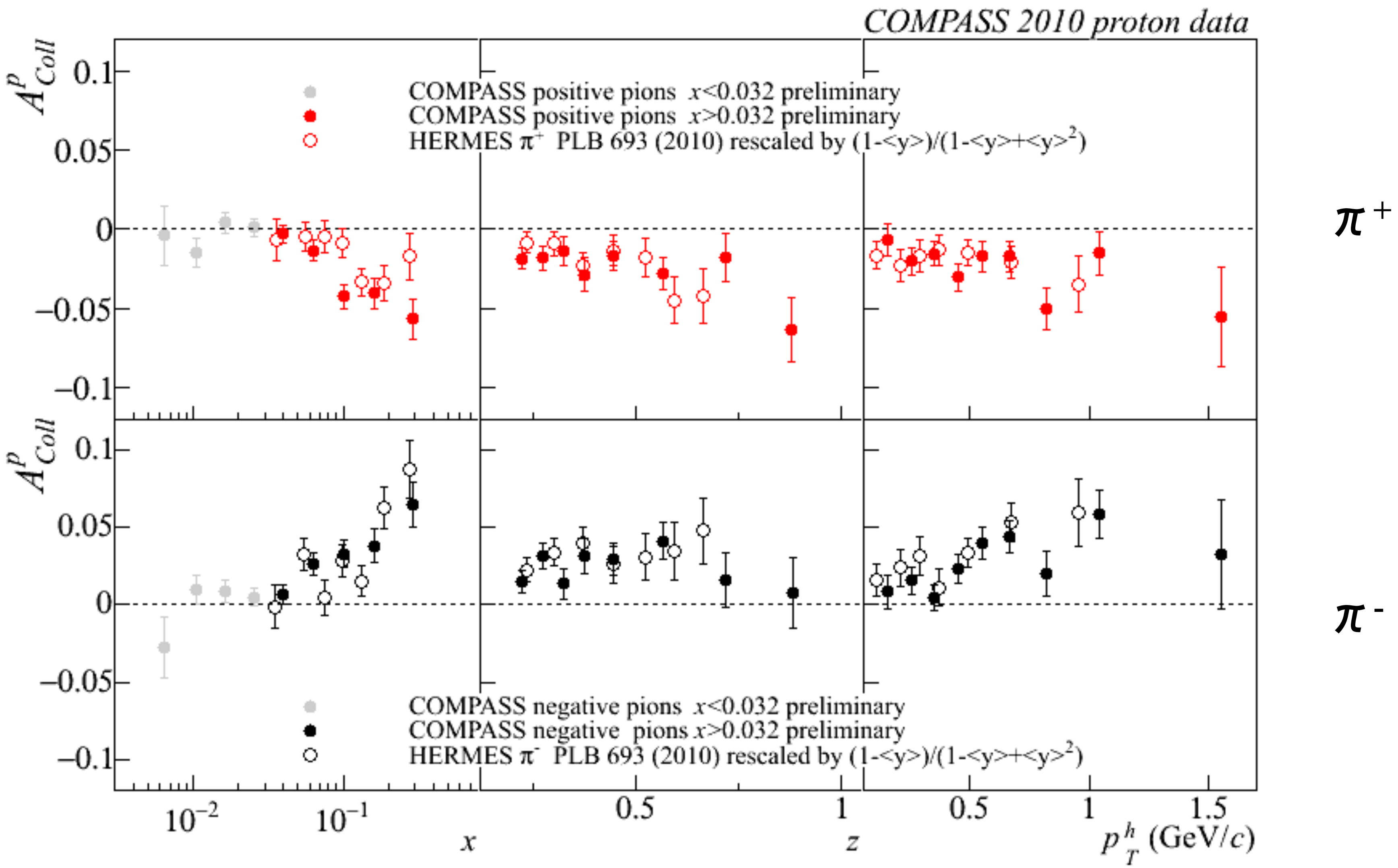


$<x>$ vs. $<Q^2>$



COMPASS vs. HERMES - Collins

- Larger cinematic coverage by COMPASS (low x)

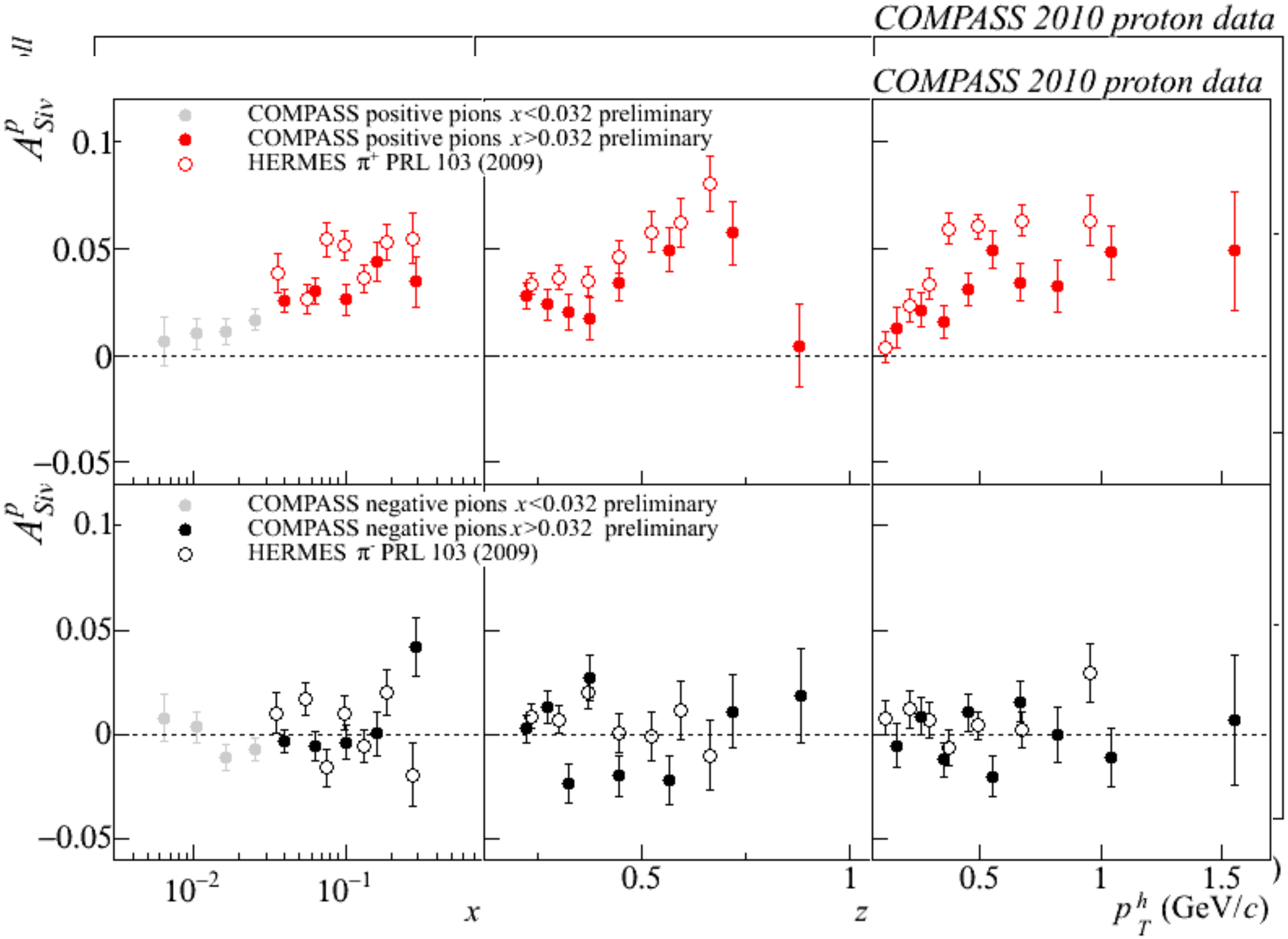


Compatible results in common kinematic range wirh energy scales different by ~ 2-3

intriguing observation …

COMPASS vs. HERMES - Collins

- Larger cinematic coverage by COMPASS (low x)



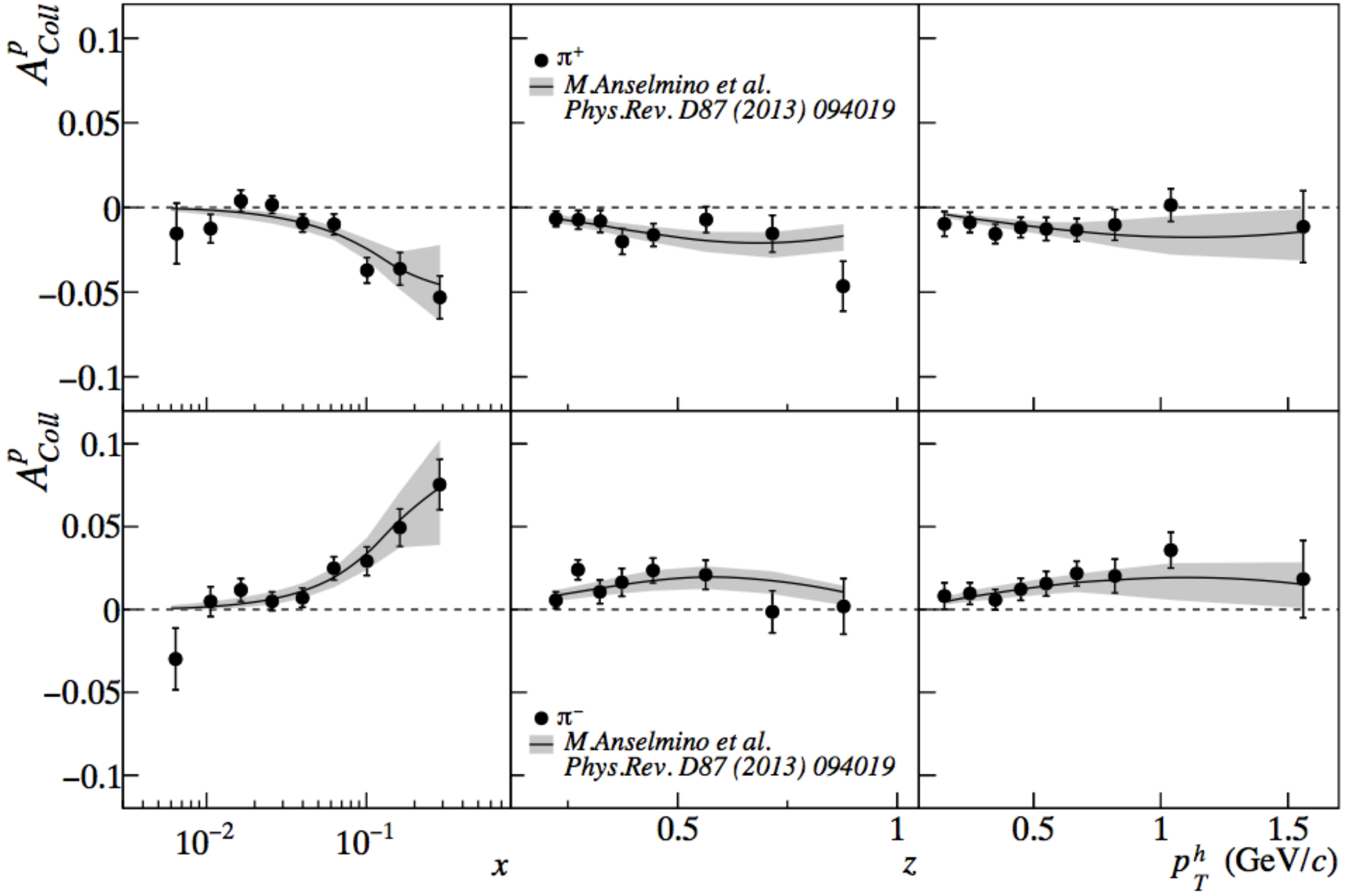
π^+

π^-

Sivers effect more pronounced at HERMES… Q^2-evolution related effect ??

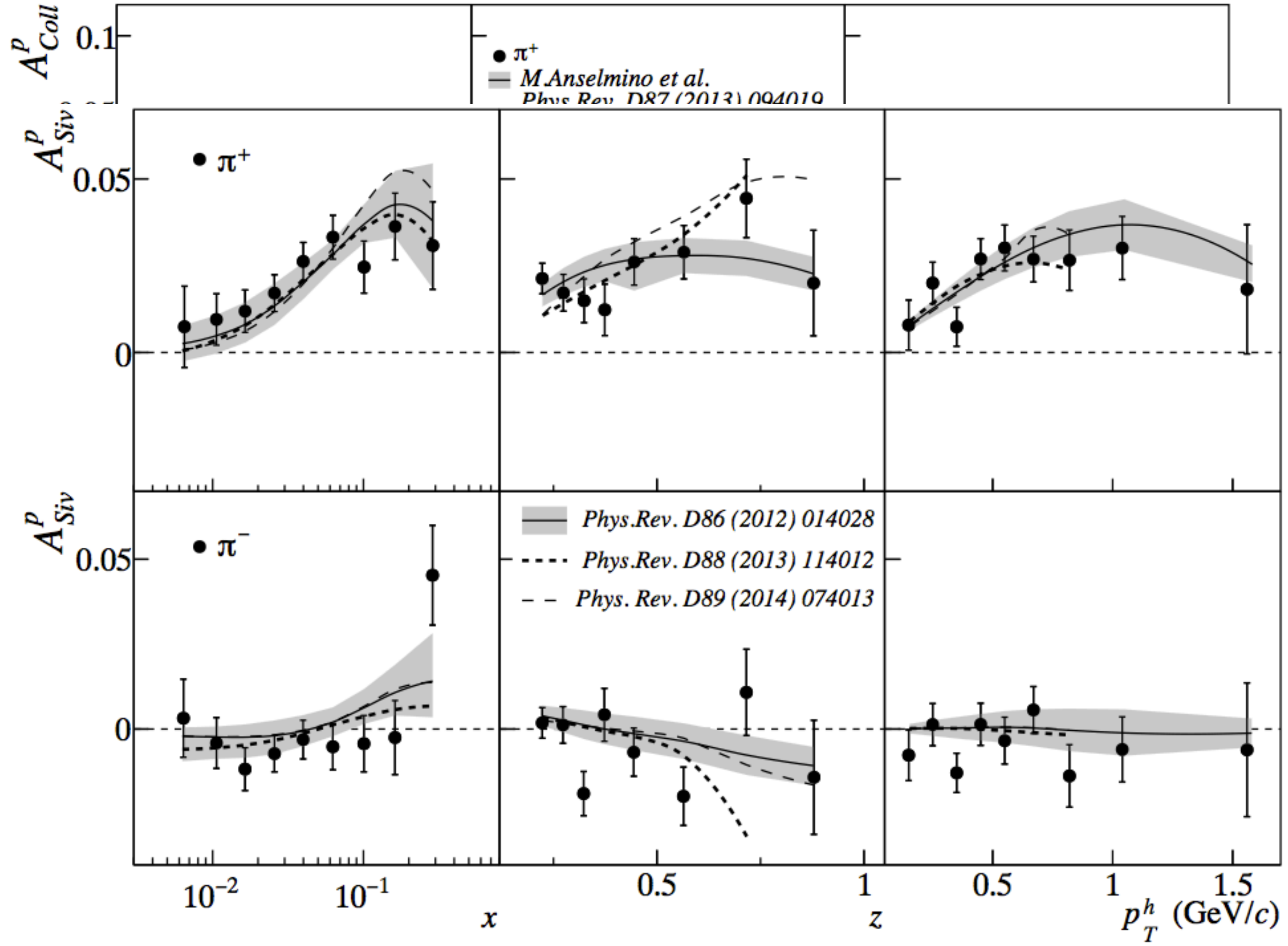
QCD analysis – Collins

Phys.Rev.D87 (2013) 094019



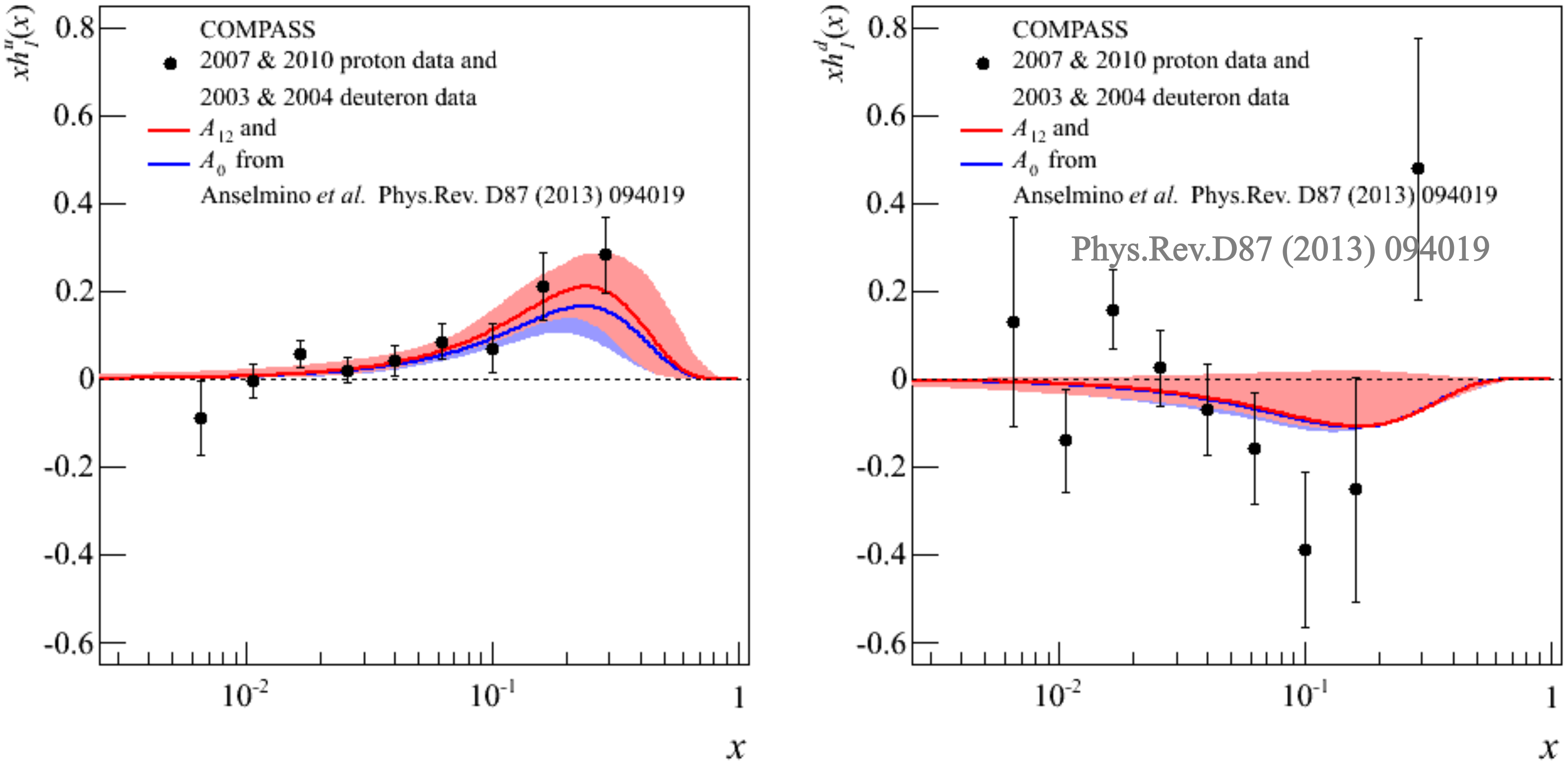
QCD analysis – Sivers

Phys.Rev.D87 (2013) 094019



QCD fit & Transversity function

NEW



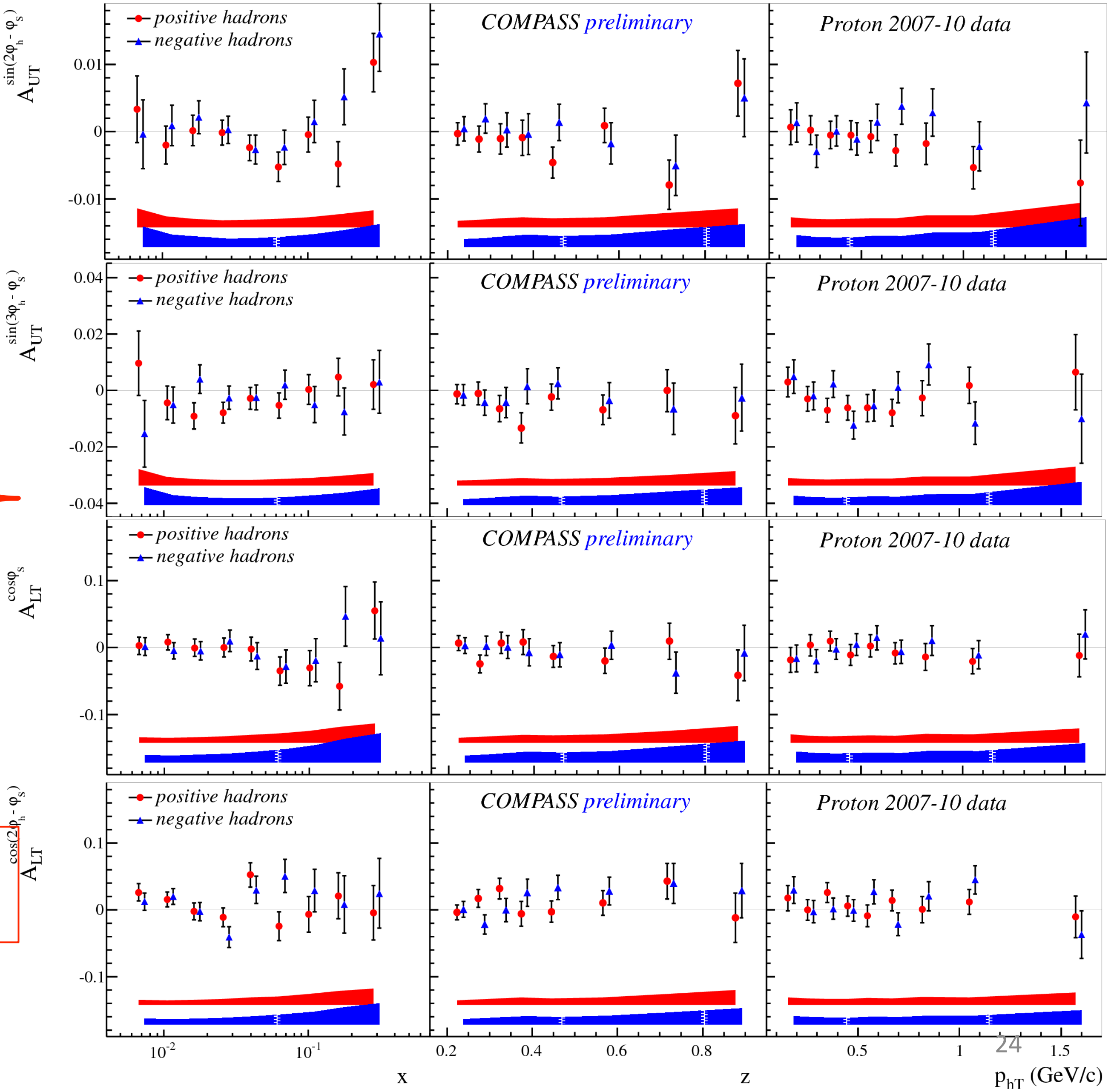
Phys.Rev.D87 (2013) 094019

- Good agreement for u quark and fair agreement for d quark

Beyond Collins & Sivers asymmetries (I)

$$\frac{d\sigma}{dx\,dy\,dz\,dP_{hT}^{2}\,d\varphi_h\,d\varphi_S} = \left[\frac{\alpha}{xyQ^2}\,\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right](F_{UU,T}+\varepsilon F_{UU,L})\times$$

$$\left(\begin{array}{ll}
\cdots + & \\
S_T & \left[\begin{array}{l}
\sin\varphi_S\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+\\
\sin(\varphi_h-\varphi_S)\left(A_{UT}^{\sin(\varphi_h-\varphi_S)}\right)+\\
\sin(\varphi_h+\varphi_S)\left(\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}\right)+\\
\sin(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}\right)+\\
\sin(3\varphi_h-\varphi_S)\left(\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right)
\end{array}\right. \\
S_T\lambda & \left[\begin{array}{l}
\cos\varphi_S\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+\\
\cos(\varphi_h-\varphi_S)\left(\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}\right)+\\
\cos(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)
\end{array}\right.
\end{array}\right.$$

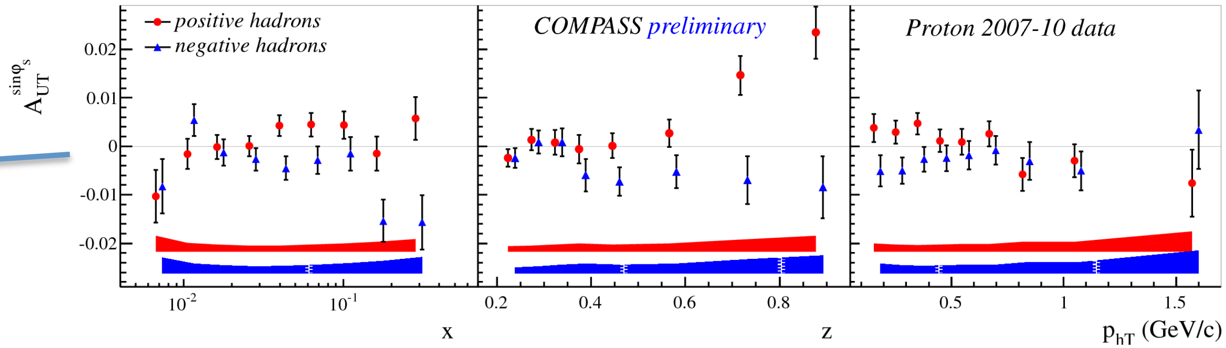


All compatible with zero within uncertainties

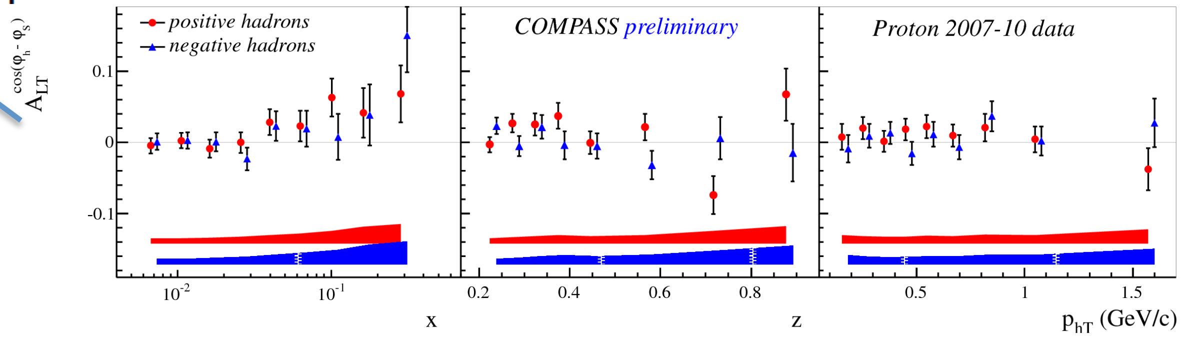
Beyond Collins & Sivers asymmetries (II)

$$\frac{d\sigma}{dxdydzdP_{hT}^2d\varphi_h d\varphi_S} = \left[\frac{\alpha}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right](F_{UU,T}+\varepsilon F_{UU,L})\times$$

$$\left(\begin{array}{l} \cdots + \\ S_T \left[\begin{array}{l} \sin\varphi_S\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+ \\ \sin(\varphi_h-\varphi_S)\left(A_{UT}^{\sin(\varphi_h-\varphi_S)}\right)+ \\ \sin(\varphi_h+\varphi_S)\left(\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}\right)+ \\ \sin(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}\right)+ \\ \sin(3\varphi_h-\varphi_S)\left(\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right) \end{array}\right] \\ S_T\lambda \left[\begin{array}{l} \cos\varphi_S\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+ \\ \cos(\varphi_h-\varphi_S)\left(\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}\right)+ \\ \cos(2\varphi_h-\varphi_S)\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right) \end{array}\right] \end{array}\right)$$

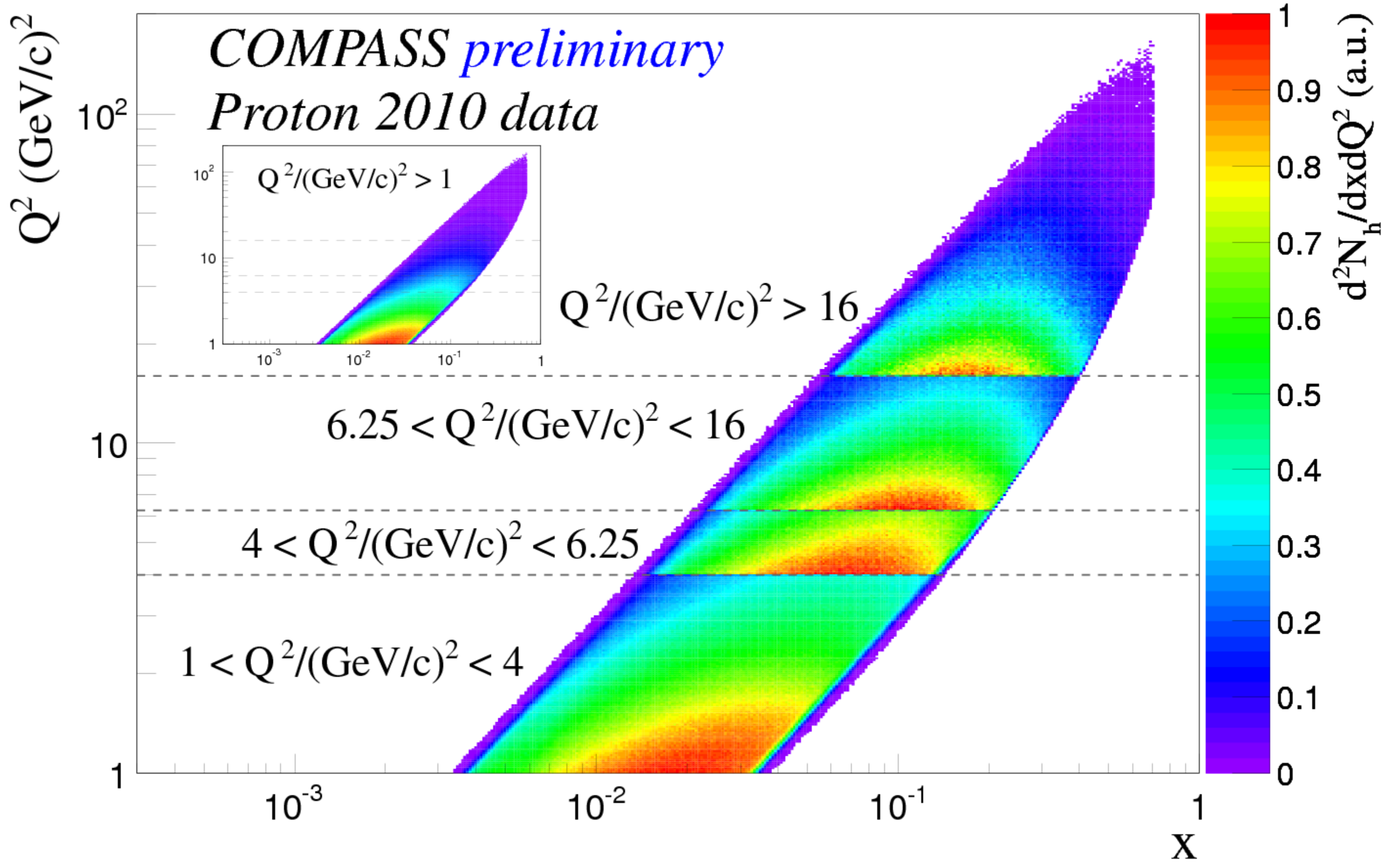


- Clear signal for h^+
- Sensitive to g_1 PDF
- Same Observation by HERMES



A Pre-Multidimensional Analysis

NEW



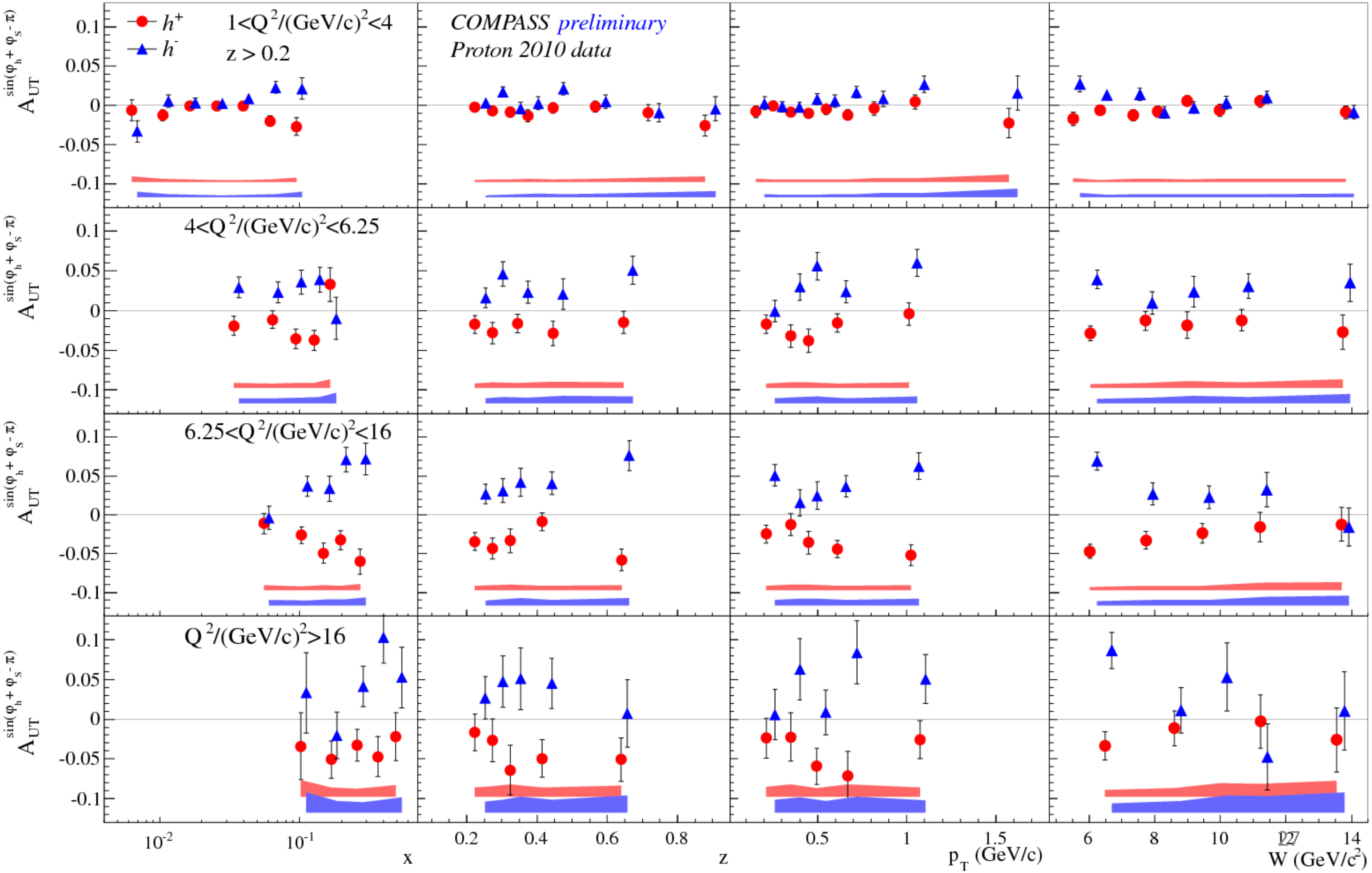
COMPASS proton 2010: $Q^2 > 1$ (GeV)^2, W > 5 (GeV), $0.1 < y < 0.9$, $z > 0.1$, $p_T > 0.1$
Four Q^2 bins & 2 z ranges:

$1 < Q^2 < 4$, $4 < Q^2 < 6.25$, $6.25 < Q^2 < 16$, $Q^2 > 16$ (GeV/c)^2
$0.2 < z < 1$, $0.1 < z < 1$

Collins asymmetries vs. x, z, p_T, W in Q^2 bins

NEW – Input for Q^2-evolution related studies

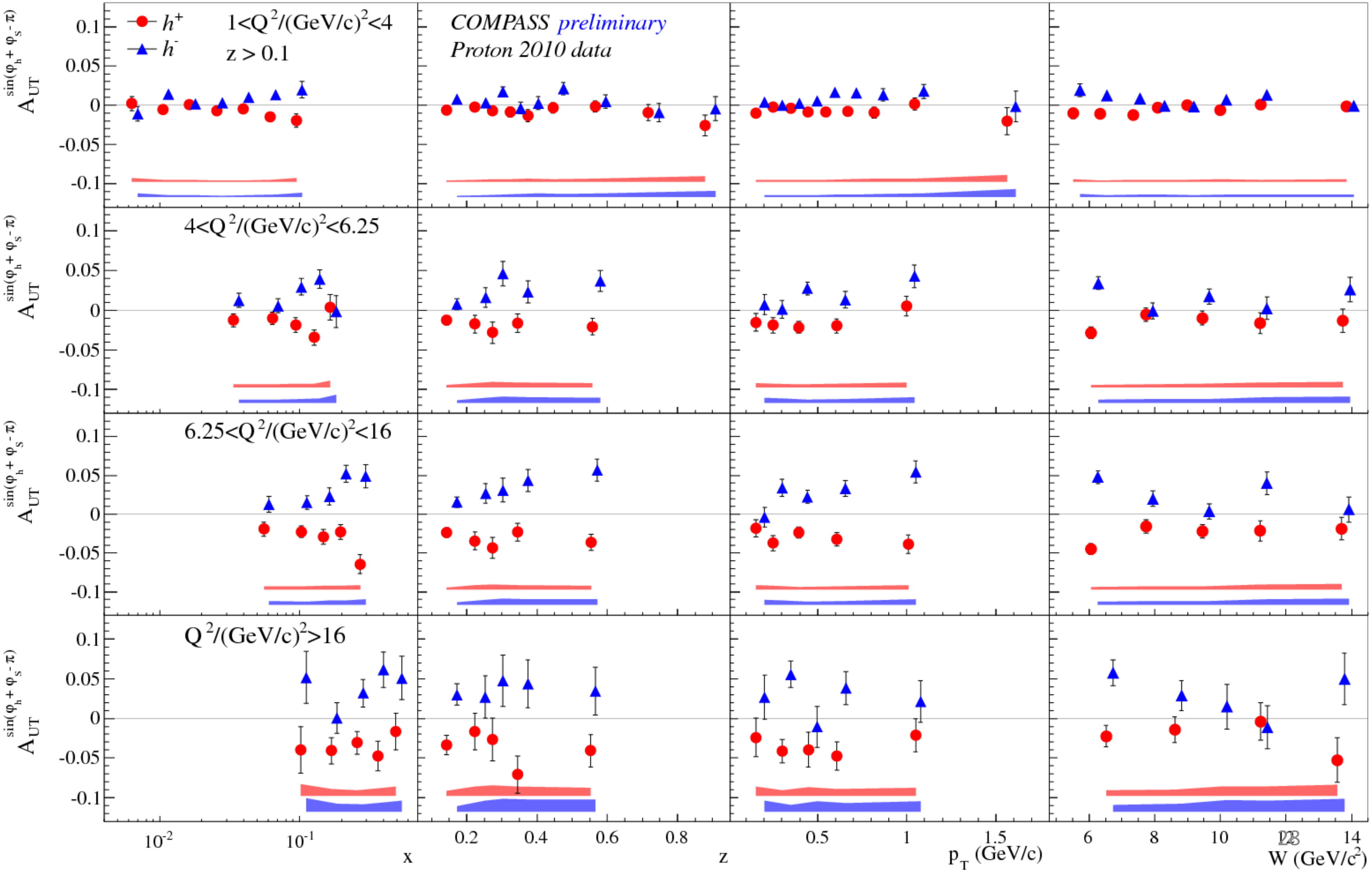
z > 0.2



Collins asymmetries vs. x, z, p_T, W in Q^2 bins

NEW – Input for Q^2-evolution related studies

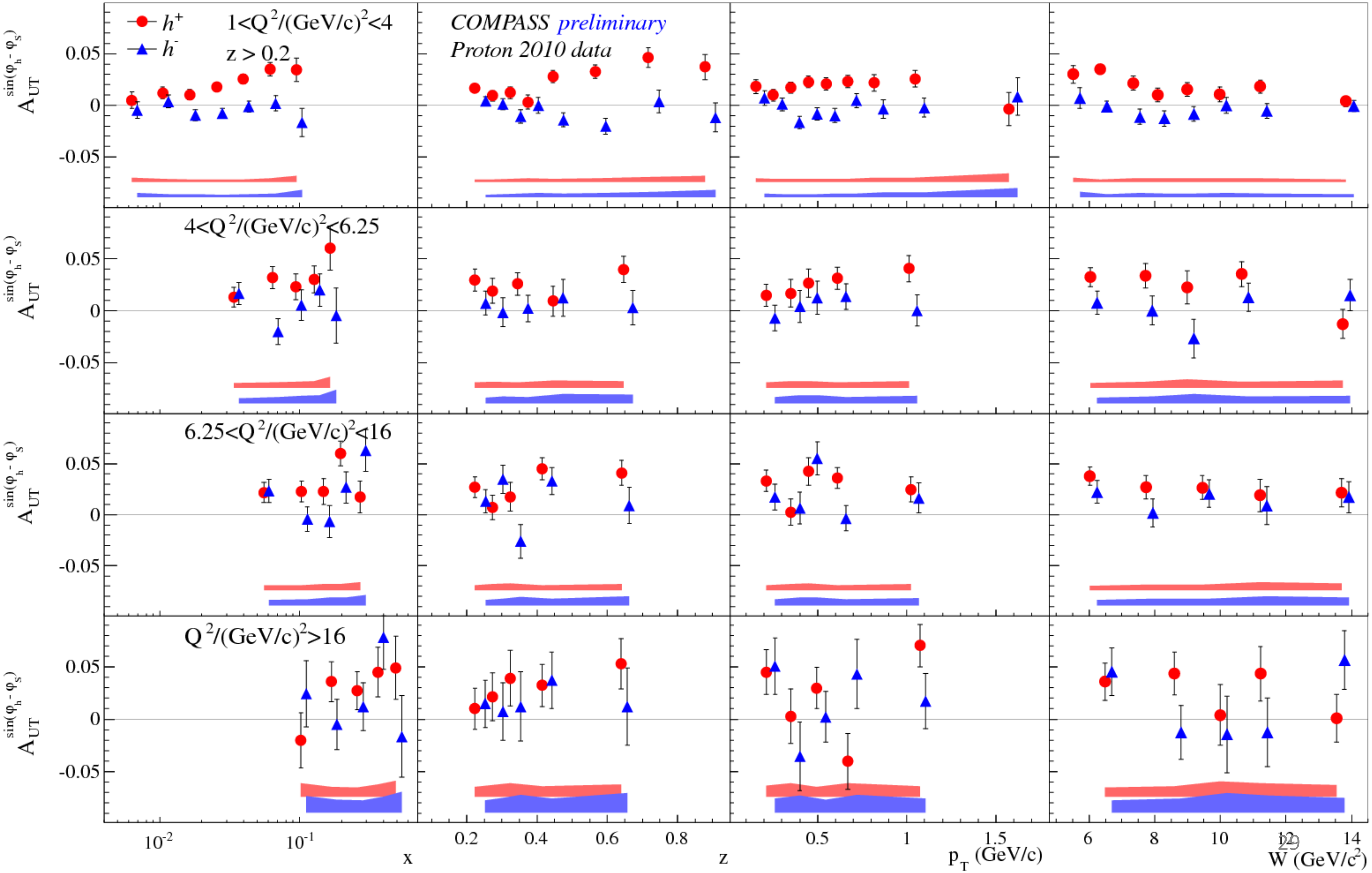
z > 0.1



Sivers asymmetries vs. x, z, p_T & W in Q^2 bins

NEW – Input for Q^2-evolution related studies

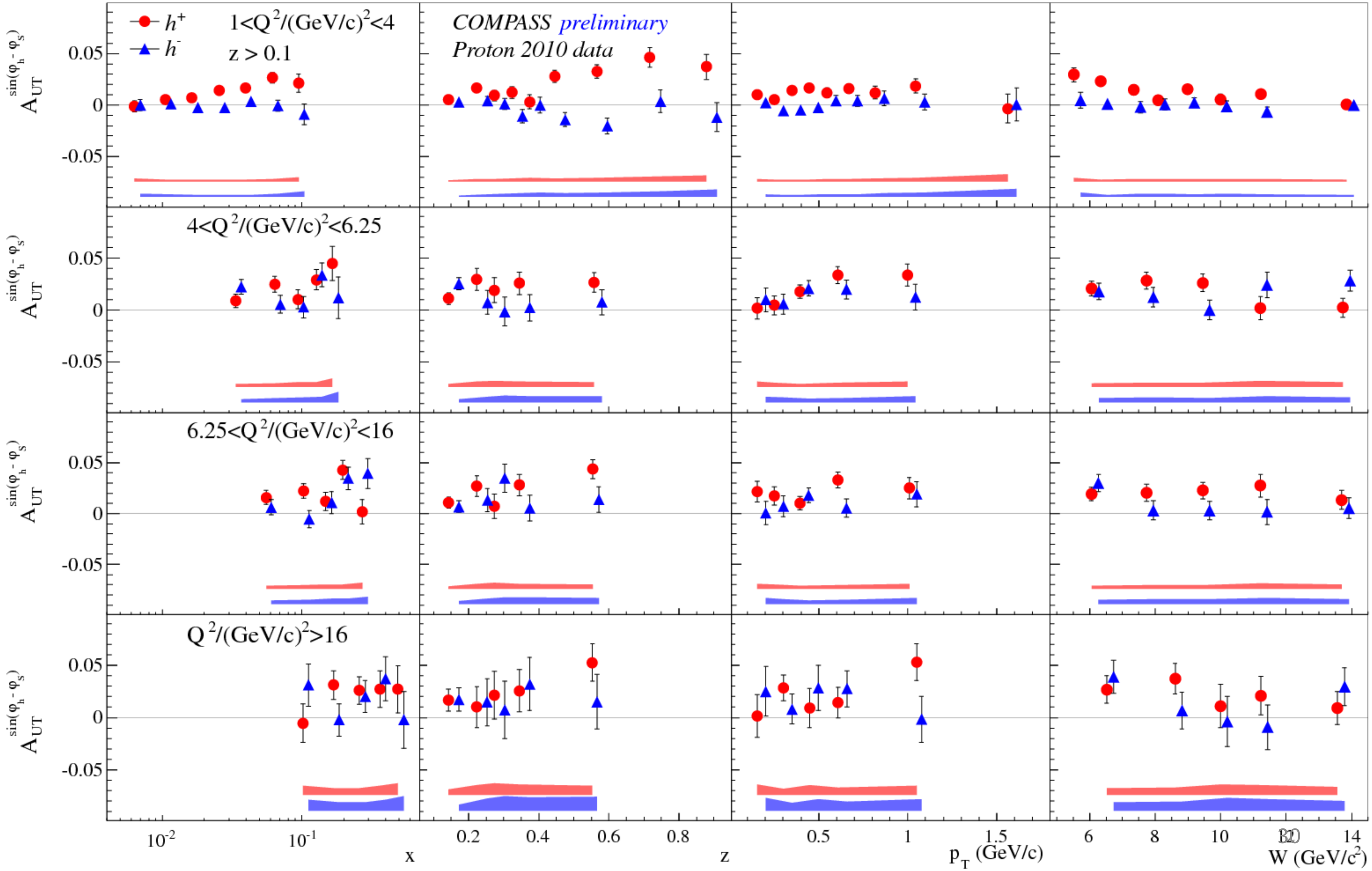
z > 0.2



Sivers asymmetries vs. x, z, p_T & W in Q^2 bins

NEW – Input for Q^2-evolution related studies

z > 0.1



Mean asymmetries

NEW

$$A_{UT}^{\sin(\varphi_h-\varphi_S)} \propto f_{1T}^{\perp q} \otimes D_{1q}^{h}$$

$$A_{UT}^{\sin(\varphi_h+\varphi_S)} \propto h_1^{q} \otimes H_{1q}^{\perp h}$$

$$A_{UT}^{(3\varphi_h-\varphi_S)} \propto h_{1T}^{\perp q} \otimes H_{1q}^{\perp h}$$

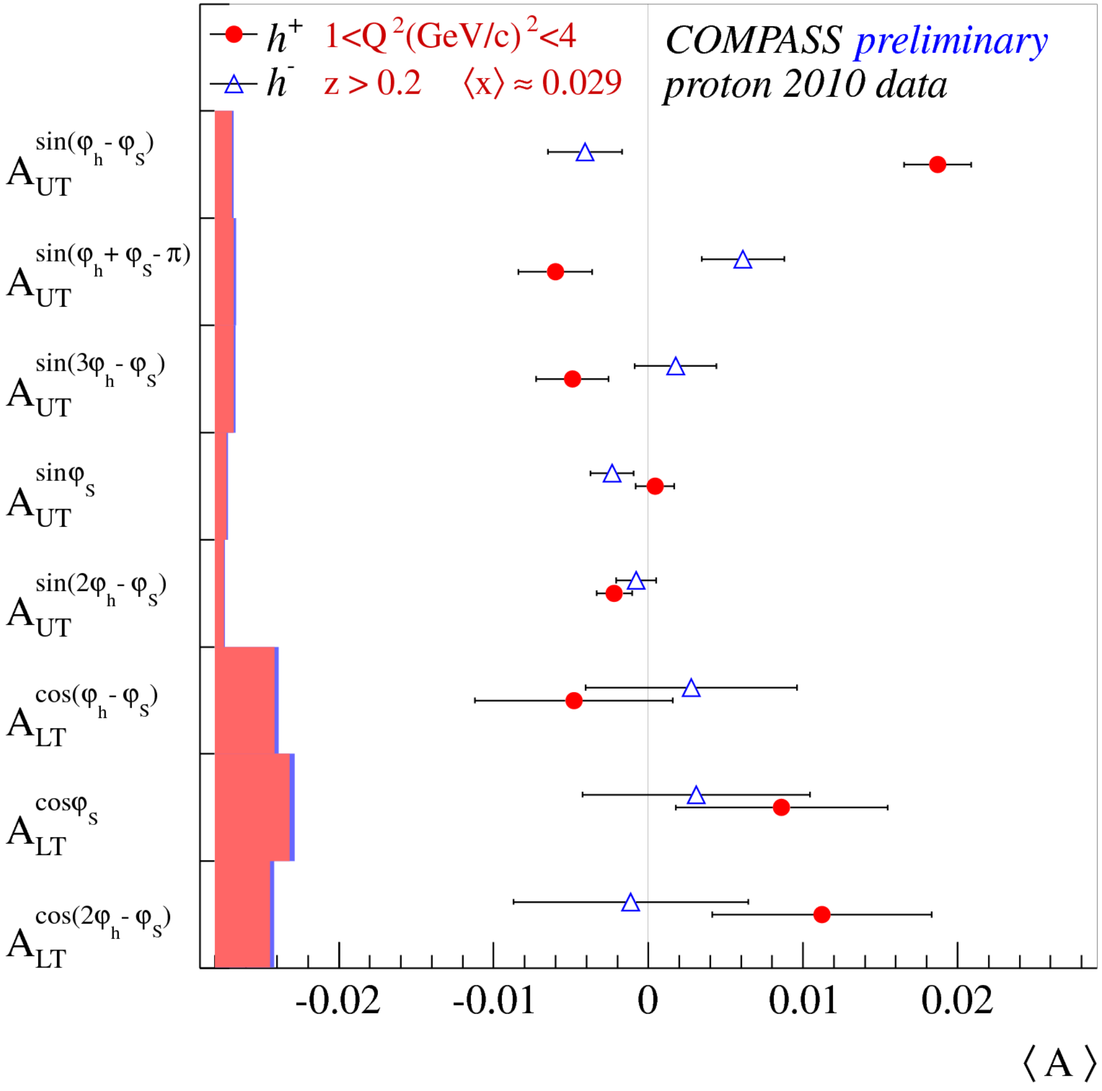
$$A_{UT}^{\sin\varphi_S} \propto Q^{-1}\left(h_1^{q} \otimes H_{1q}^{\perp h} + f_{1T} \otimes D_{1q}^{h} + \cdots\right)$$

$$A_{UT}^{\sin(2\varphi_h-\varphi_S)} \propto Q^{-1}\Big(h_{1T}^{\perp q} \otimes H_{1q}^{\perp h} + f_{1T}^{\perp h} \otimes D_{1q}^{h} + \cdot$$

$$A_{LT}^{\cos(\varphi_h-\varphi_S)} \propto g_{1T}^{q} \otimes D_{1q}^{h}$$

$$A_{LT}^{\cos\varphi_S} \propto Q^{-1}\left(g_{1T}^{q} \otimes D_{1q}^{h} + \cdots\right)$$

$$A_{LT}^{\cos(2\varphi_h-\varphi_S)} \propto Q^{-1}\left(g_{1T}^{q} \otimes D_{1q}^{h} + \cdots\right)$$



Mean asymmetries

NEW

$A \propto$ TMDs

$$A_{UT}^{\sin(\varphi_h-\varphi_S)} \propto f_{1T}^{\perp q} \otimes D_{1q}^{h}$$

$$A_{UT}^{\sin(\varphi_h+\varphi_S)} \propto h_{1}^{q} \otimes H_{1q}^{\perp h}$$

$$A_{UT}^{(3\varphi_h-\varphi_S)} \propto h_{1T}^{\perp q} \otimes H_{1q}^{\perp h}$$

$$A_{UT}^{\sin\varphi_S} \propto Q^{-1}\left(h_{1}^{q} \otimes H_{1q}^{\perp h} + f_{1T} \otimes D_{1q}^{h} + \cdots\right)$$

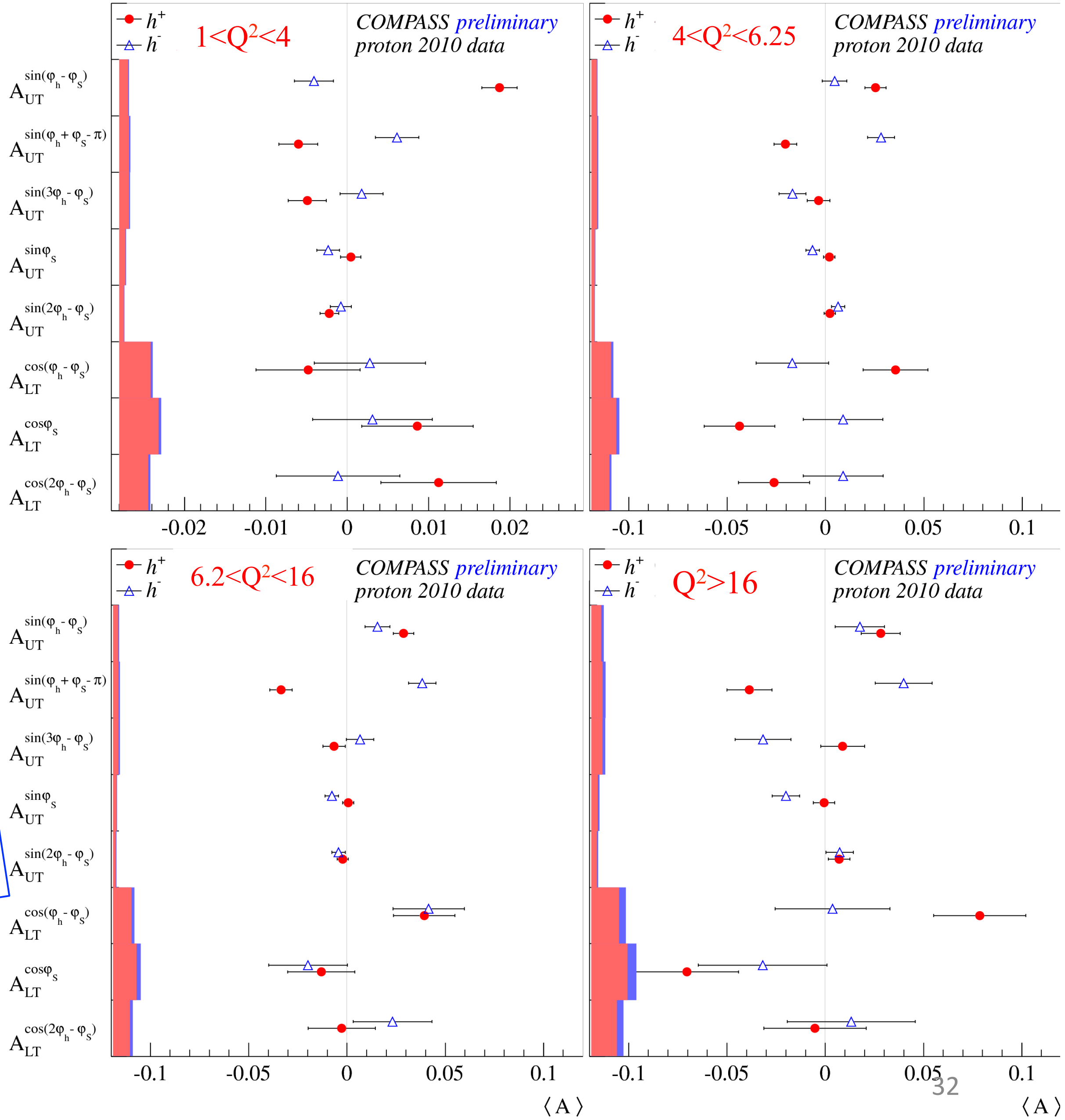
$$A_{UT}^{\sin(2\varphi_h-\varphi_S)} \propto Q^{-1}\Big(h_{1T}^{\perp q} \otimes H_{1q}^{\perp h} + f_{1T}^{\perp h} \otimes D_{1q}^{h}$$

$$A_{LT}^{\cos(\varphi_h-\varphi_S)} \propto g_{1T}^{q} \otimes D_{1q}^{h}$$

$$A_{LT}^{\cos\varphi_S} \propto Q^{-1}\left(g_{1T}^{q} \otimes D_{1q}^{h} + \cdots\right)$$

$$A_{LT}^{\cos(2\varphi_h-\varphi_S)} \propto Q^{-1}\left(g_{1T}^{q} \otimes D_{1q}^{h} + \cdots\right)$$

All TMD PDFs encoded in the data



Unpolarized Azimuthal Asymmetries

$$\frac{d\sigma}{dx\,dy\,d\psi\,dz\,d\phi_h\,dP_{h\perp}^2} =$$

$$\frac{\alpha^2}{xyQ^2}\,\frac{y^2}{2\,(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\Big\{F_{UU,T}+\varepsilon F_{UU,L}+\sqrt{2\,\varepsilon(1+\varepsilon)}\,\cos\phi_h\,\boxed{F_{UU}^{\cos\phi_h}}$$

$$+\,\varepsilon\cos(2\phi_h)\,\boxed{F_{UU}^{\cos 2\phi_h}}+\lambda_e\,\sqrt{2\,\varepsilon(1-\varepsilon)}\,\sin\phi_h\,F_{LU}^{\sin\phi_h}\qquad+\ldots$$

SIDIS cross-section
Unpolarized
nucleons

Kinematical effect due to quark intrinsic transverse momentum

Boer-Mulders DF

Cahn effect

→ $\langle k_T^2\rangle$
M. Aghasyan

$$\boxed{F_{UU}^{\cos\phi_h}} = \frac{2M}{Q}\,\mathcal{C}\left[-\frac{\hat{\boldsymbol{h}}\cdot\boldsymbol{k}_T}{M_h}\left(xh\,H_1^\perp+\frac{M_h}{M}\,f_1\frac{\tilde{D}^\perp}{z}\right)-\frac{\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T}{M}\left(xf^\perp D_1+\frac{M_h}{M}\,h_1^\perp\frac{\tilde{H}}{z}\right)\right]$$

$$xh = x\tilde{h}+\frac{p_T^2}{M^2}\,h_1^\perp \qquad xf^\perp = x\tilde{f}^\perp + f_1 \qquad\qquad F_{UU}^{\cos\phi_h}\approx\frac{2M}{Q}\,\mathcal{C}\left[-\frac{\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T}{M}\,f_1D_1\right]$$

$$\boxed{F_{UU}^{\cos 2\phi_h}} = \mathcal{C}\left[-\frac{2\,(\hat{\boldsymbol{h}}\cdot\boldsymbol{k}_T)\,(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)-\boldsymbol{k}_T\cdot\boldsymbol{p}_T}{M\,M_h}\,h_1^\perp H_1^\perp\right]$$

Boer-Mulders PDF x Collins FF
+ Cahn effect (twist 4, $1/Q^2$)

Correlation between quark transverse momentum and quark spin inside unpolarized nucleon

Unpolarized asymmetries: kinematic range

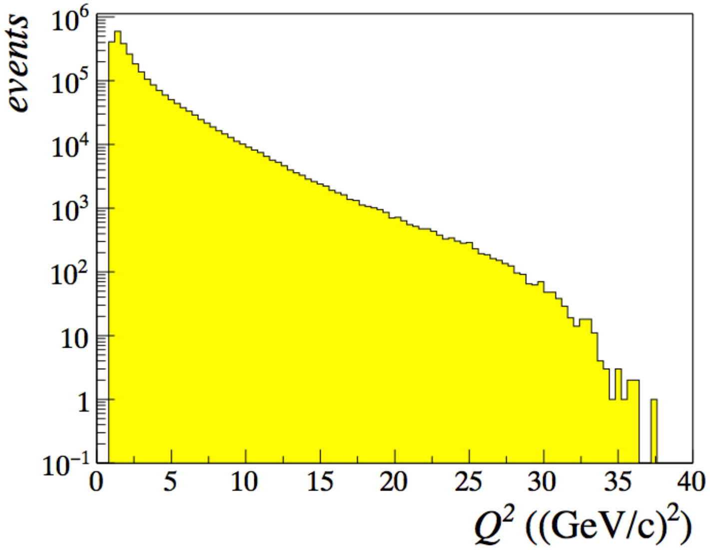
SIDIS data collected in 2004 using ^{6}LiD target

Kinematic selection:

- ○ $Q^2 > 1\ (\mathrm{GeV})^2$
- ○ $W > 5\ (\mathrm{GeV}/c^2)$

- ○ $0.003 < x \underline{\leq 0.13}$
- ○ $0.2 < y < 0.9$

Submitted for publication
CERN-PH-EP-2014-009



Unpolarized asymmetries: kinematic range

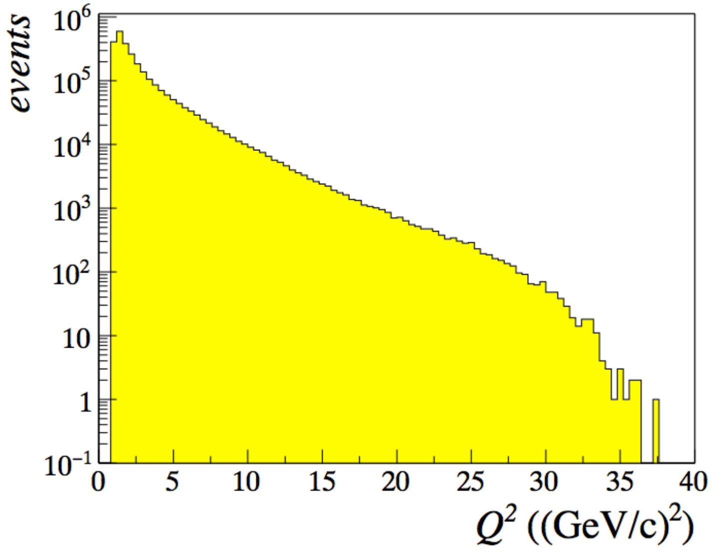
SIDIS data collected in 2004 using ^{6}LiD target
Kinematic selection:

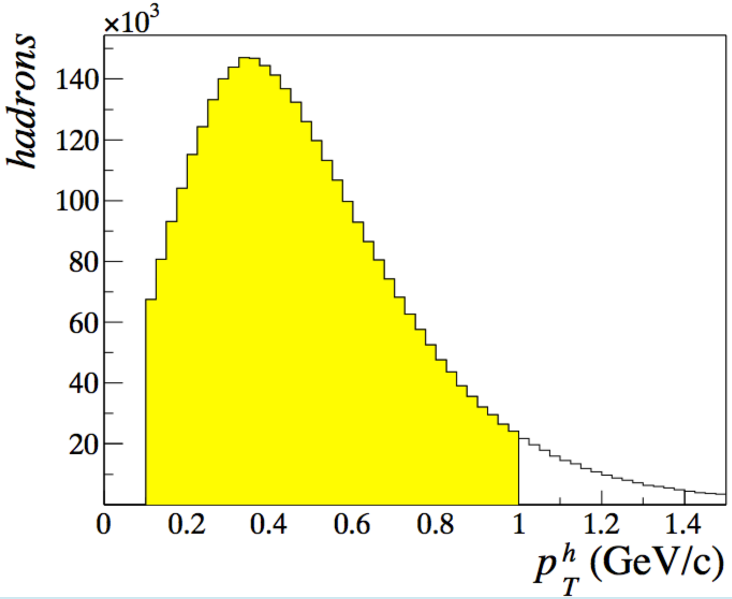
- $Q^2 > 1$ (GeV)^2
- $W > 5$ (GeV/c^2)

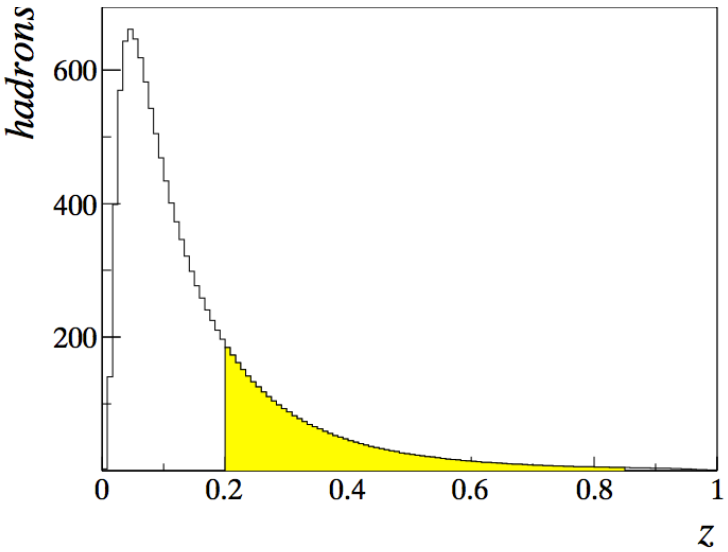
- $0.003 < x < 0.13$
- $0.2 < y < 0.9$

- $0.2 < z < 0.85$
- $0.1 < p_T < 1$

CERN-PH-EP-2014-009

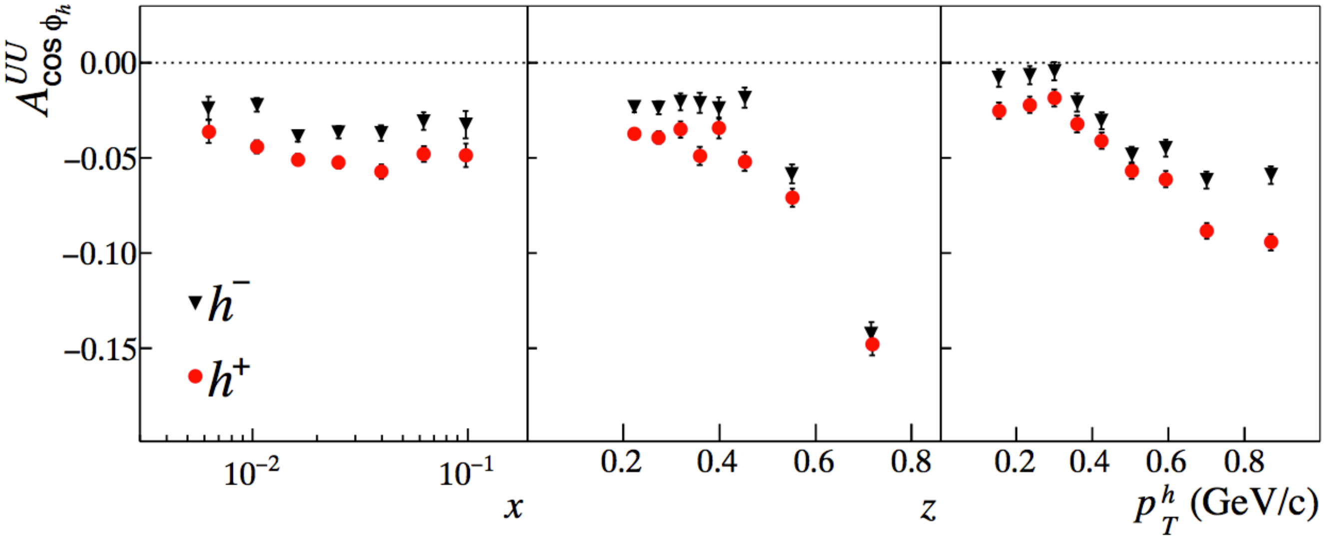






Azimuthal Asymmetries: $A_{UU}^{\cos\Phi}$ and $A_{UU}^{\cos2\Phi}$ amplitudes h^+/h^-

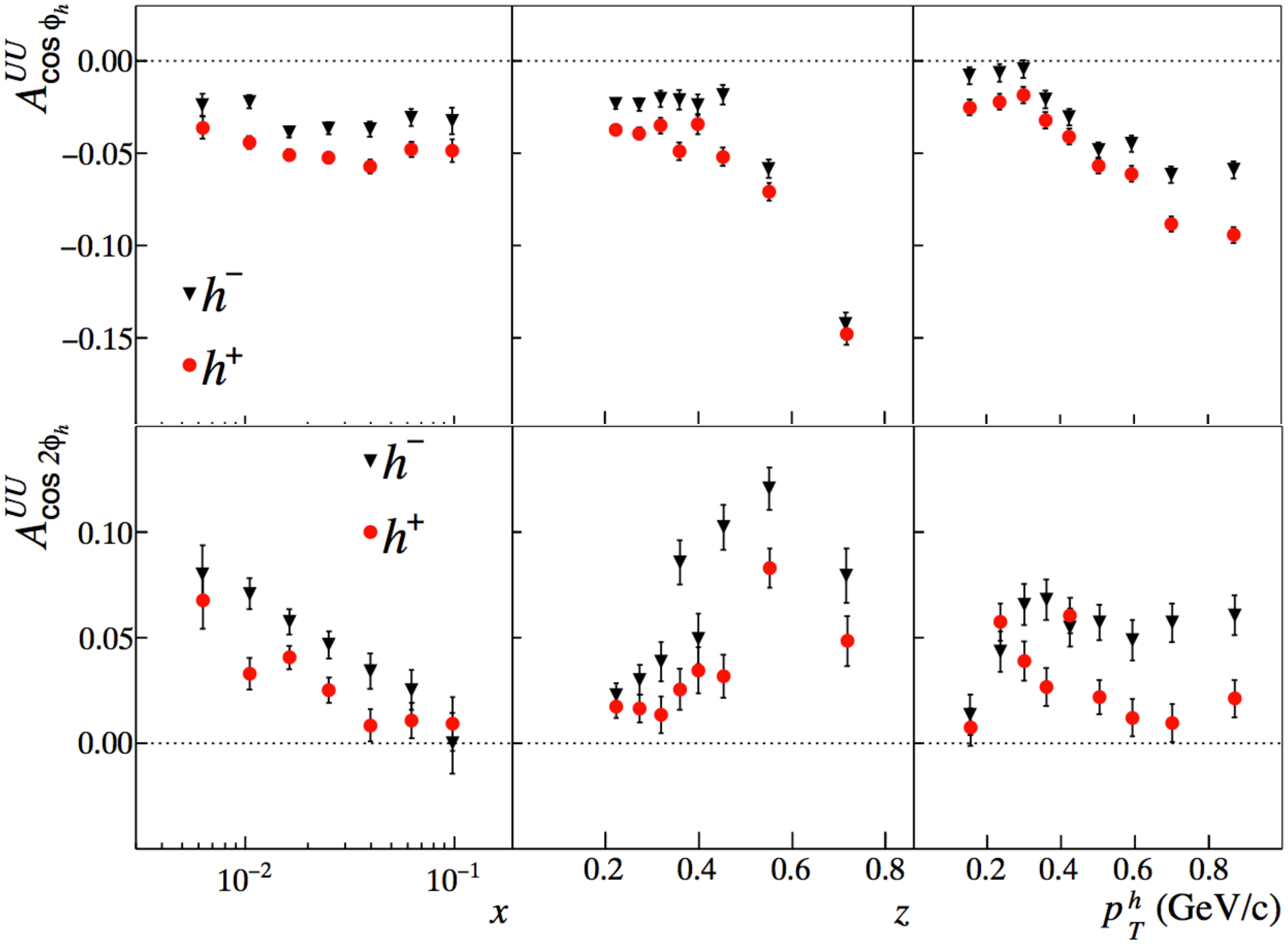
CERN-PH-EP-2014-009



- Negative amplitudes h^+/h^-
- Clear differences between h^+/h^-
  - Larger amplitude for h^+
- Strong z dependence (>0.5)
- Large signal over all x

Azimuthal Asymmetries: $A_{UU}^{\cos\Phi}$ and $A_{UU}^{\cos2\Phi}$ amplitudes h^+/h^-

CERN-PH-EP-2014-009



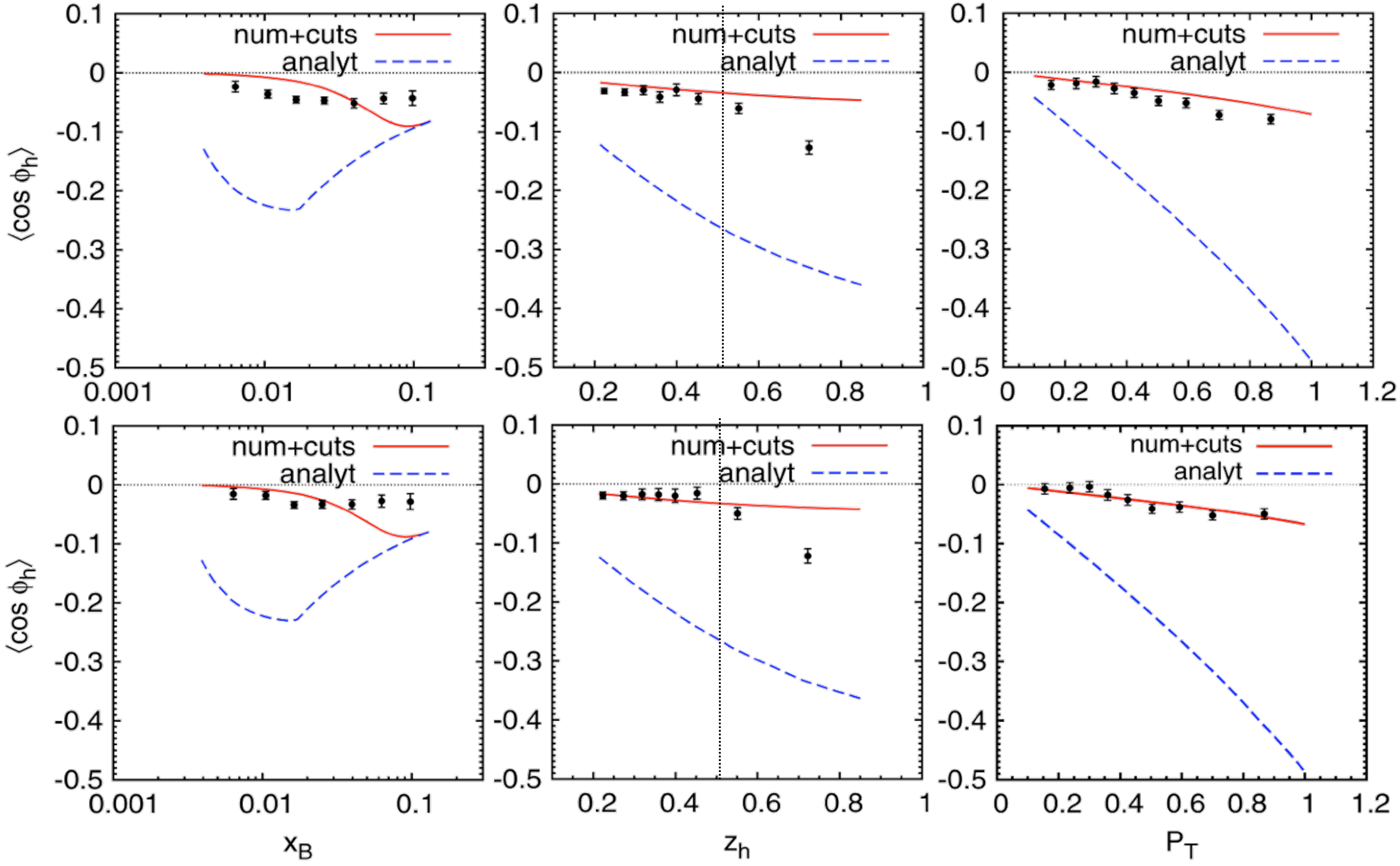
- Negative amplitudes h^+/h^-
- Clear differences between h^+/h^-
  - Larger amplitude for h^+
- Strong z dependence (>0.5)
- Large signal over all x

- Positive amplitudes h^+/h^-
- Clear differences between h^+/h^-
- Large signal at small x
- Strong dependence on kinematic variables x,z,p_T

⇒ Multi-dimensional analysis for a better understanding of kinematic dependences

$A_{UU}^{\cos\Phi}$ – amplitude: comparison with theory h^+/h^-

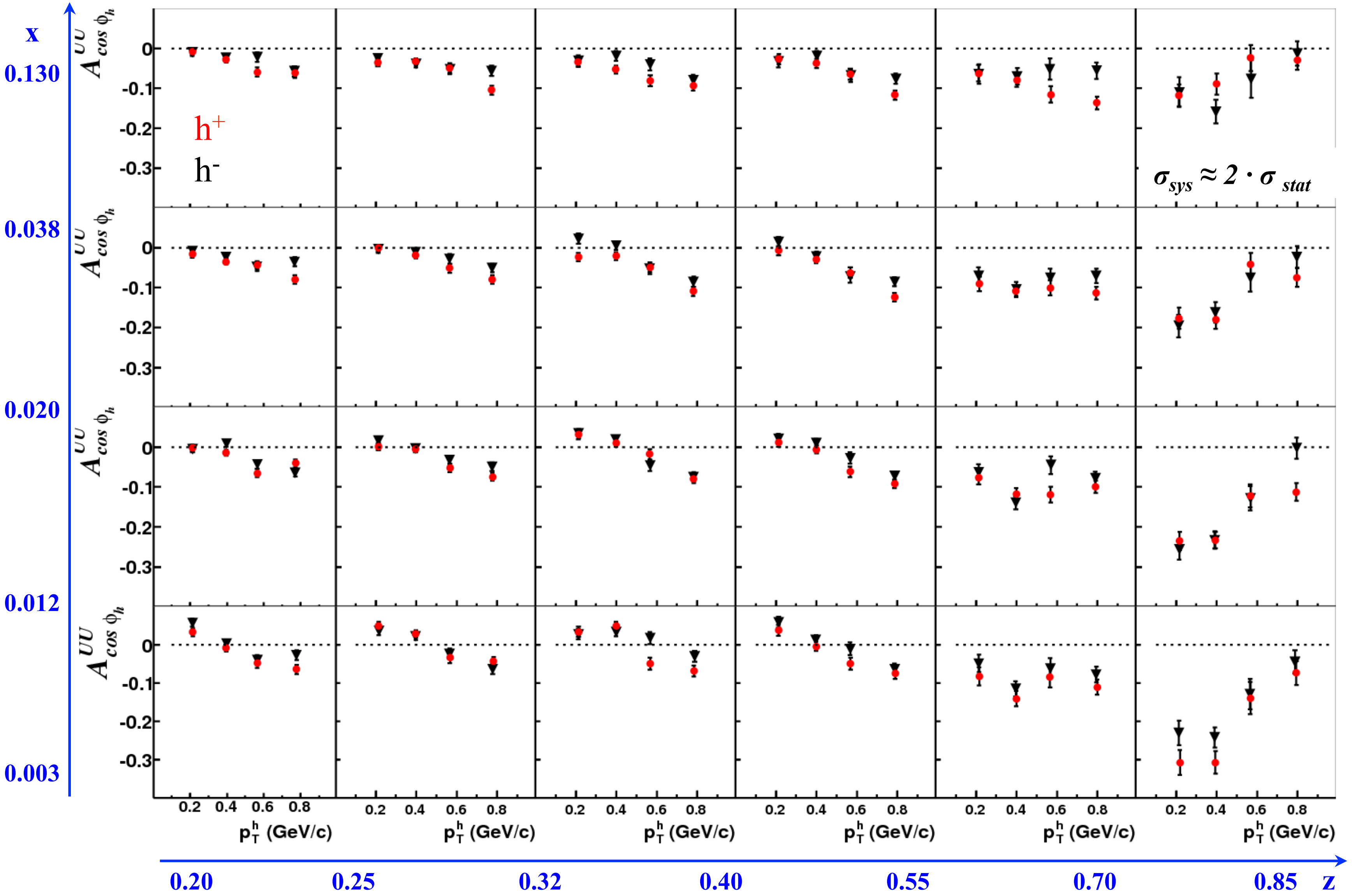
M. Boglione, S. Melis, and A. Prokudin, **Phys. Rev. D 84,** 034033 (2011)



1) the energy of the parton to be less than the energy of the parent hadron → $k_\perp^2 \leq (2-x_B)(1-x_B)Q^2, \qquad 0 < x_B < 1.$

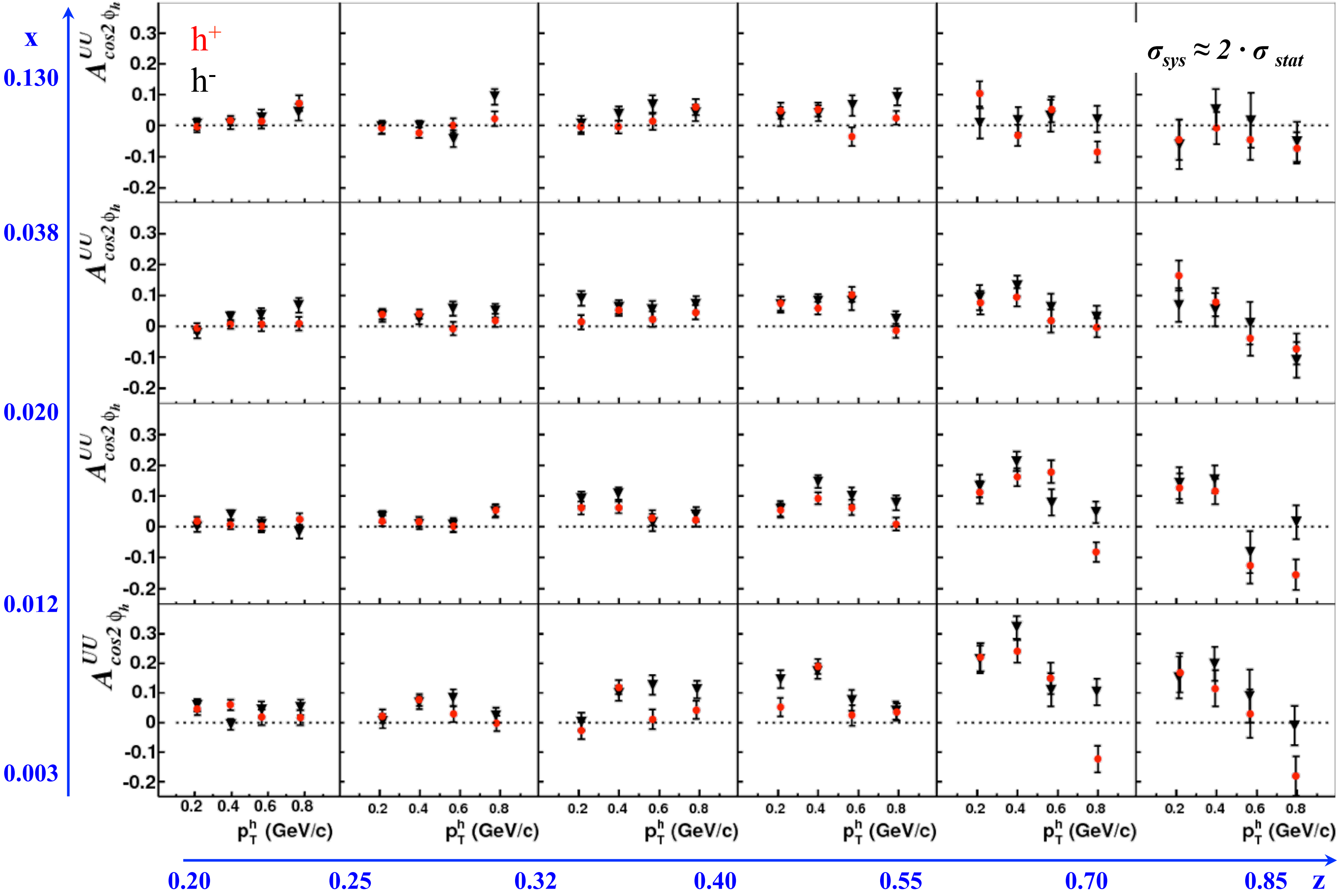
2) the parton to move in the forward direction with respect to the parent hadron → $k_\perp^2 \leq \dfrac{x_B(1-x_B)}{(1-2x_B)^2}Q^2, \qquad x_B < 0.5.$

$A_{UU}{}^{\cos\Phi}$ – asymmetry: p_T dependence



Strong z dependence, more evident at small x and small p_T

$A_{UU}^{\cos 2\Phi}$ – asymmetry: p_T dependence



p_T trend not described by the models arises at large z and low x

$A_{UU}^{\cos 2\Phi}$ – asymmetry: x and p_T dependence

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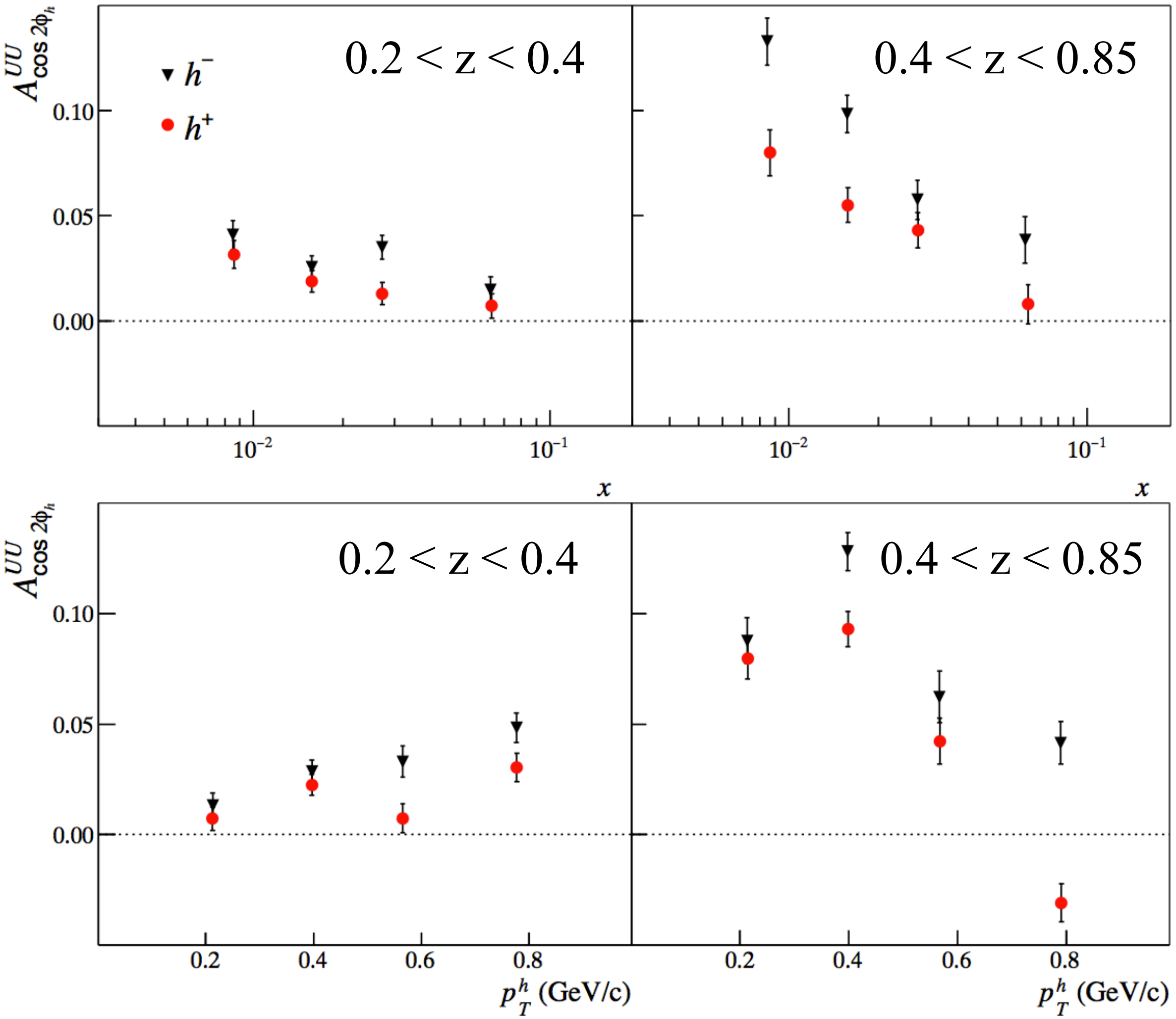


⇒ Different z and p_T^2 dependencies for different z regimes … to be understood

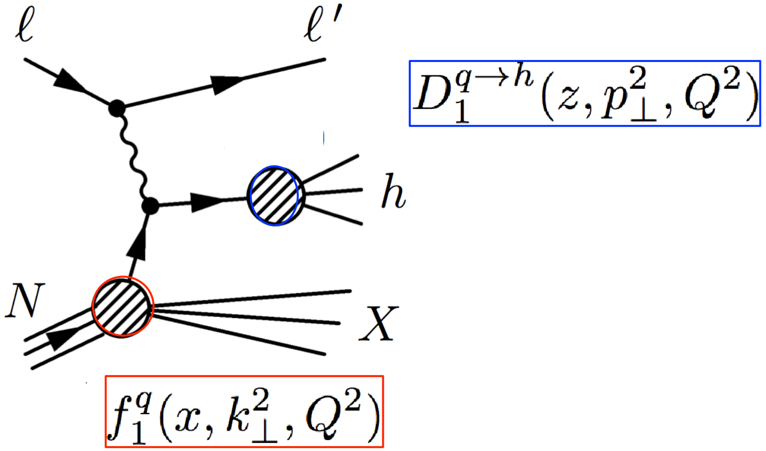
… more to come from 2006 deuteron data (with PID)

… another interesting observable sensitive to
TMD PDFs & FFs

Hadron multiplicity

Experimental observable: Multiplicity

Defined as average number of hadrons
produced per DIS event



$$\boxed{D_1^{q\rightarrow h}(z, p_\perp^2, Q^2)}$$

$$\boxed{f_1^q(x, k_\perp^2, Q^2)}$$

$$M_N^h(x, z, p_T^2, Q^2) = \frac{d^4\sigma_N^h/(dx dz dp_T^2 dQ^2)}{d^2\sigma_{DIS}/(dx dQ^2)} \sim \frac{F_{UU}(x, z, p_T^2; Q^2)}{F_T(x, Q^2)}$$

$$\sim f_1^q(x, k_\perp^2, Q^2) \times D_1^{q\rightarrow h}(z, p_\perp^2, Q^2)$$

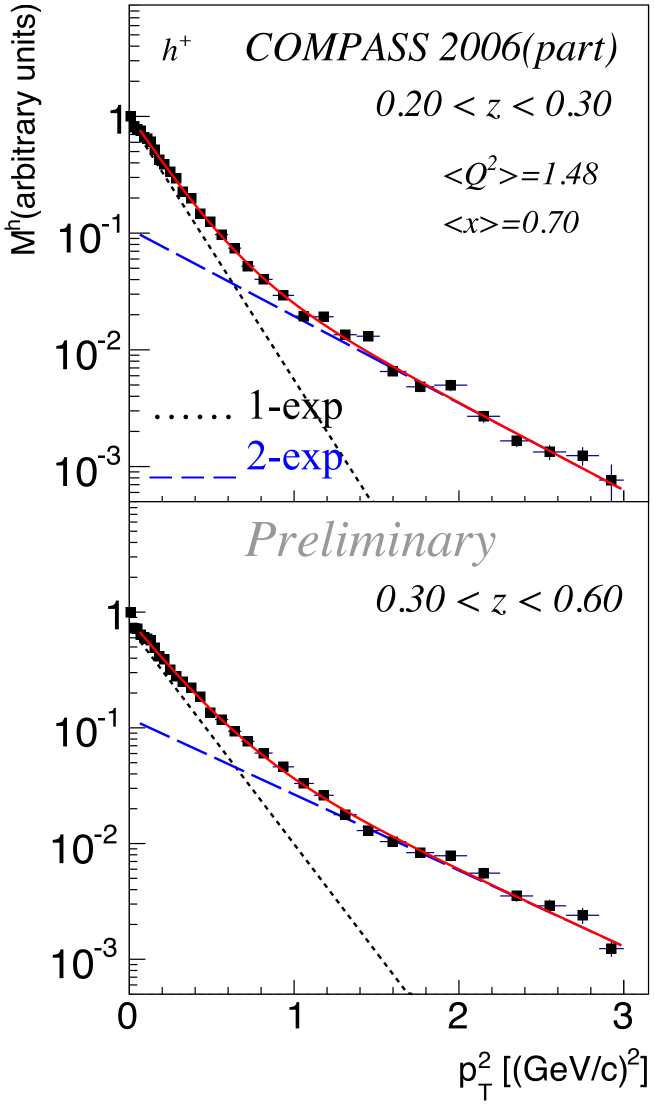
TMD-PDFs TMD-FFs

p_T integrated multiplicities not covered in this talk

h^+ distributions, $Q^2 \in [1.5, 2.5]$, $x \in [0.018, 0.025]$

COMPASS 2006 data

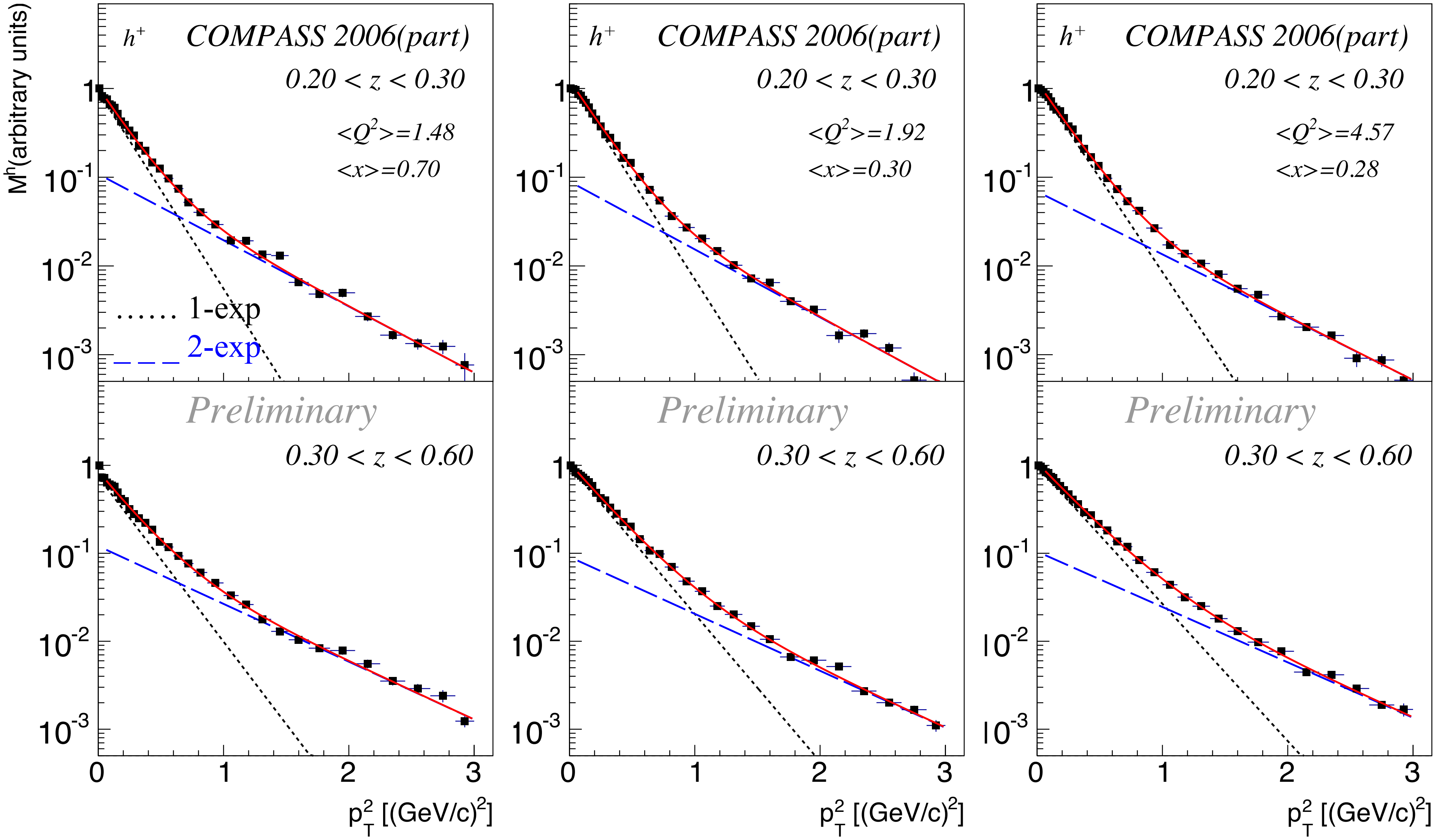
NEW



- Precise measurement using 2006 data with larger angular acceptance
- p_T^2 range extended to 3 (GeV/c)^2
- Very promising to extract physics on transverse momentum dependent PDFs and FFs
- Fit multiplicities with
  - ○ 1-exponential for $p_T^2 \in [0.05, 0.68]$
  - ○ 2-exponentials for $p_T^2 \in [0.05, 3]$
  - ⇒ Need 2-exponentials to describe p_T^2 shape of COMPASS data
- Ongoing analysis to extract complete set of multiplicities in full kinematic domain

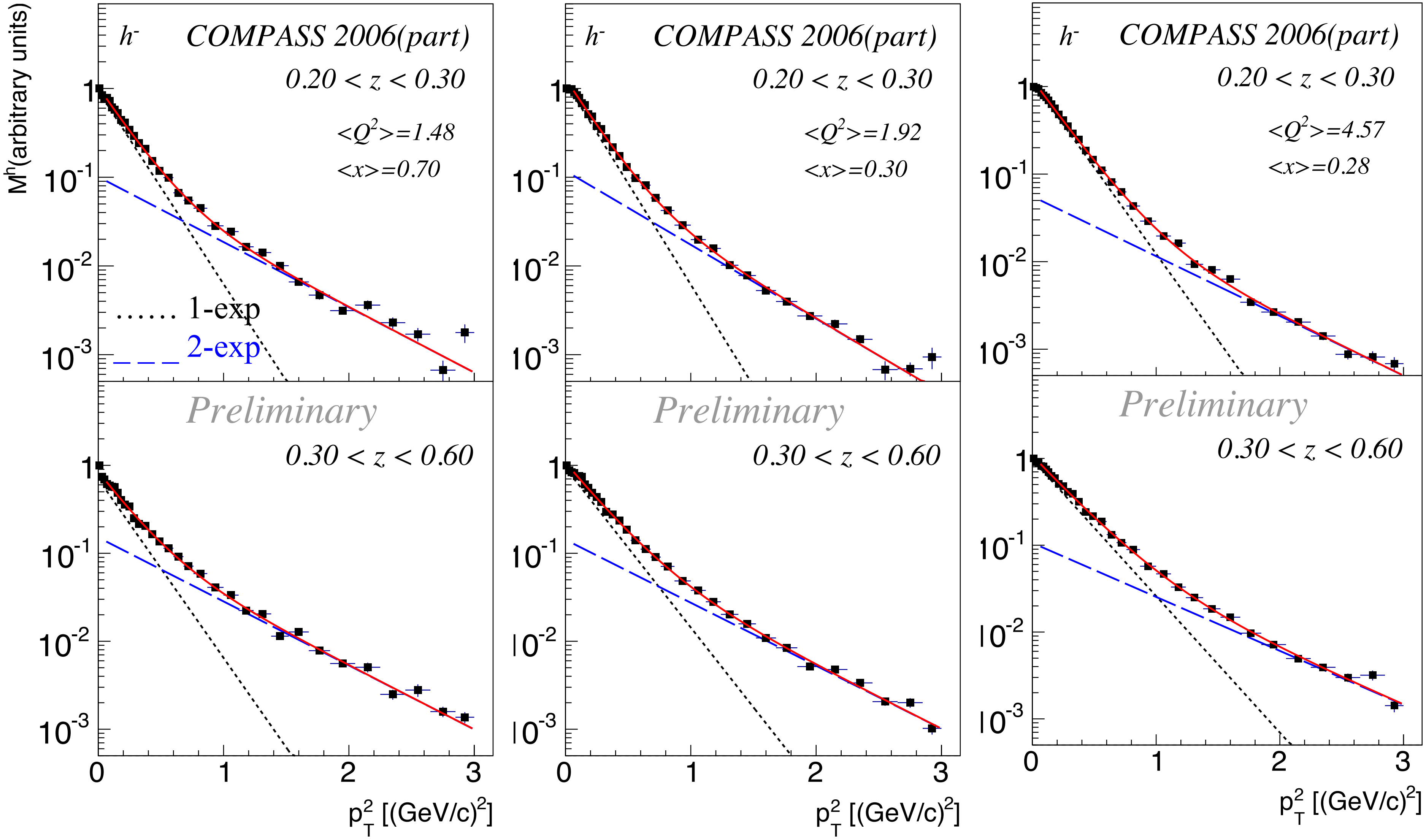
p_T^2 – dependent distributions vs. (x,z,p_T^2,Q^2) for h^+

NEW



p_T^2 – dependent distributions vs. (x,z,p_T^2,Q^2) for h^-

NEW



Summary & conclusions

- First input for the future global SIDIS studies is provided
    - All eight SIDIS TSAs were extracted from COMPASS proton-2010 data in four Q^2-bins.

- Several asymmetries show a non-zero trend in different kinematical regions
    - i.e. Sivers, Collins, $A_{LT}^{\cos(\phi h-\phi S)}$, $A_{UT}^{\sin\phi S}$

- Interesting input to the "Q^2-evolution" related studies
    - No strong Q^{2-} dependence observed

- More refined multi-dimensional analysis ongoing… More results to come soon

- Hadron multiplicities encode interesting details about intrinsic transverse momenta of quarks … complete set of results ongoing

Stay tuned !

Backup

Transversity

Proton target

$$A^{p,\pi^+}_{\mathrm{Coll}} \sim e_u^2 h_1^u H_1^{\perp,\mathrm{fav}} + e_d^2 h_1^d H_1^{\perp,\mathrm{unf}}\,, \qquad A^{p,\pi^-}_{\mathrm{Coll}} \sim e_u^2 h_1^u H_1^{\perp,\mathrm{unf}} + e_d^2 h_1^d H_1^{\perp,\mathrm{fav}}\,.$$

$$|A^{p,\pi^+}_{\mathrm{Coll}}| \simeq |A^{p,\pi^-}_{\mathrm{Coll}}| \quad \Leftrightarrow \quad H_1^{\perp,\mathrm{fav}} \simeq -H_1^{\perp,\mathrm{unf}}\,.$$

Deuteron target

$$A^{d,\pi^+}_{\mathrm{Coll}} \sim (h_1^u + h_1^d)(e_u^2 H_1^{\perp,\mathrm{fav}} + e_d^2 H_1^{\perp,\mathrm{unf}})\,, \qquad A^{d,\pi^-}_{\mathrm{Coll}} \sim (h_1^u + h_1^d)(e_u^2 H_1^{\perp,\mathrm{fav}} + e_d^2 H_1^{\perp,\mathrm{unf}})$$

→ $h_1^u \sim - h_1^d$