New results on transverse spin asymmetries from COMPASS: Part I

BAKUR PARSAMYAN

University of Turin and INFN section of Turin

on behalf of the COMPASS Collaboration

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Outline

- Introduction
  - Brief review of COMPASS results with TSAs
- COMPASS – "SIDIS-DY bridge"
- New results!
  - Asymmetries
  - Re-evaluation of $A_{LT}^{\cos\varphi_S}$ and $A_{LT}^{\cos(\varphi_h - \varphi_S)}$: from the lp to $\gamma^* p$ cross-section
  - $A_{LT}^{\cos(\varphi_h - \varphi_S)}$: Comparison with predictions
  - Multi-D map of kinematical distributions
- Conclusions

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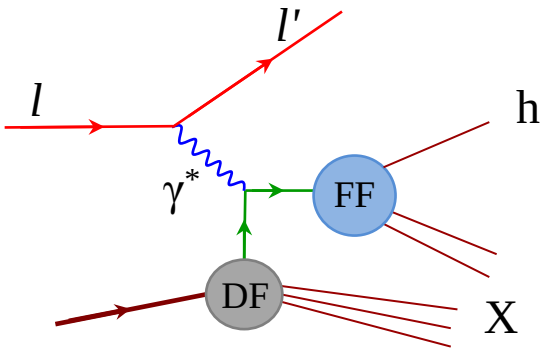
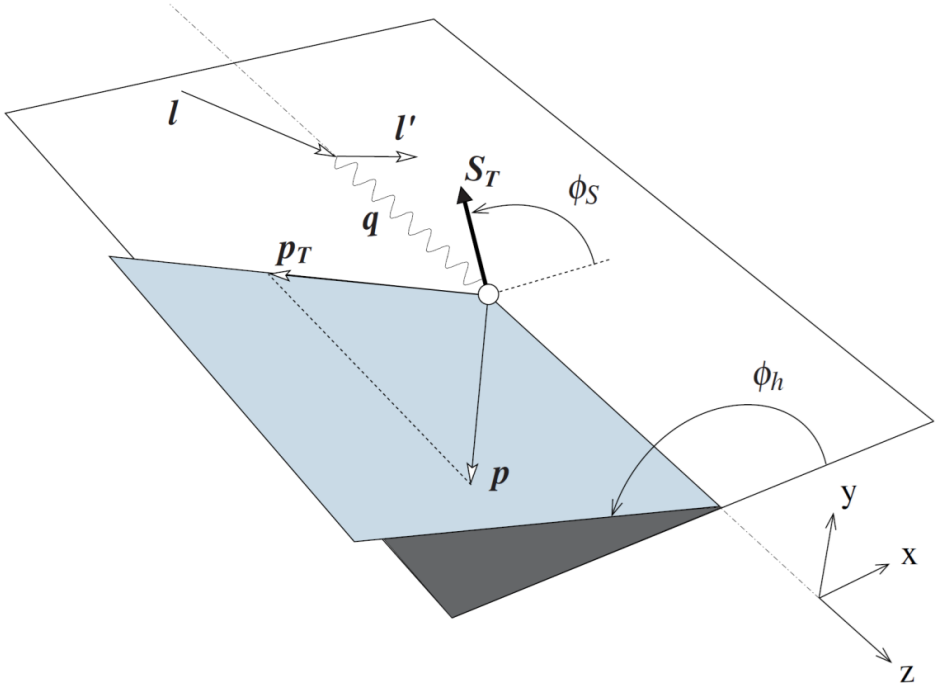
SIDIS x-section

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

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





$$A_{U(L),T}^{w(\varphi_h,\varphi_s)}=\frac{F_{U(L),T}^{w(\varphi_h,\varphi_s)}}{F_{UU,T}+\varepsilon F_{UU,L}};\qquad \varepsilon=\frac{1-y-\frac{1}{4}\gamma^2y^2}{1-y+\frac{1}{2}y^2+\frac{1}{4}\gamma^2y^2},\quad \gamma=\frac{2Mx}{Q}$$

SIDIS x-section

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

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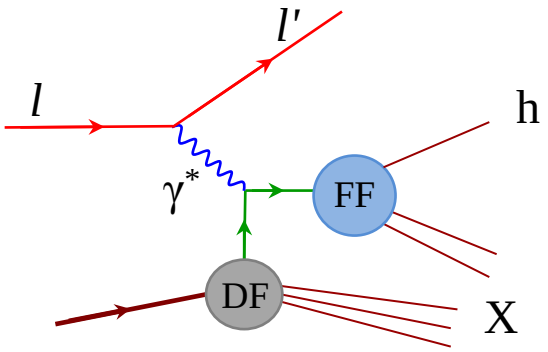
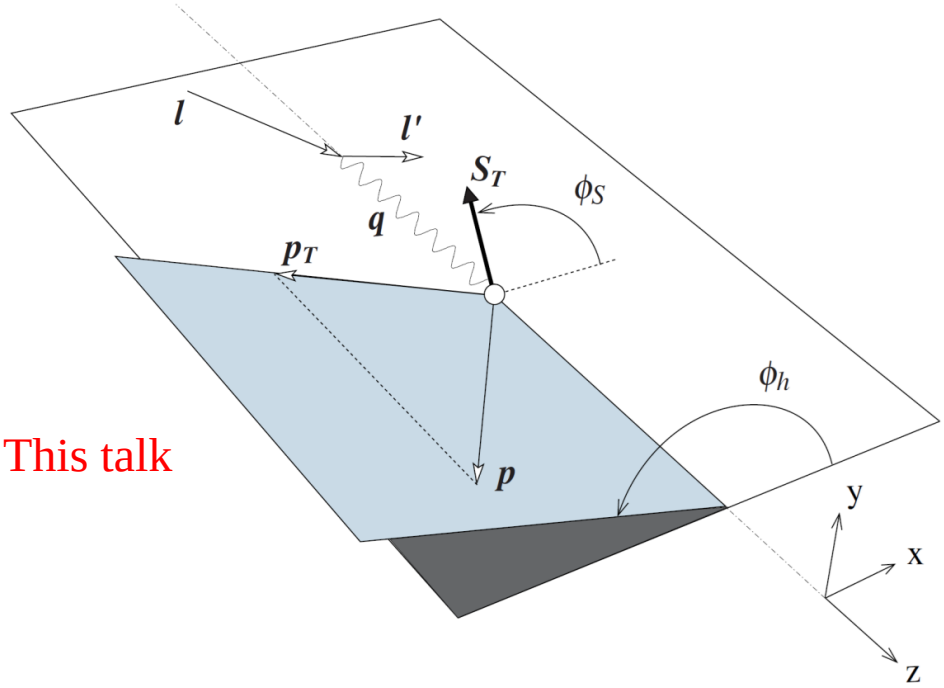
\cos(2\varphi_h-\varphi_S)\times\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)
\end{array}\right]
\end{array}\right\}+$$

This talk





$$A_{U(L),T}^{w(\varphi_h,\varphi_s)} = \frac{F_{U(L),T}^{w(\varphi_h,\varphi_s)}}{F_{UU,T}+\varepsilon F_{UU,L}};\qquad \varepsilon = \frac{1-y-\frac{1}{4}\gamma^2y^2}{1-y+\frac{1}{2}y^2+\frac{1}{4}\gamma^2y^2},\quad \gamma=\frac{2Mx}{Q}$$

SIDIS x-section

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\end{array}\right]+\\
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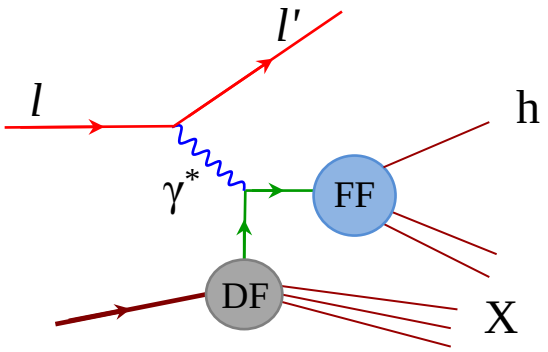
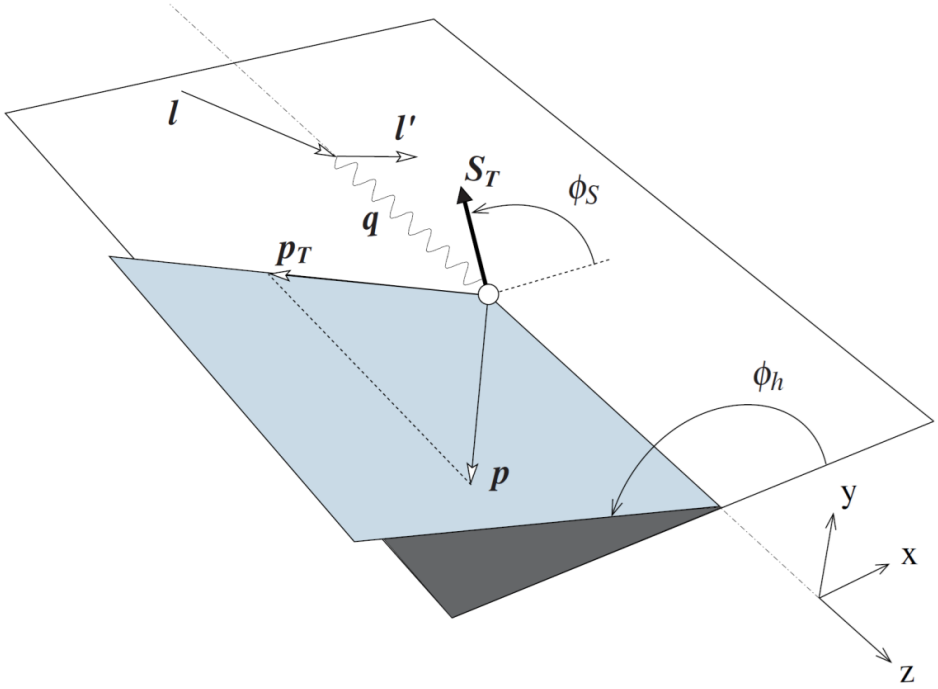
\cos(2\varphi_h-\varphi_S)\times\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)
\end{array}\right]
\end{array}\right.$$

SSA

DSA





$$A_{U(L),T}^{w(\varphi_h,\varphi_s)} = \frac{F_{U(L),T}^{w(\varphi_h,\varphi_s)}}{F_{UU,T}+\varepsilon F_{UU,L}};\qquad \varepsilon = \frac{1-y-\frac{1}{4}\gamma^2y^2}{1-y+\frac{1}{2}y^2+\frac{1}{4}\gamma^2y^2},\quad \gamma=\frac{2Mx}{Q}$$

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\left\{\begin{array}{l}
S_T\left[\begin{array}{l}
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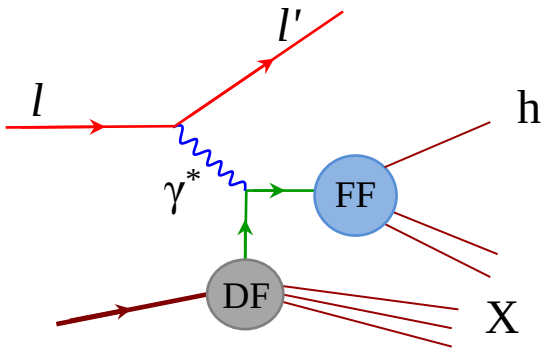
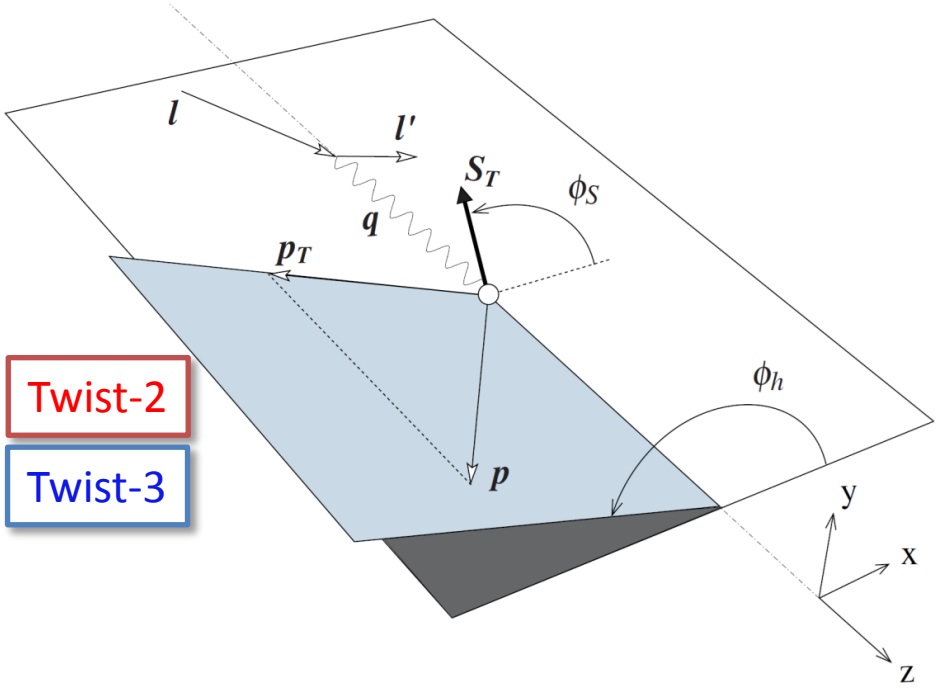
\end{array}\right]
\end{array}\right.
\end{array}\right.$$

SSA

DSA





Twist-2

Twist-3

$$A_{U(L),T}^{w(\varphi_h,\varphi_s)} = \frac{F_{U(L),T}^{w(\varphi_h,\varphi_s)}}{F_{UU,T}+\varepsilon F_{UU,L}};\qquad \varepsilon = \frac{1-y-\frac{1}{4}\gamma^2y^2}{1-y+\frac{1}{2}y^2+\frac{1}{4}\gamma^2y^2},\quad \gamma=\frac{2Mx}{Q}$$

SIDIS x-section

$$A_{UT}^{\sin(\phi_h+\phi_s)} \propto h_1^q \otimes H_{1q}^{\perp h} \quad \text{SSA [twist-2]}$$

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

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S_L\left[\sqrt{2\varepsilon(1+\varepsilon)}\sin\phi_h A_{UL}^{\sin\phi_h}+\varepsilon\sin(2\phi_h)A_{UL}^{\sin(2\phi_h)}\right]+ \\
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S_T\begin{bmatrix}
\sin(\varphi_h-\varphi_S)\times\left(A_{UT}^{\sin(\varphi_h-\varphi_S)}\right)+ \\
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\end{bmatrix}+ \\
S_T\lambda\begin{bmatrix}
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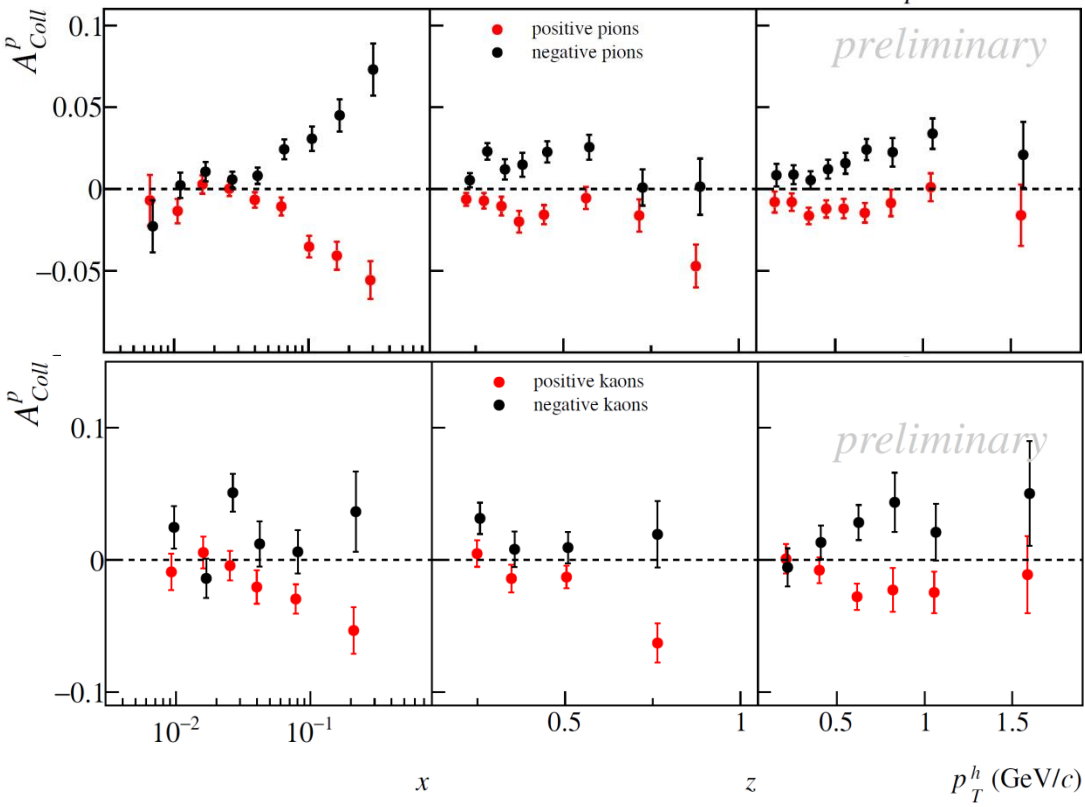
\cos\varphi_S\times\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+ \\
\cos(2\varphi_h-\varphi_S)\times\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)
\end{bmatrix}
\end{Bmatrix}$$

COMPASS 2007 and 2010 proton data



- Asymmetries are compatible with zero at small x
- Strong signal in the valence region of opposite sign for π^+ and π^-
- Opposite sign also for K^+/K^- negative trend in the valence region
- Compatible with zero on deuteron

SIDIS x-section

$$A_{UT}^{\sin(\phi_h+\phi_s)} \propto h_1^q \otimes H_{1q}^{\perp h} \quad \text{SSA [twist-2]}$$

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

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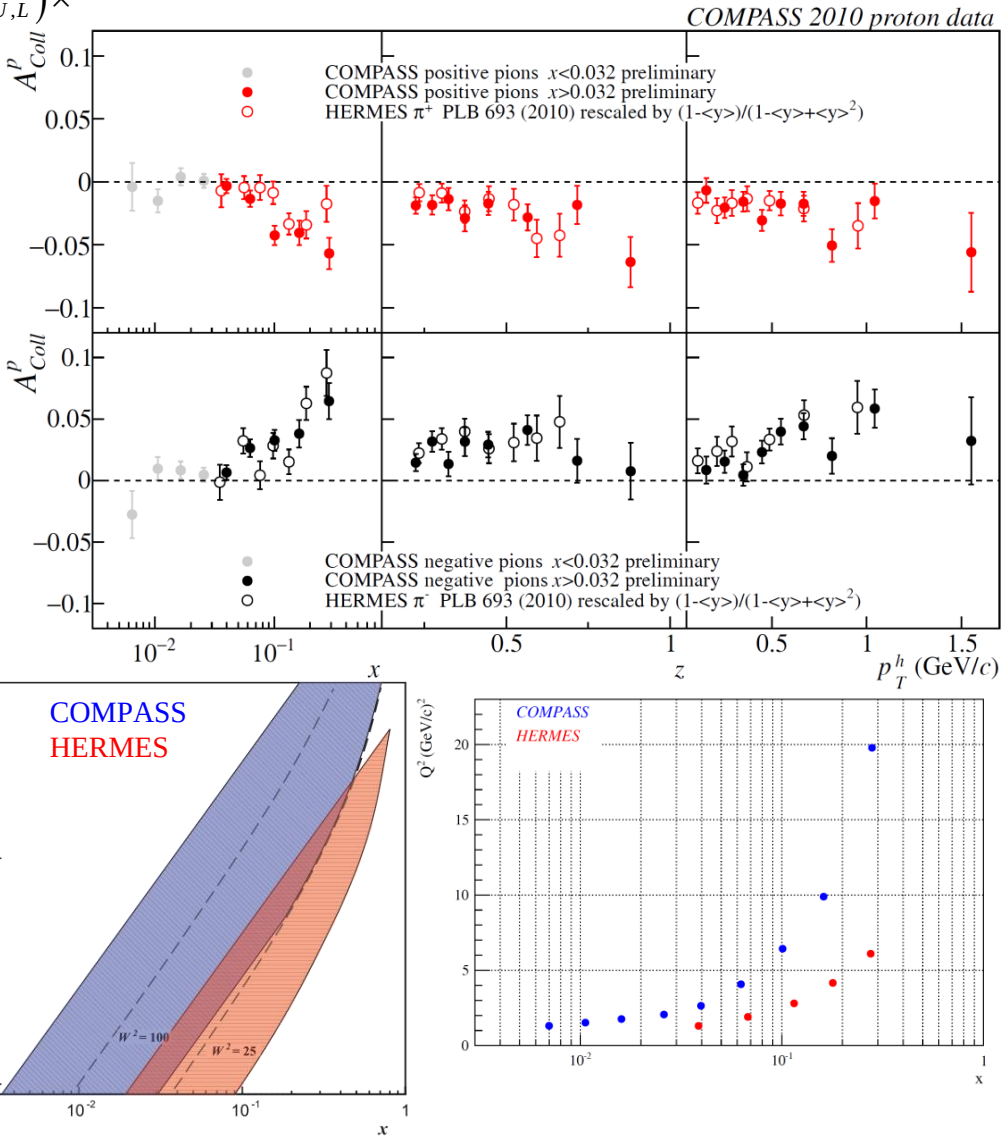
\cos(2\varphi_h-\varphi_S)\times\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)
\end{array}\right]
\end{Bmatrix}$$



- COMPASS and HERMES results are compatible - intriguing result! (Q^2 is different by a factor of ~2-3)

SIDIS x-section

$$A_{UT}^{\sin(\phi_h+\phi_s)} \propto h_1^q \otimes H_{1q}^{\perp h}$$ SSA [twist-2]

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

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\end{bmatrix}+ \\
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\end{bmatrix}
\end{Bmatrix}$$

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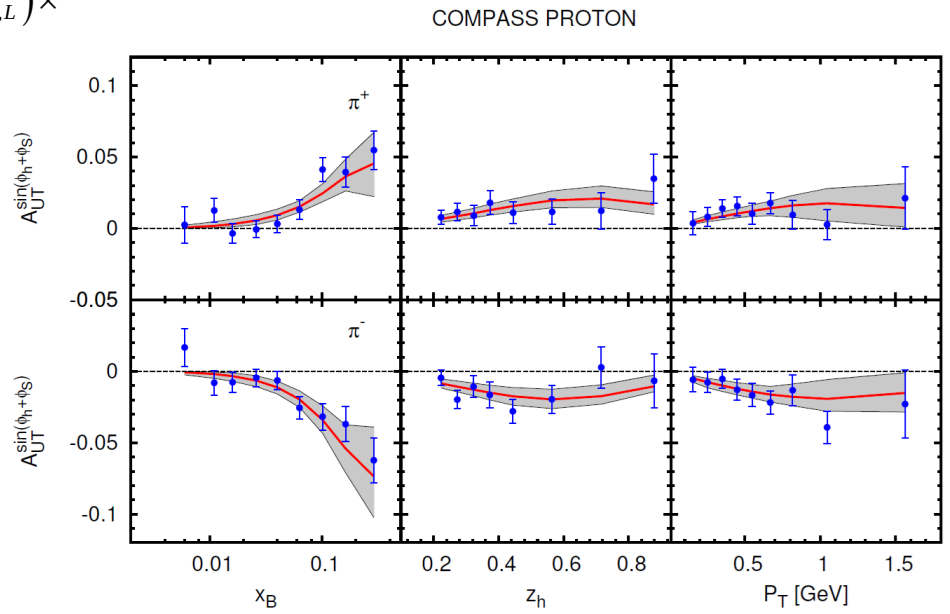
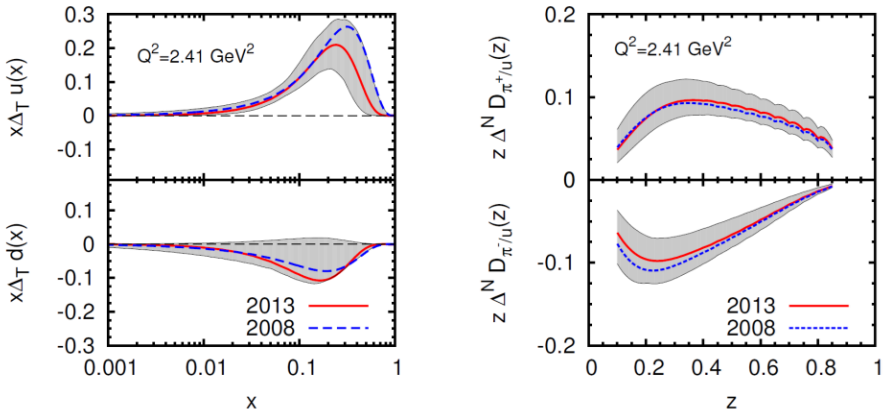


- Global fit of HERMES-COMPASS-BELLE data



- Transversity PDF + Collins FF

SIDIS x-section

$$A_{UT}^{\sin(\phi_h-\phi_s)} \propto f_{1T}^{\perp q} \otimes D_{1q}^{h} \quad \text{SSA}\left[\text{twist-2}\right]$$

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

$$\left\{
\begin{aligned}
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\begin{aligned}
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\end{aligned}\right.+\\
&S_T\lambda\left[
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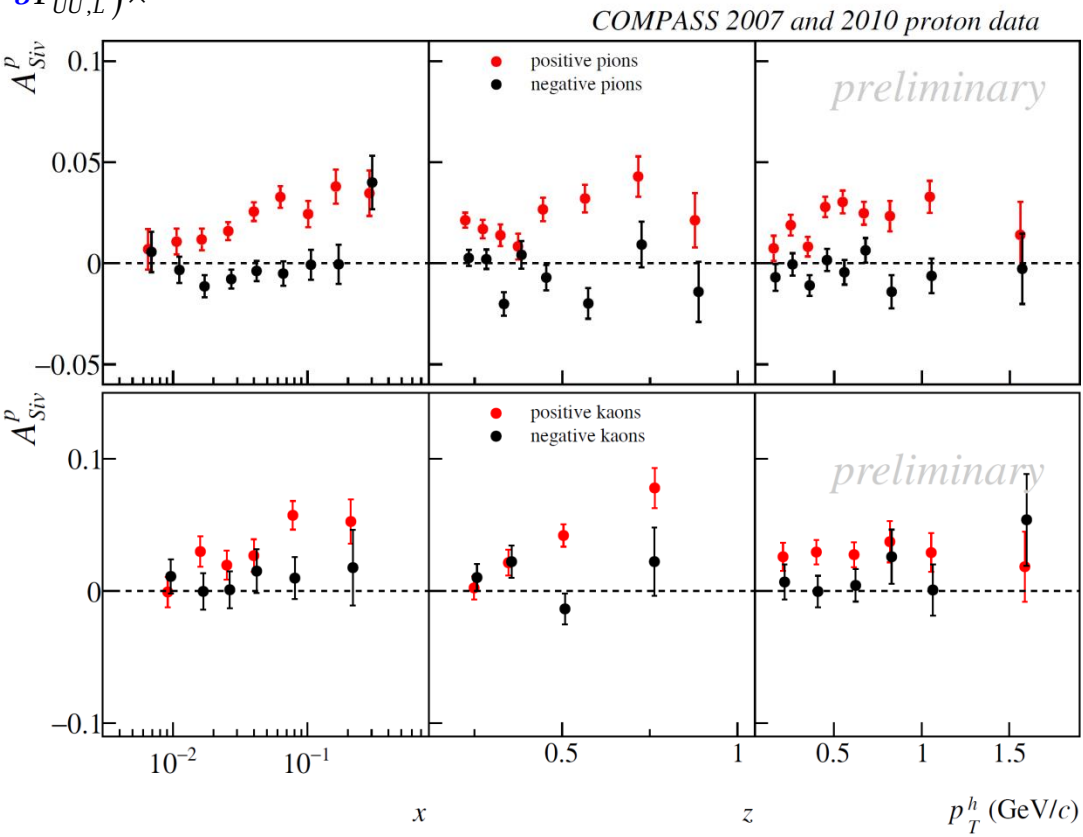
&\cos(\varphi_h-\varphi_S)\times\left(\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}\right)+\\
&\cos\varphi_S\times\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}\right)+\\
&\cos(2\varphi_h-\varphi_S)\times\left(\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)
\end{aligned}\right.
\end{aligned}
\right\}$$



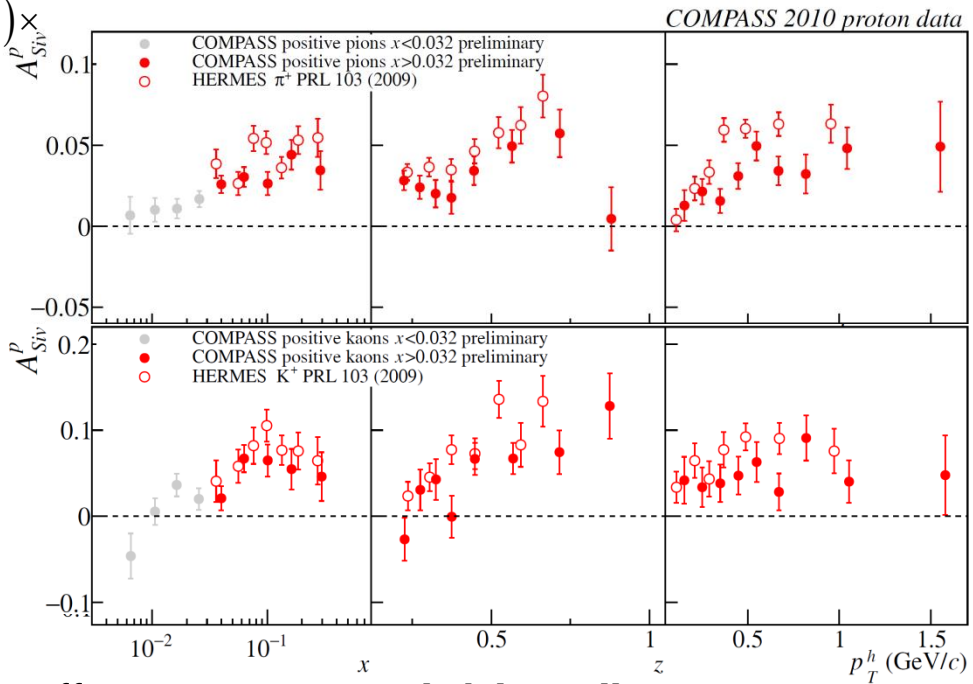
- Significantly large amplitude for π^+ and K^+ in whole range of x
- Compatible with zero for π^- and K^-
  - (maybe except the last bin of x for π^-).
- Compatible with zero on deuteron

SIDIS x-section

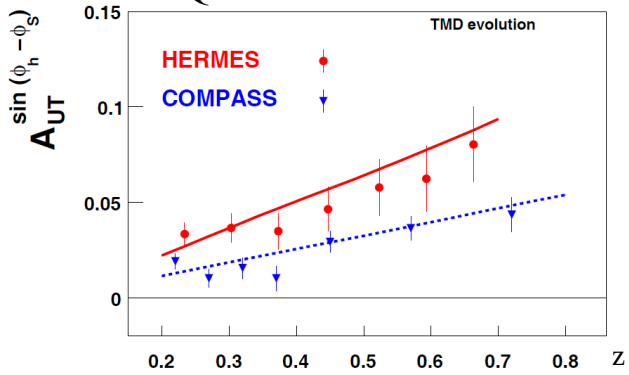
$$A_{UT}^{\sin(\phi_h-\phi_s)} \propto f_{1T}^{\perp q} \otimes D_{1q}^{h} \quad \text{SSA[twist-2]}$$

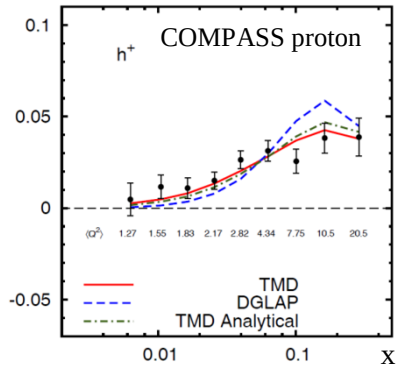
$$\frac{d\sigma}{dxdydzdP_{hT}^2 d\varphi_h d\psi} = \left[\frac{\alpha}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right]\times\left(F_{UU,T}+\varepsilon F_{UU,L}\right)\times$$

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



- Sivers effect at COMPASS is slightly smaller w.r.t HERMES results… Q^2-evolution?





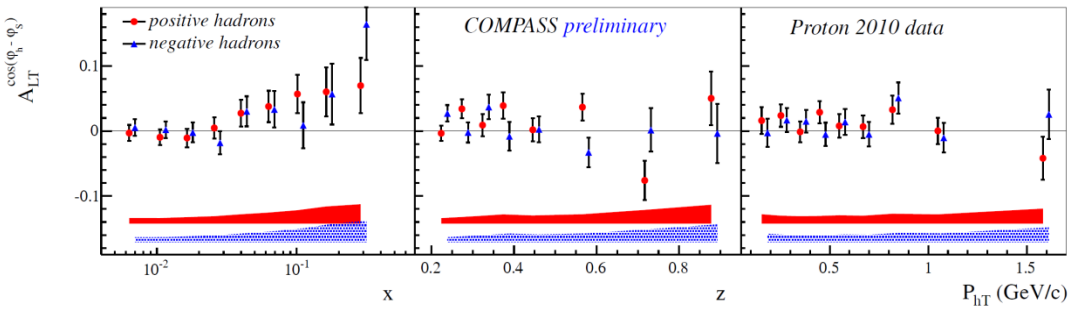
S. M. Aybat, A. Prokudin, T. C. Rogers **PRL 108 (2012) 242003**
M. Anselmino, M. Boglione, S. Melis **PRD 86 (2012) 014028**

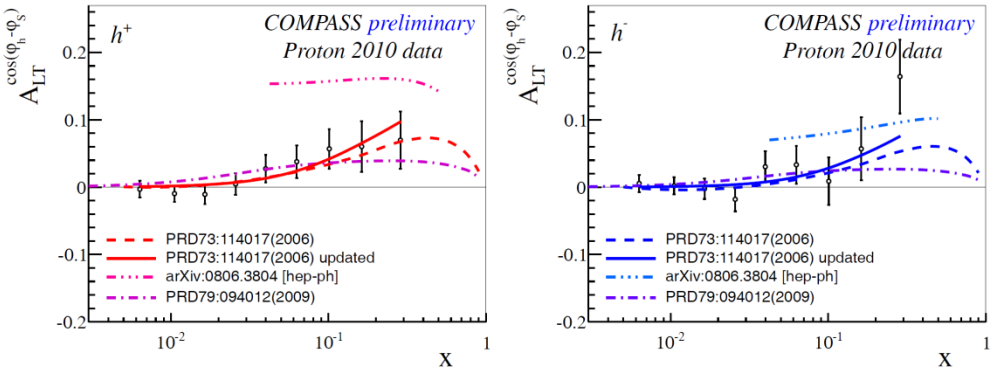
SIDIS x-section

$$A_{LT}^{\cos(\phi_h-\phi_s)} \propto g_{1T}^{q} \otimes D_{1q}^{h} \qquad \text{DSA}\left[\text{twist-2}\right]$$

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

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



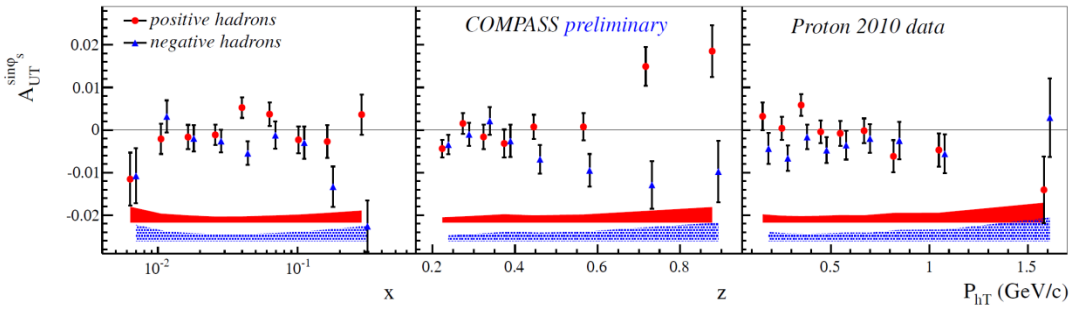


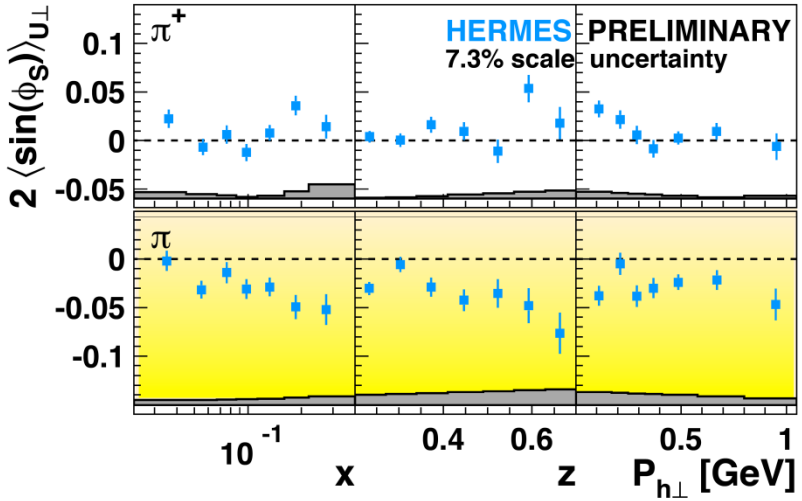
- Gives access to g_{1T} "twist-2" PDF (worm-gear-T)
- Visible signal for h^+ (*preliminary* confirmation also by HERMES)
- In agreement with several model predictions
- Compatible with zero on deuteron

$$A_{UT}^{\sin(\phi_s)\,WW} \propto Q^{-1}\left(h_1^q \otimes H_{1q}^{\perp h} + f_{1T}^{\perp q} \otimes D_{1q}^{h} + \ldots\right) \quad \text{SSA}\left[\text{higher-twist}\right]$$

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

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





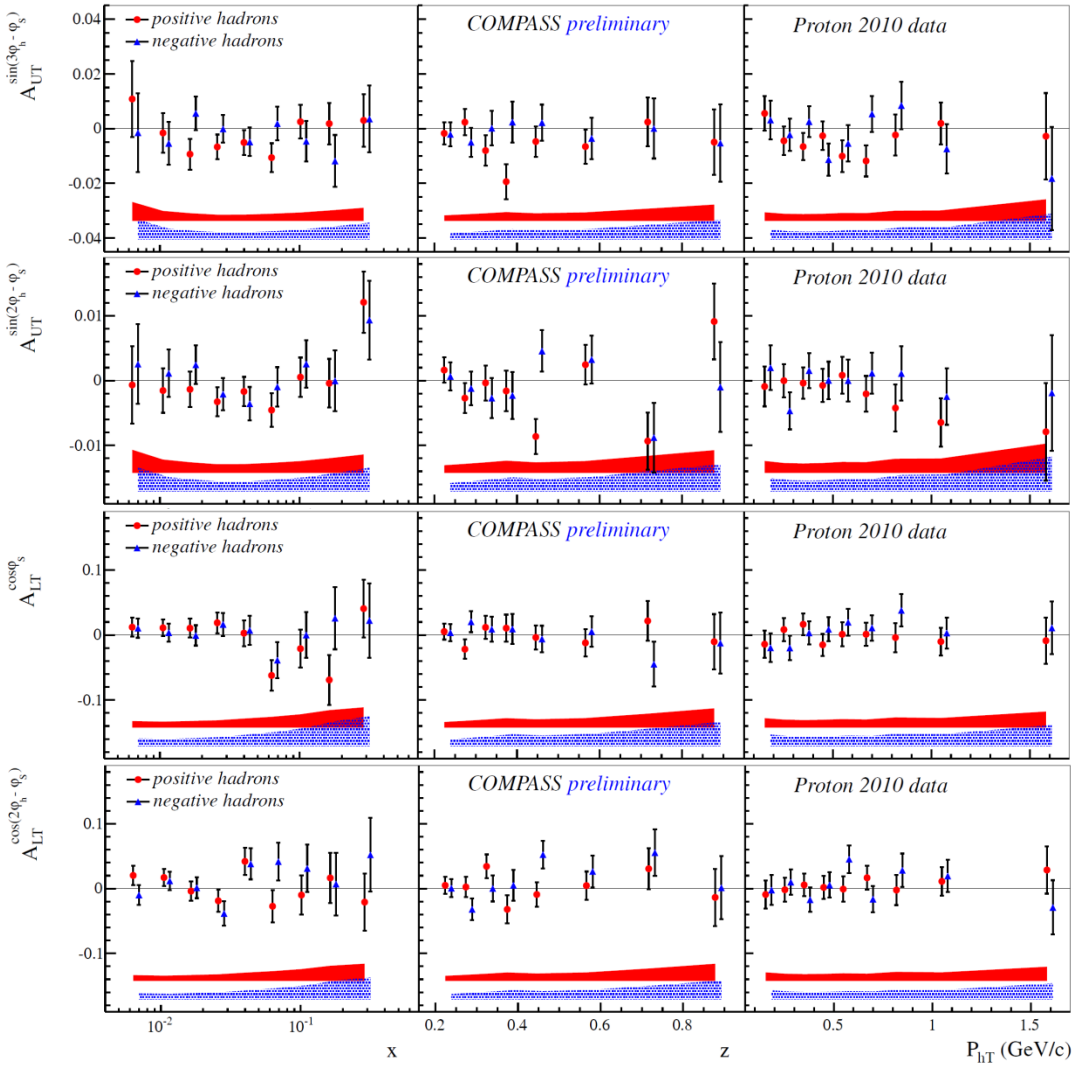
- Higher twist effect..
- In WW-approximation is related to Sivers and Collins
- Non-zero trend for negative hadrons both in COMPASS and HERMES
- Compatible with zero on deuteron

$A_{UT}^{\sin(3\phi_h-\phi_s)} \propto h_{1T}^{\perp q} \otimes H_{1q}^{\perp h}$ SSA[twist-2]; $A_{UT}^{\sin(2\phi_h-\phi_s)} \overset{WW}{\propto} Q^{-1}\left(h_{1T}^{\perp q} \otimes H_{1q}^{\perp h} + f_{1T}^{\perp q} \otimes D_{1q}^{h} + \ldots\right)$ SSA[higher-twist]

$A_{LT}^{\cos(\phi_s)} \overset{WW}{\propto} Q^{-1}\left(g_{1T}^{q} \otimes D_{1q}^{h} + \ldots\right)$ DSA[higher-twist]; $A_{LT}^{\cos(2\phi_h-\phi_s)} \overset{WW}{\propto} Q^{-1}\left(g_{1T}^{q} \otimes D_{1q}^{h} + \ldots\right)$ DSA[higher-twist]

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

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



- All compatible with zero within uncertainties (P/D)

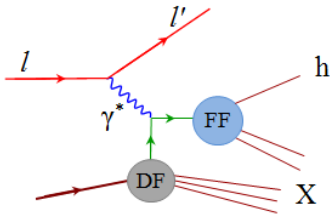
Outline

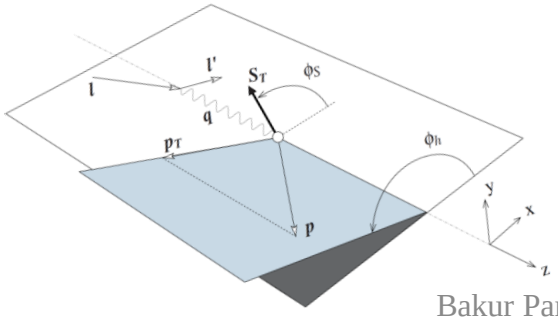
- Introduction
  - Brief review of COMPASS results with TSAs
- **COMPASS – "SIDIS-DY bridge"**
- New results!
  - Asymmetries
  - Re-evaluation of $A_{LT}^{\cos\varphi_S}$ and $A_{LT}^{\cos(\varphi_h - \varphi_S)}$: from the lp to $\gamma^* p$ cross-section
  - $A_{LT}^{\cos(\varphi_h - \varphi_S)}$: Comparison with predictions
  - Multi-D map of kinematical distributions
- Conclusions

SIDIS x-section

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

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



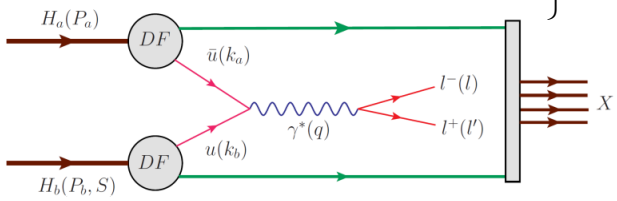


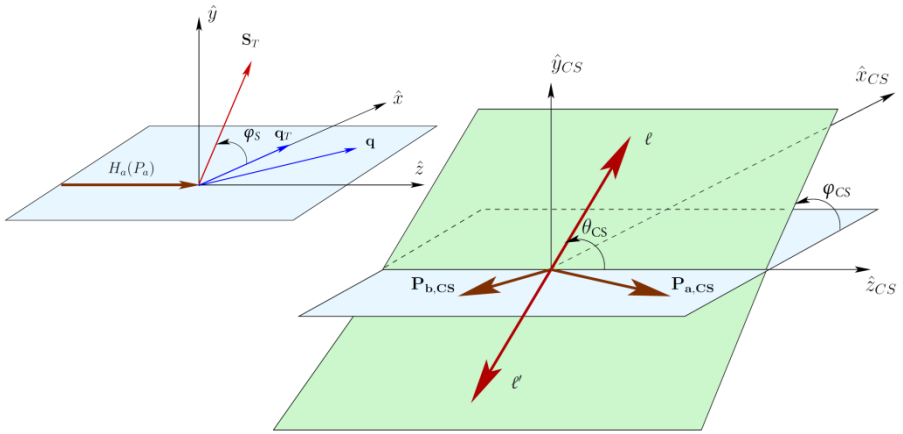
DY x-section

LO single polarized

$$\frac{d\sigma^{LO}}{d\Omega} = \frac{\alpha_{em}^2}{Fq^2}F_U^1\times$$

$$\left\{\begin{array}{l}
1+\cos^2\theta+\sin^2\theta A_U^{\cos 2\varphi}\cos 2\varphi\\
+S_L\sin^2\theta A_L^{\sin 2\varphi}\sin 2\varphi\\
\pm\left|\overrightarrow{S_T}\right|\left[\begin{array}{l}
\left(1+\cos^2\theta\right)A_T^{\sin\varphi_S}\sin\varphi_S+\\
\sin^2\theta\left(\begin{array}{l}
A_T^{\sin(2\varphi_{CS}+\varphi_S)}\sin(2\varphi+\varphi_S)+\\
A_T^{\sin(2\varphi_{CS}-\varphi_S)}\sin(2\varphi-\varphi_S)
\end{array}\right)
\end{array}\right]
\end{array}\right\}$$





TMDs accessed in SIDIS and DY

SIDIS

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

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

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

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

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

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

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

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

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

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

Single polarized DY (LO)

$$A_U^{\cos 2\varphi_{CS}} \propto h_{1,\pi}^{\perp q} \otimes h_{1,\mathrm{p}}^{\perp q}$$

$$A_T^{\sin\varphi_S} \propto f_{1,\pi}^q \otimes f_{1T,\mathrm{p}}^{\perp q}$$

$$A_T^{\sin(2\varphi_{CS} - \varphi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1,\mathrm{p}}^q$$

$$A_T^{\sin(2\varphi_{CS} + \varphi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1T,\mathrm{p}}^{\perp q}$$

Nucleon TMD PDFs accessed in SIDIS and DY

SIDIS

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

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

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

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

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

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

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

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

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

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

Single polarized DY (LO)

$$A_U^{\cos 2\varphi_{CS}} \propto h_{1,\pi}^{\perp q} \otimes h_{1,\mathrm{p}}^{\perp q}$$

$$A_T^{\sin\varphi_S} \propto f_{1,\pi}^q \otimes f_{1T,\mathrm{p}}^{\perp q}$$

$$A_T^{\sin(2\varphi_{CS} - \varphi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1,\mathrm{p}}^q$$

$$A_T^{\sin(2\varphi_{CS} + \varphi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1T,\mathrm{p}}^{\perp q}$$

Nucleon TMD PDFs accessed in SIDIS and DY

SIDIS

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

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

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

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

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

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

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

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

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

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

Single polarized DY (LO)

$$A_U^{\cos 2\varphi_{CS}} \propto h_{1,\pi}^{\perp q} \otimes h_{1,\mathrm{p}}^{\perp q}$$

$$A_T^{\sin\varphi_S} \propto f_{1,\pi}^q \otimes f_{1T,\mathrm{p}}^{\perp q}$$

$$A_T^{\sin(2\varphi_{CS} - \varphi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1,\mathrm{p}}^q$$

$$A_T^{\sin(2\varphi_{CS} + \varphi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1T,\mathrm{p}}^{\perp q}$$

Nucleon TMD PDFs accessed in SIDIS and DY

SIDIS

Single polarized DY (LO)

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

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

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

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

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

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

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

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

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Nucleon TMD PDFs accessed in SIDIS and DY

SIDIS

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

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

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

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

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

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All the answers are encoded in the data...
In few years many new asymmetries measured by different experiments in different reactions, at different energies and kinematical ranges will wait for a "global analysis"…

Nucleon TMD PDFs accessed in SIDIS and DY

SIDIS $\ell^{\rightarrow}N^{\uparrow}$	Nucleon TMD PDF	Drell-Yan $\pi N^{\uparrow}$ (LO)
$A_{UU}^{cos2\phi_h}$, $A_{UU}^{cos\phi_h}$	$h_1^{\perp q}$ - "Boer-Mulders"	$A_U^{cos2\varphi_{CS}}$
$A_{UT}^{\sin(\phi_h-\phi_s)}$, $A_{UT}^{\sin\phi_s}$, $A_{UT}^{\sin(2\phi_h-\phi_s)}$	$f_{1T}^{\perp q}$ - "Sivers"	$A_T^{sin\varphi_S}$
$A_{UT}^{\sin(\phi_h+\phi_s-\pi)}$, $A_{UT}^{\sin\phi_s}$	h_1^q - "Transversity"	$A_T^{\sin(2\varphi_{CS}-\varphi_s)}$
$A_{UT}^{\sin(3\phi_h-\phi_s)}$, $A_{UT}^{\sin(2\phi_h-\phi_s)}$	$h_{1T}^{\perp q}$ - "Pretzelosity"	$A_T^{\sin(2\varphi_{CS}+\varphi_s)}$
$A_{LT}^{\cos(\phi_h-\phi_s)}$, $A_{LT}^{\cos\phi_s}$, $A_{LT}^{\cos(2\phi_h-\phi_s)}$	g_{1T}^q - "Worm-Gear" (T)	**Double-polarized DY** to be accessed by NICA see talk by O. Teryaev on 13.06

DY measurements at COMPASS are complementary to the previous COMPASS SIDIS results. Unique opportunity to access TMD PDFs via two mechanisms and test their universality and key features.

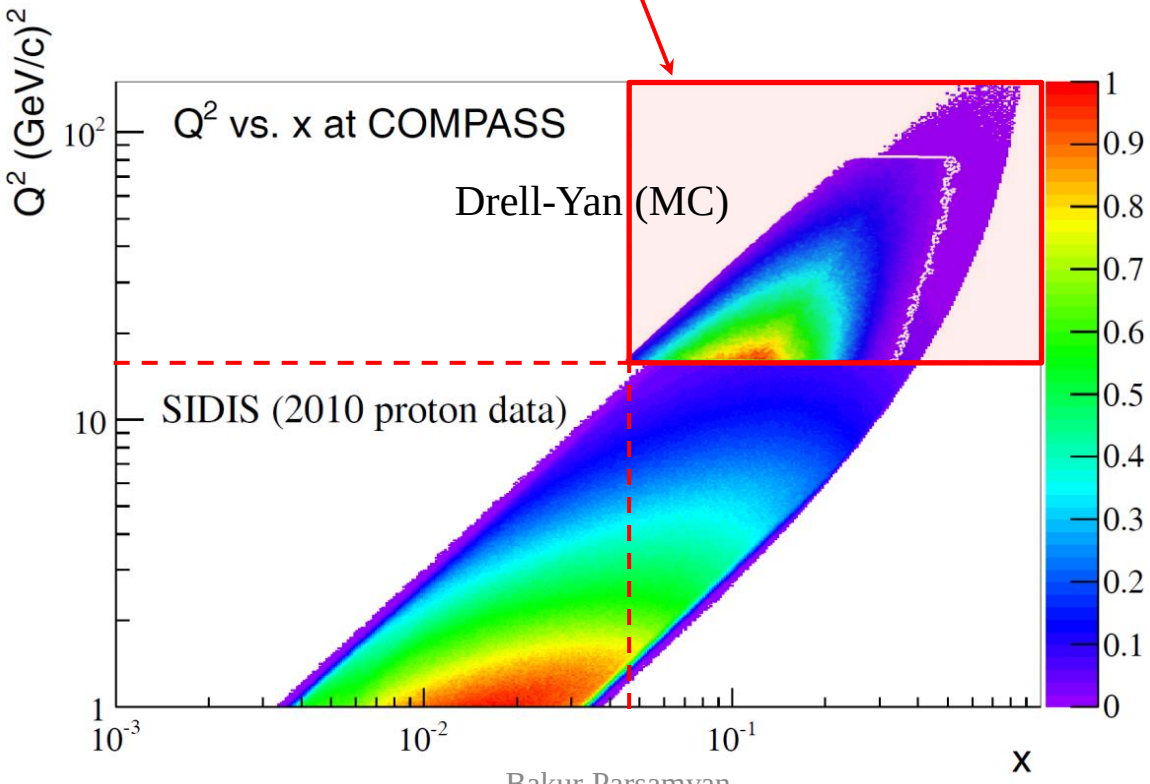
red - "twist-2", blue - "twist-3"

COMPASS Drell-Yan program: Q^2 ranges

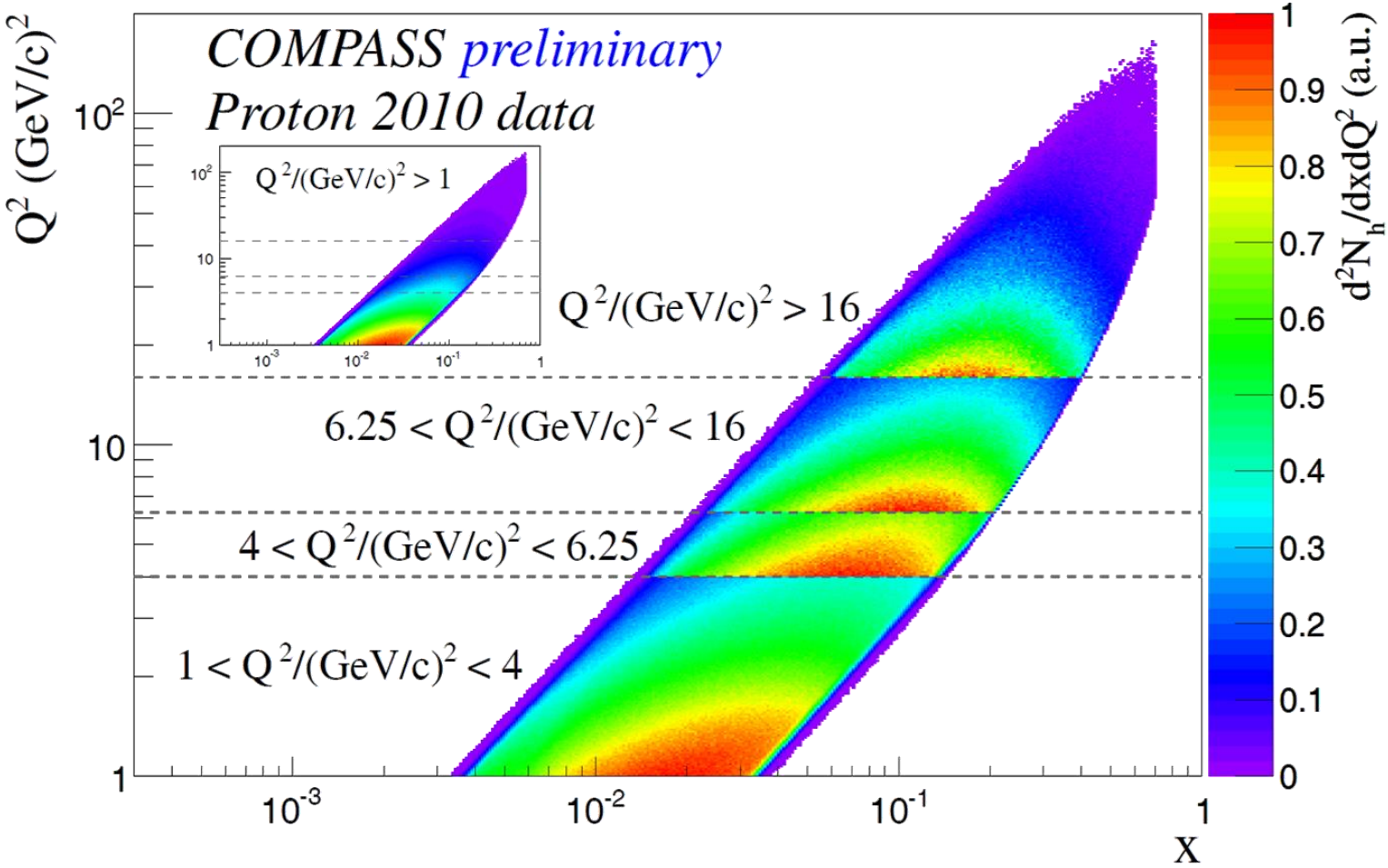
Four Q^2-ranges:

See talk by M. Chiosso on 13.06

- $1 < Q^2/(GeV/c)^2 < 4$ "Low"
- $4 < Q^2/(GeV/c)^2 < 6.25$ "Intermediate"
- $6.25 < Q^2/(GeV/c)^2 < 16$ "J/ψ"
- $Q^2/(GeV/c)^2 > 16$ "High mass"



COMPASS phase-space x:Q^2 ("DY" Q^2-ranges)



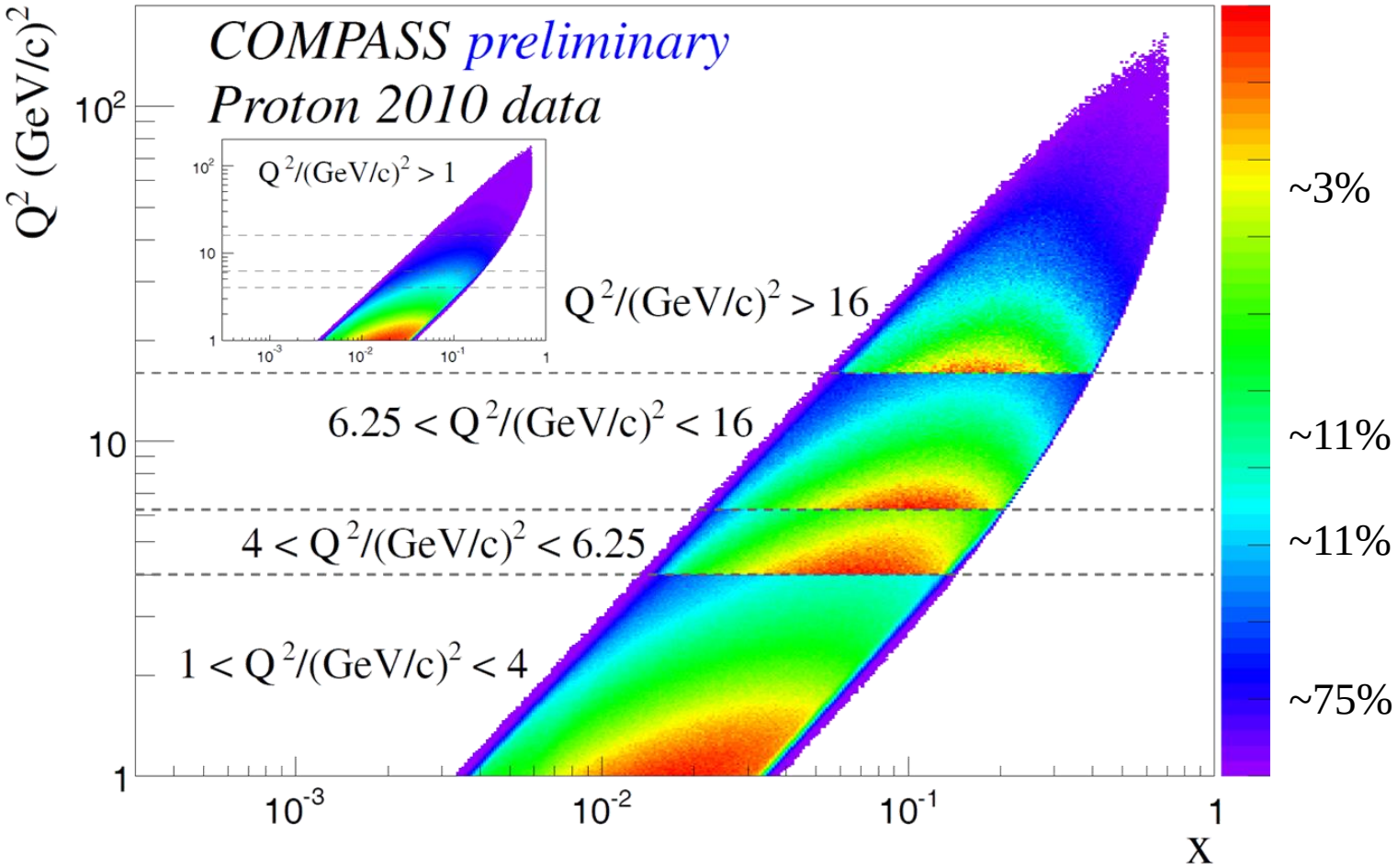
Proton 2010 data-sample ($Q^2 > 1$ (GeV/c)^2; $0.1 < y < 0.9$; $W > 5$ GeV, $z > 0.1$, $p_T > 0.1$ GeV/c)

Four Q^2-bins: $1 < Q^2/(GeV/c)^2 < 4$, $4 < Q^2/(GeV/c)^2 < 6.25$, $6.25 < Q^2/(GeV/c)^2 < 16$, $Q^2/(GeV/c)^2 > 16$

For each Q^2-bin → two different z-ranges:

- $z \in [0.2; 1.0]$ – "standard" selection
- $z \in [0.1; 1.0]$ – "extended" region: Low z ($z \in [0.1; 0.2]$) + "standard" selection

COMPASS phase-space x:Q^2 ("DY" Q^2-ranges)



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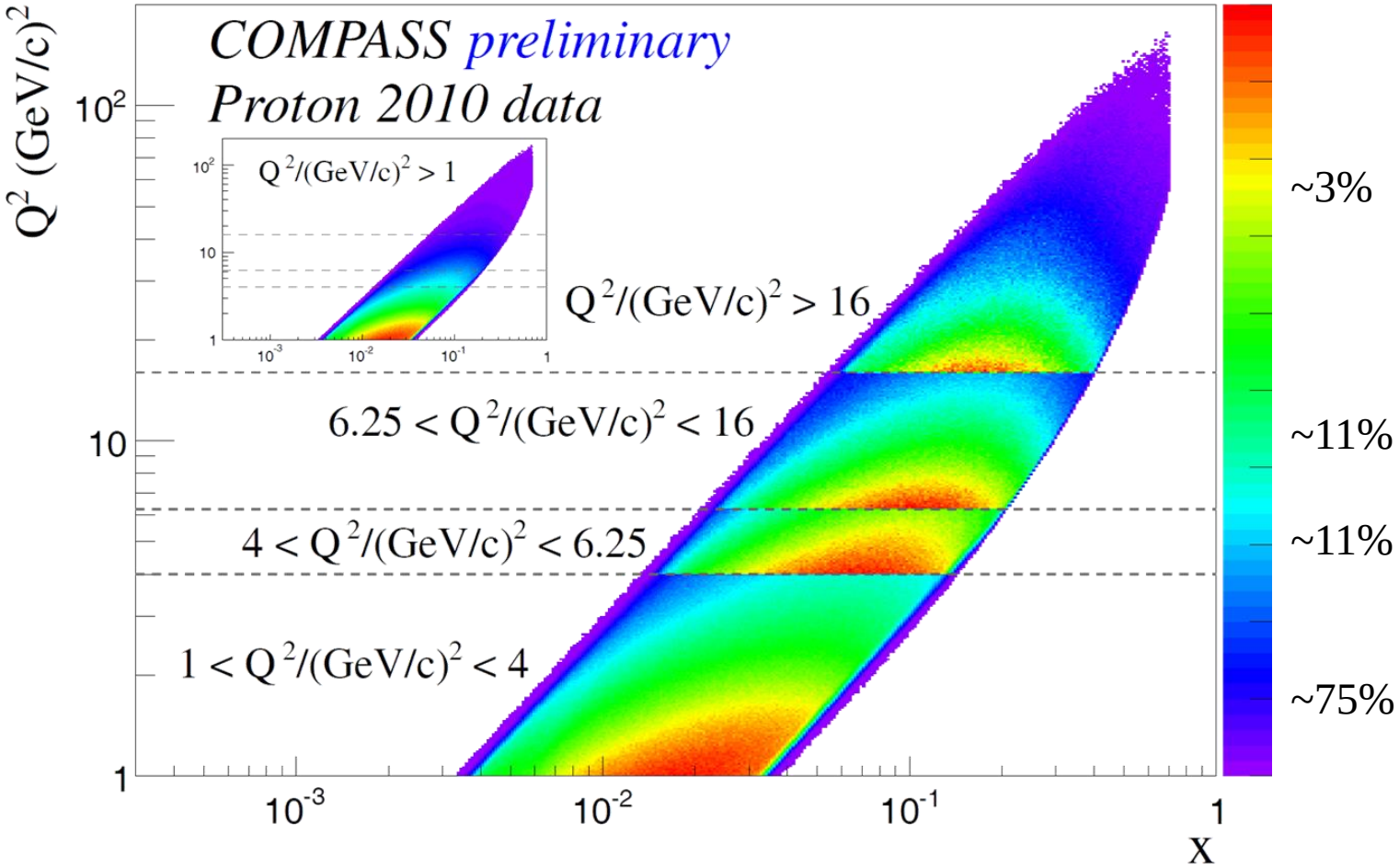

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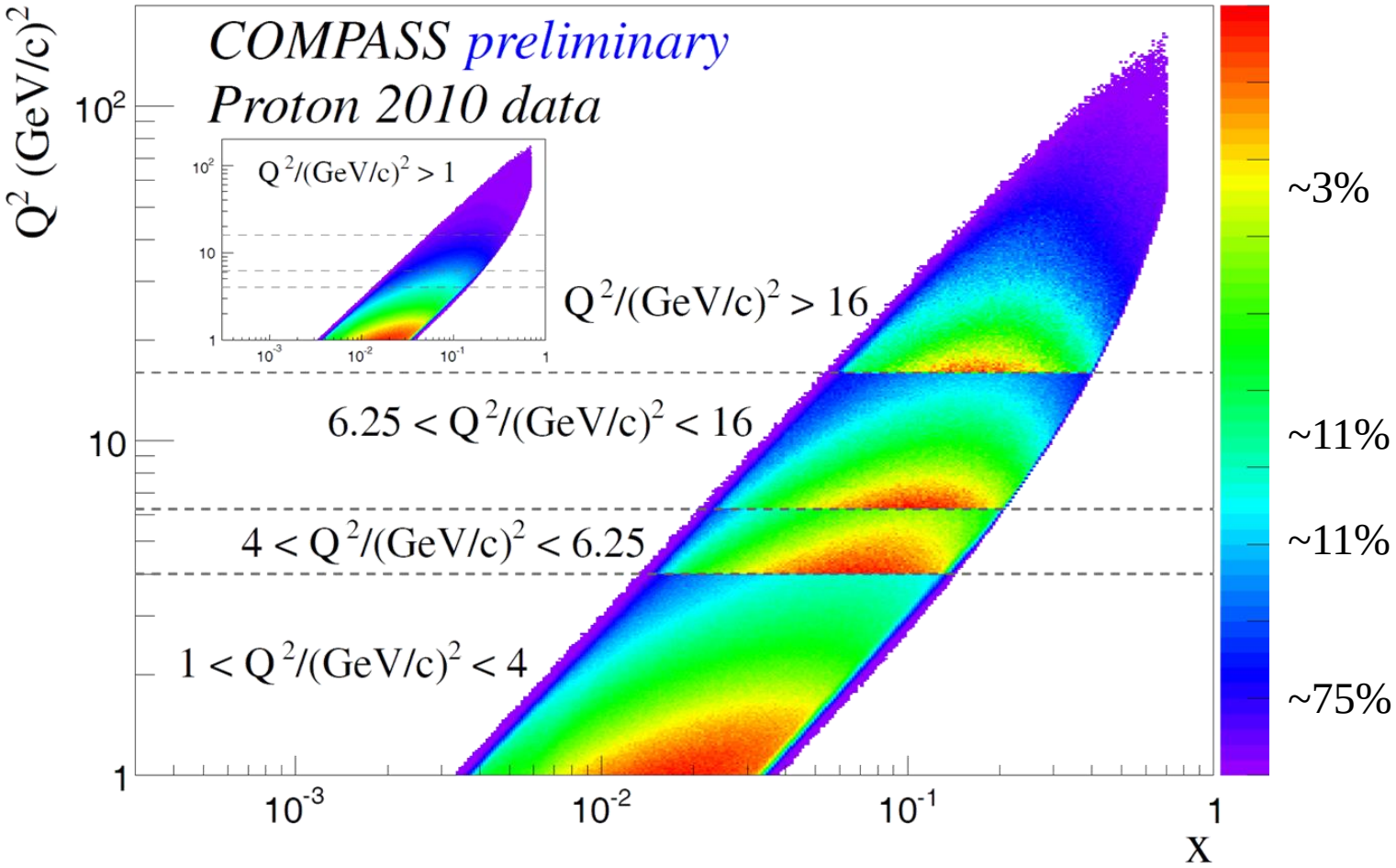

On a way towards multi-dimensional analysis..! More news soon!

Four Q^2-bins: $1 < Q^2/(GeV/c)^2 < 4$, $4 < Q^2/(GeV/c)^2 < 6.25$, $6.25 < Q^2/(GeV/c)^2 < 16$, $Q^2/(GeV/c)^2 > 16$

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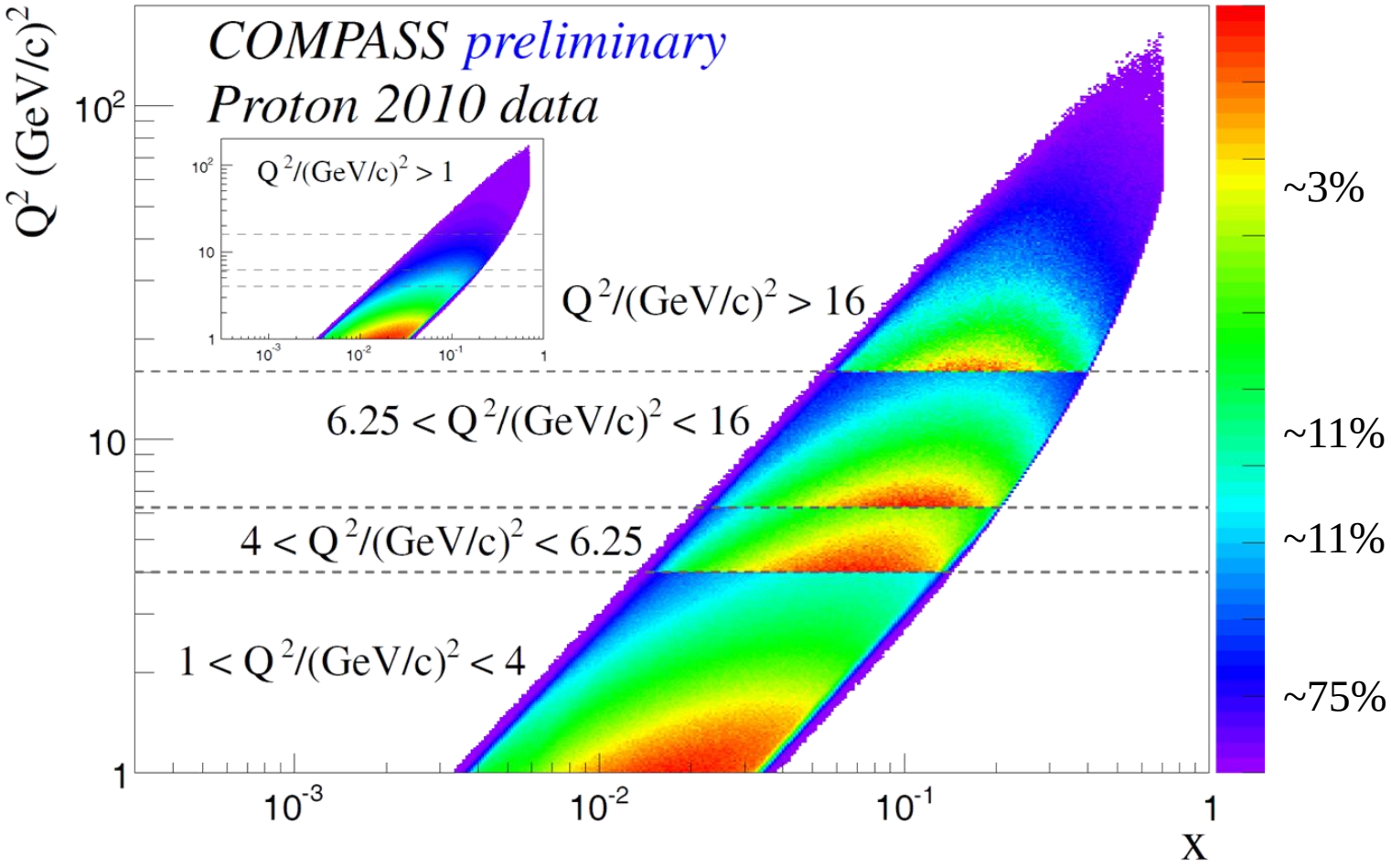
COMPASS phase-space x:Q^2 ("DY" Q^2-ranges)



- In SIDIS with z>0.2 and $Q^2 > 16$ (GeV/c)^2: $\delta A_{UT}^{\sin(\phi_h - \phi_s)} \approx$ **0.01** (for h^+) and ≈ **0.012** (for h^-)
- $\delta A_T^{\sin\varphi_s}$ in DY "high mass" range with 2.85 10^5 events (140 days) ≈ **0.013**

See talk by M. Chiosso on 13.06

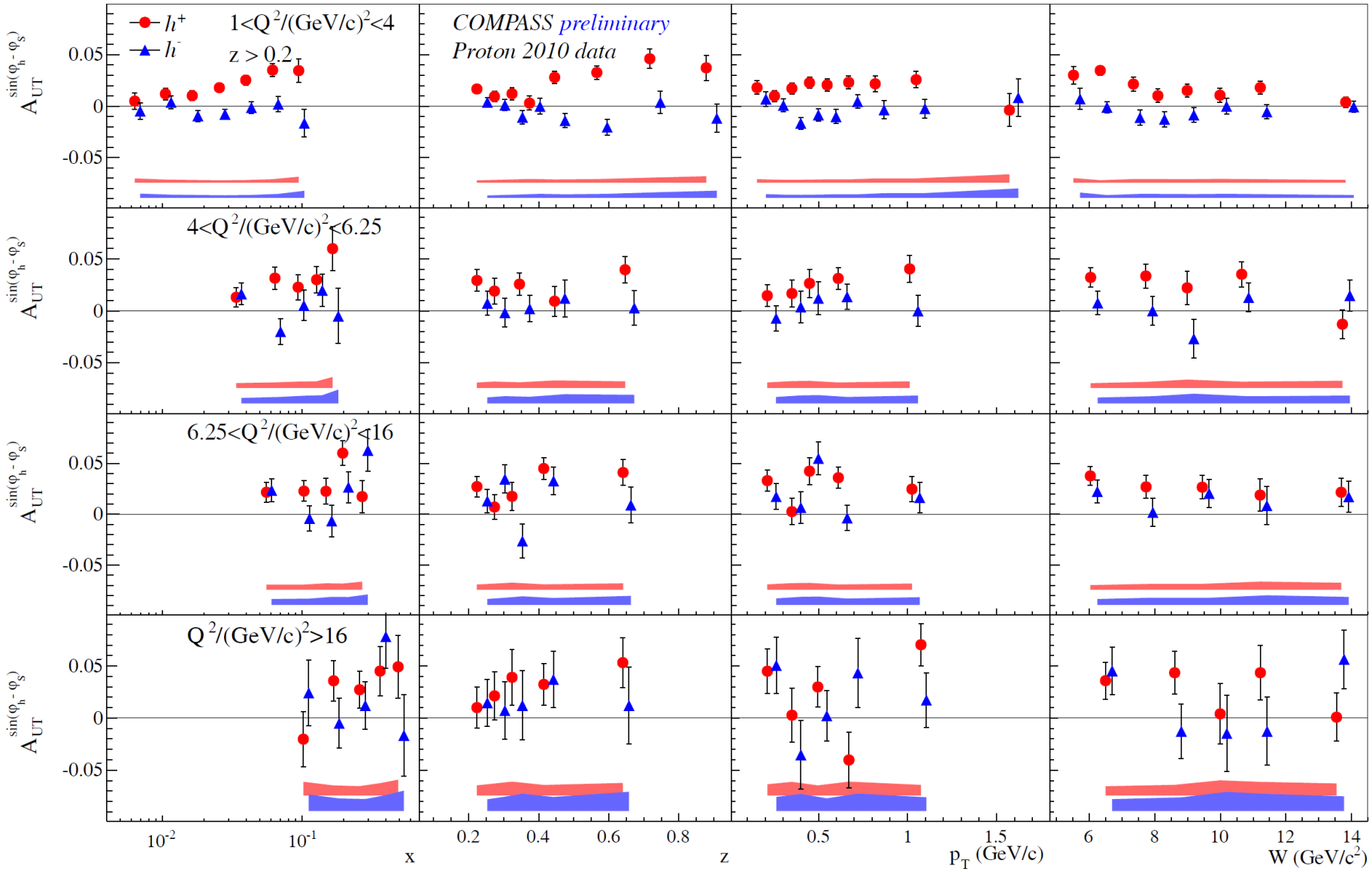
Outline

- Introduction
  - Brief review of COMPASS results with TSAs
- COMPASS – "SIDIS-DY bridge"
- **New results!**
  - **Asymmetries**
  - Re-evaluation of $A_{LT}^{\cos\varphi_S}$ and $A_{LT}^{\cos(\varphi_h - \varphi_S)}$: from the lp to $\gamma^* p$ cross-section
  - $A_{LT}^{\cos(\varphi_h - \varphi_S)}$: Comparison with predictions
  - Multi-D map of kinematical distributions
- Conclusions

Sivers in DY Q^2-bins: $z > 0.2$

Input for "Q^2-evolution"-related studies

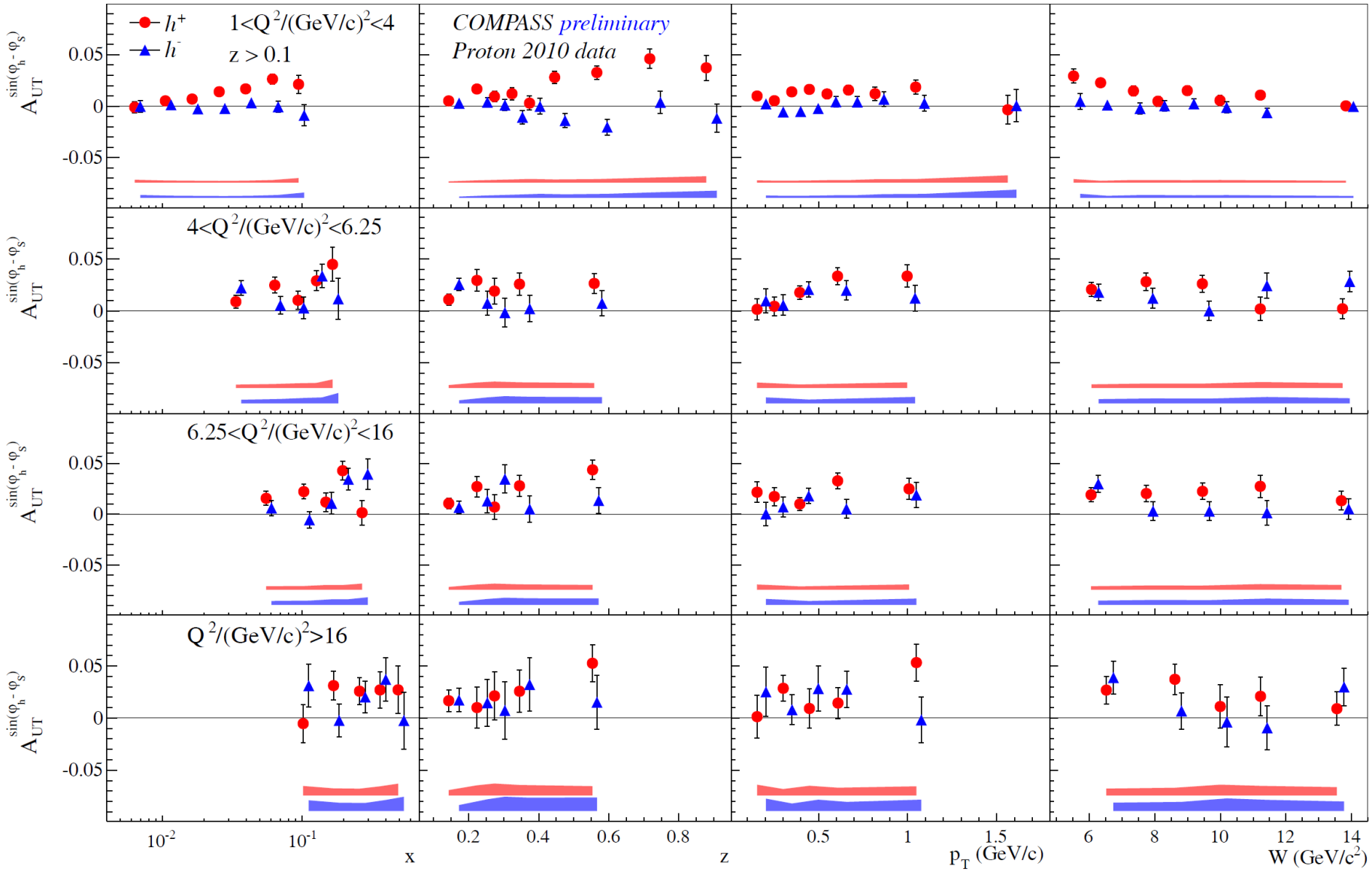
NEW! These results are being shown for the first time



Sivers in DY Q^2-bins: $z > 0.1$

Input for "Q^2-evolution"-related studies

NEW! These results are being shown for the first time



Collins in DY Q^2-bins: $z > 0.2$

Input for "Q^2-evolution"-related studies

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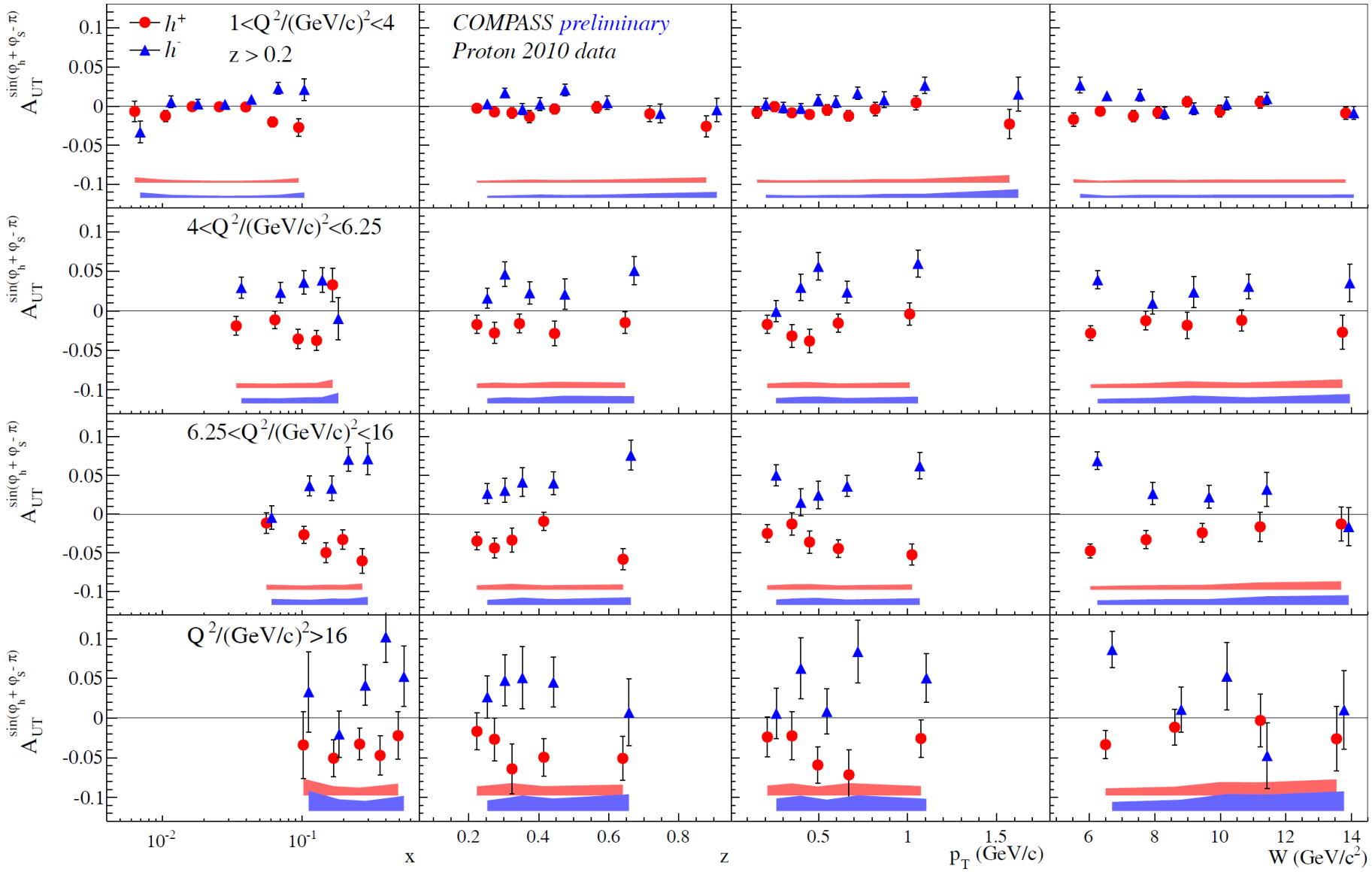

Collins in DY Q^2-bins: $z > 0.1$

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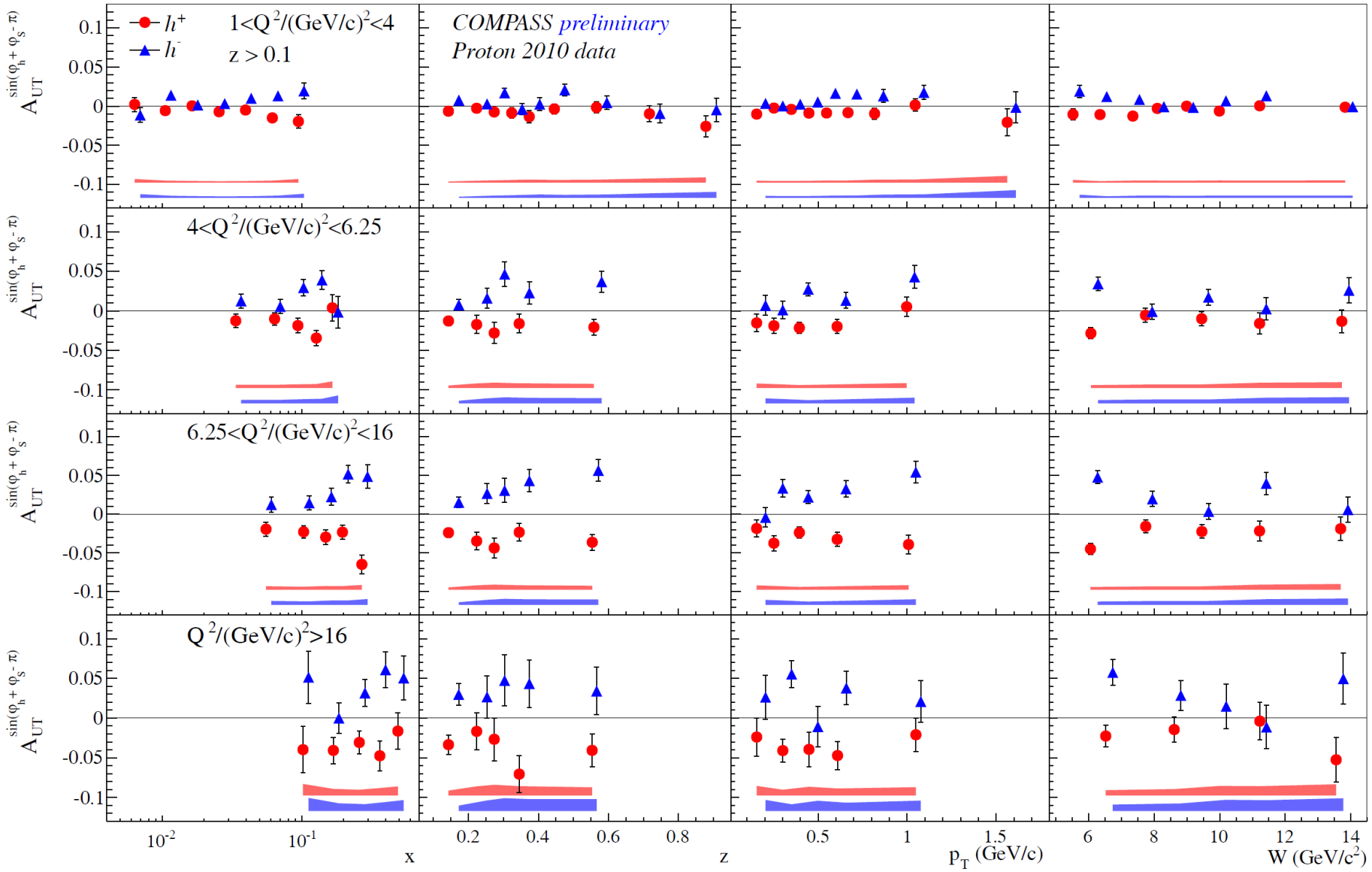

$A_{LT}^{\cos(\varphi_h-\varphi_S)}$ in DY Q^2-bins: $z > 0.2$

Input for "Q^2-evolution"-related studies

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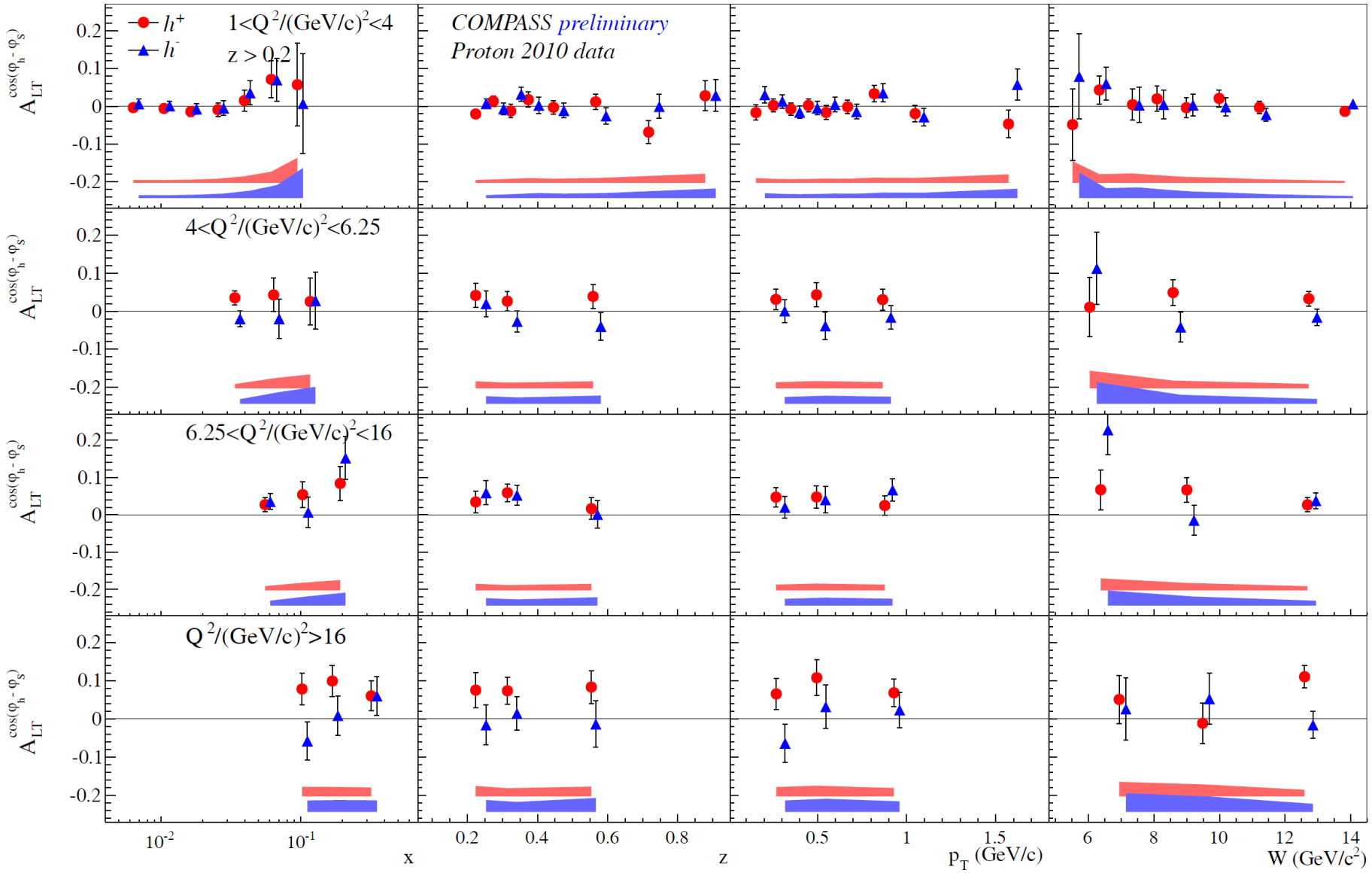

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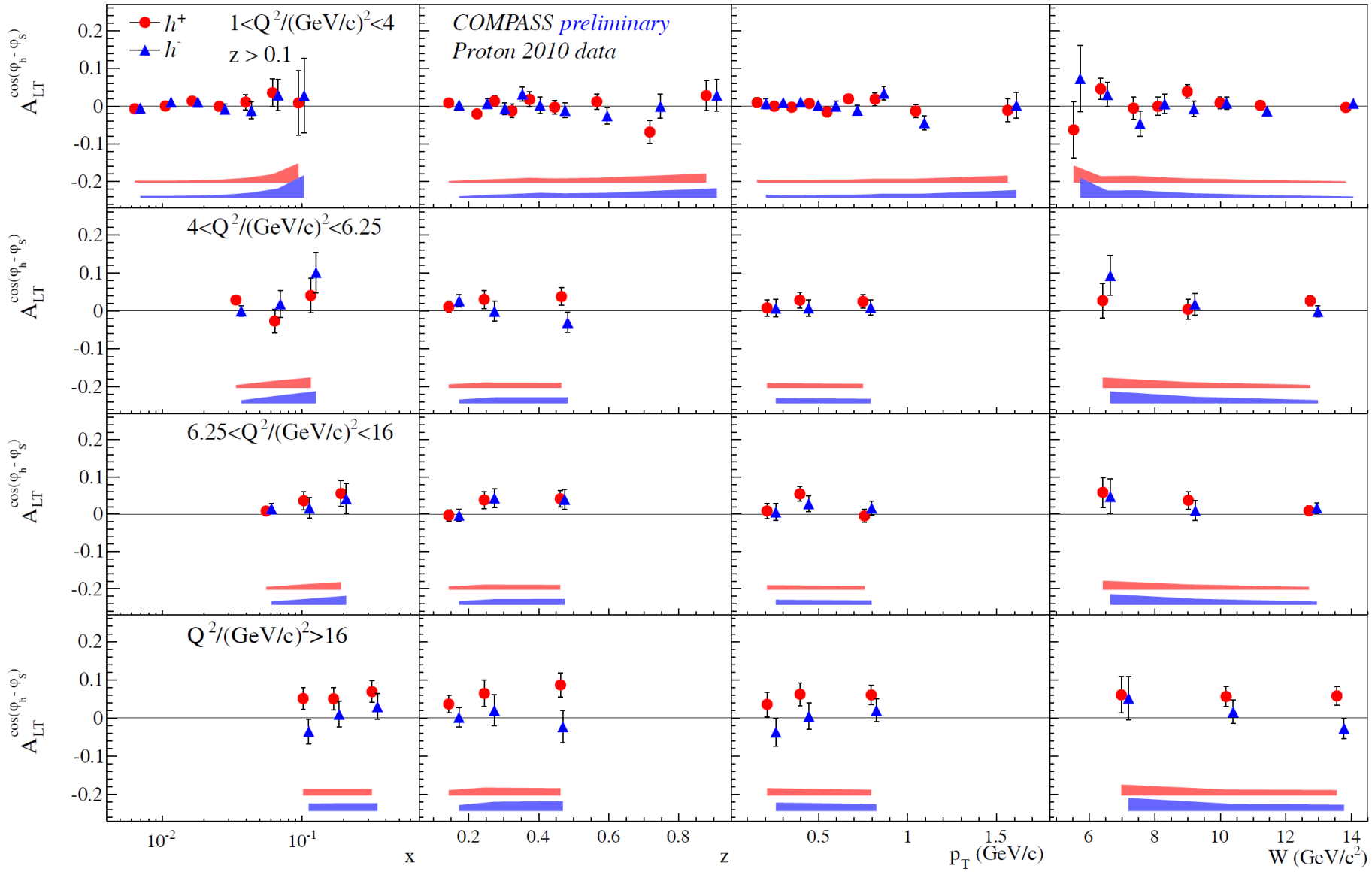
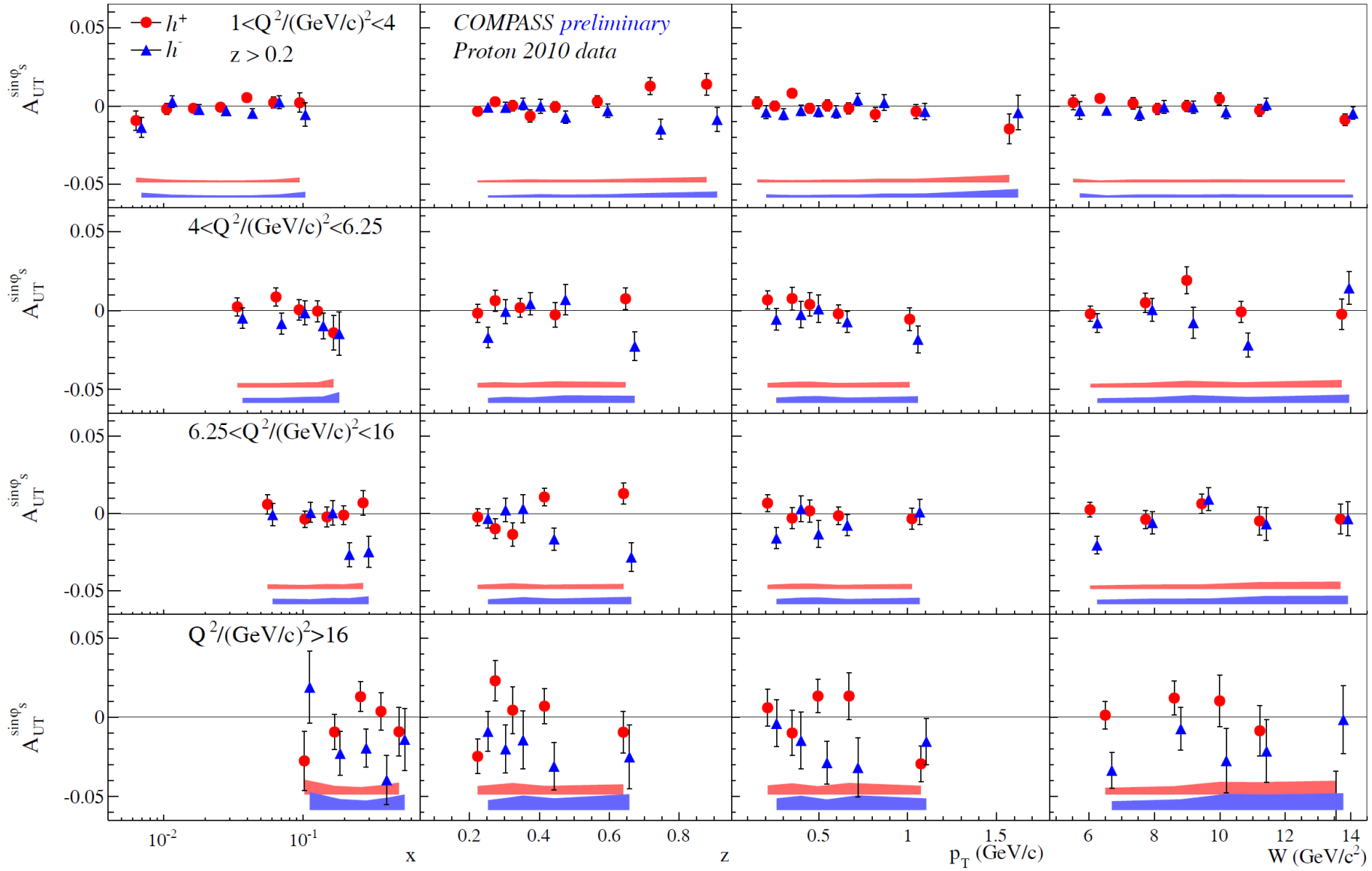


$A_{UT}^{\sin\varphi_S}$ in DY Q^2-bins: z > 0.2

Input for "Q^2-evolution"-related studies

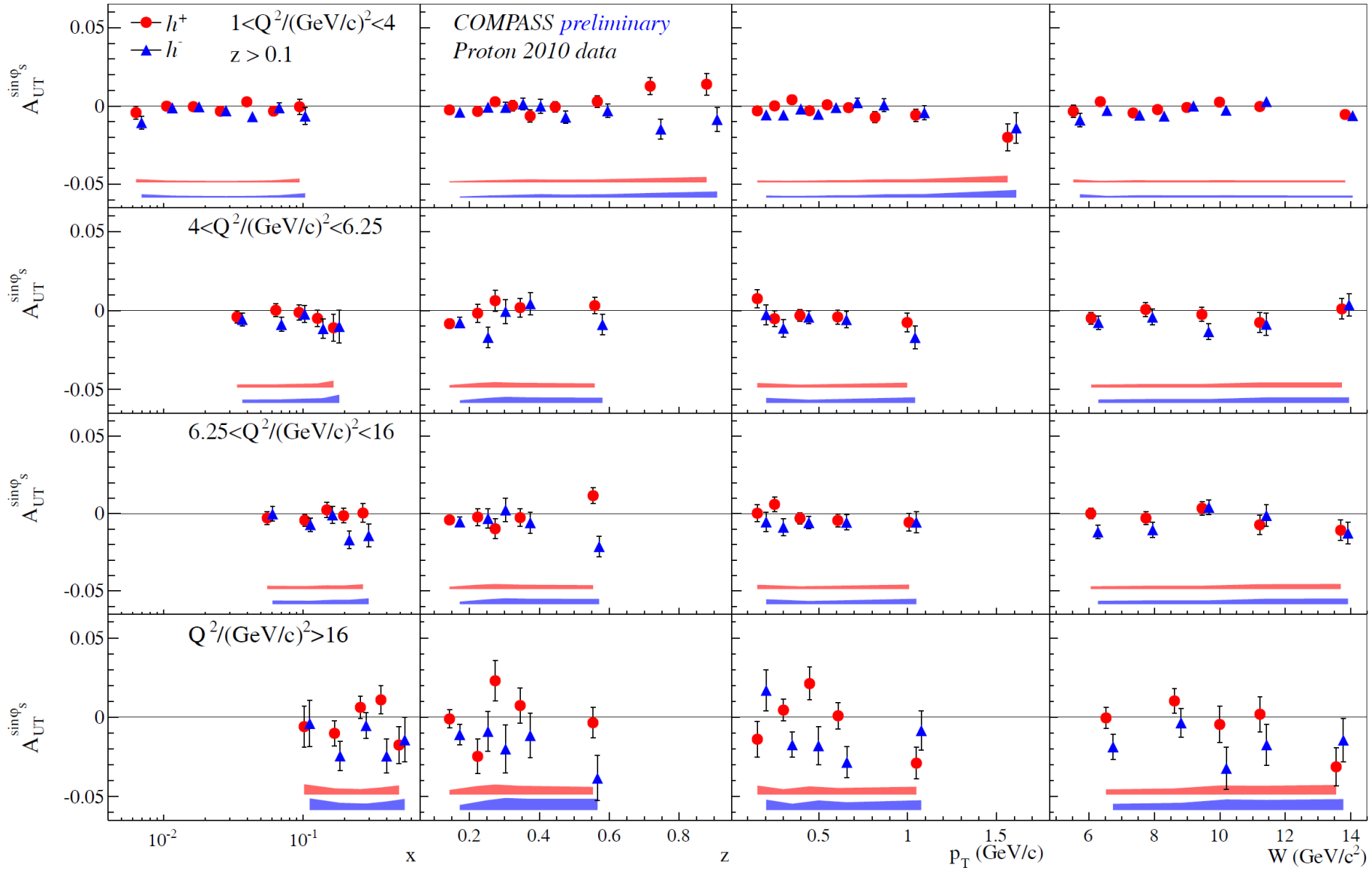
NEW! These results are being shown for the first time



$A_{UT}^{\sin\varphi_S}$ in DY Q^2-bins: z > 0.1

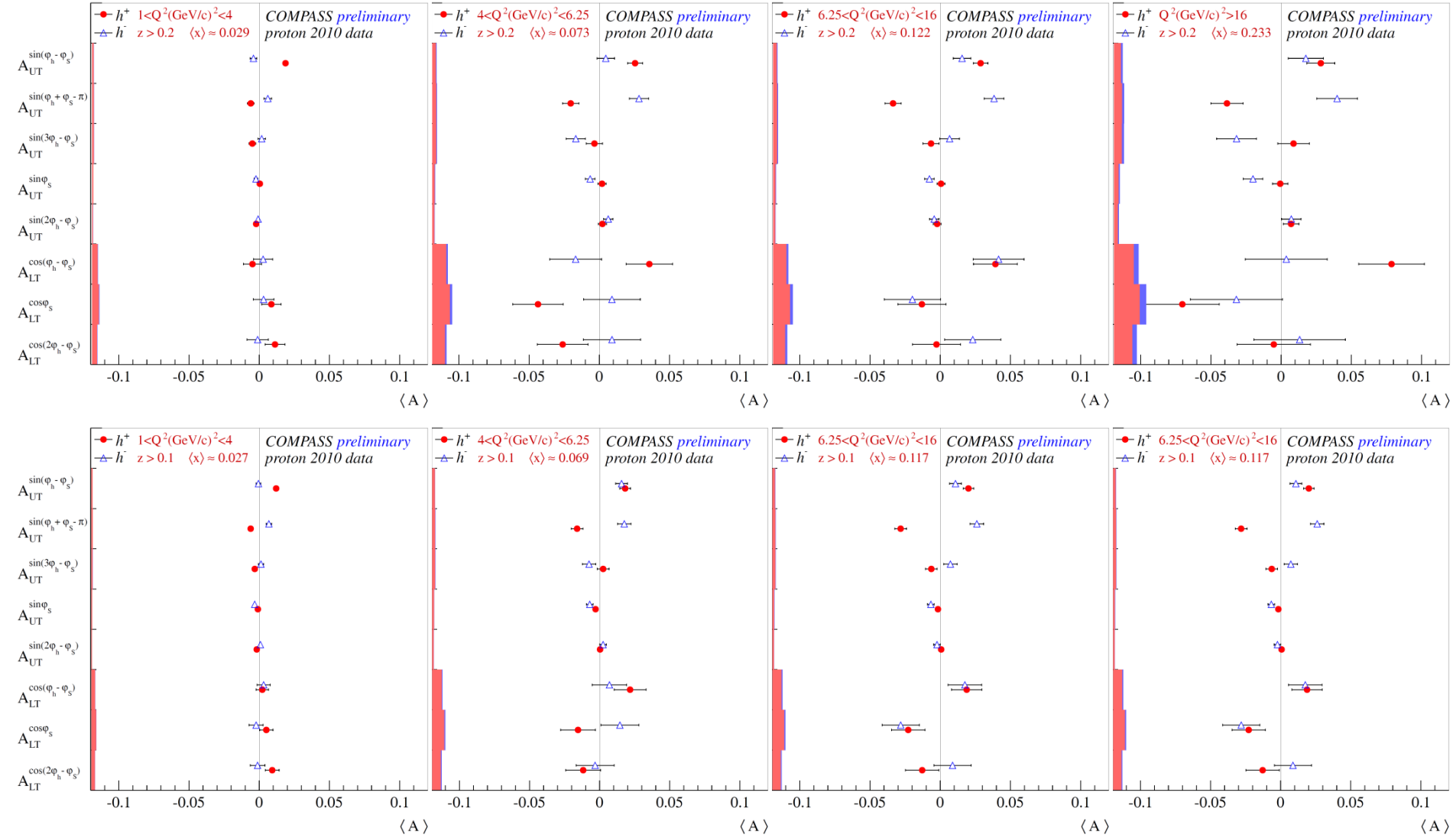
Input for "Q^2-evolution"-related studies

NEW! These results are being shown for the first time

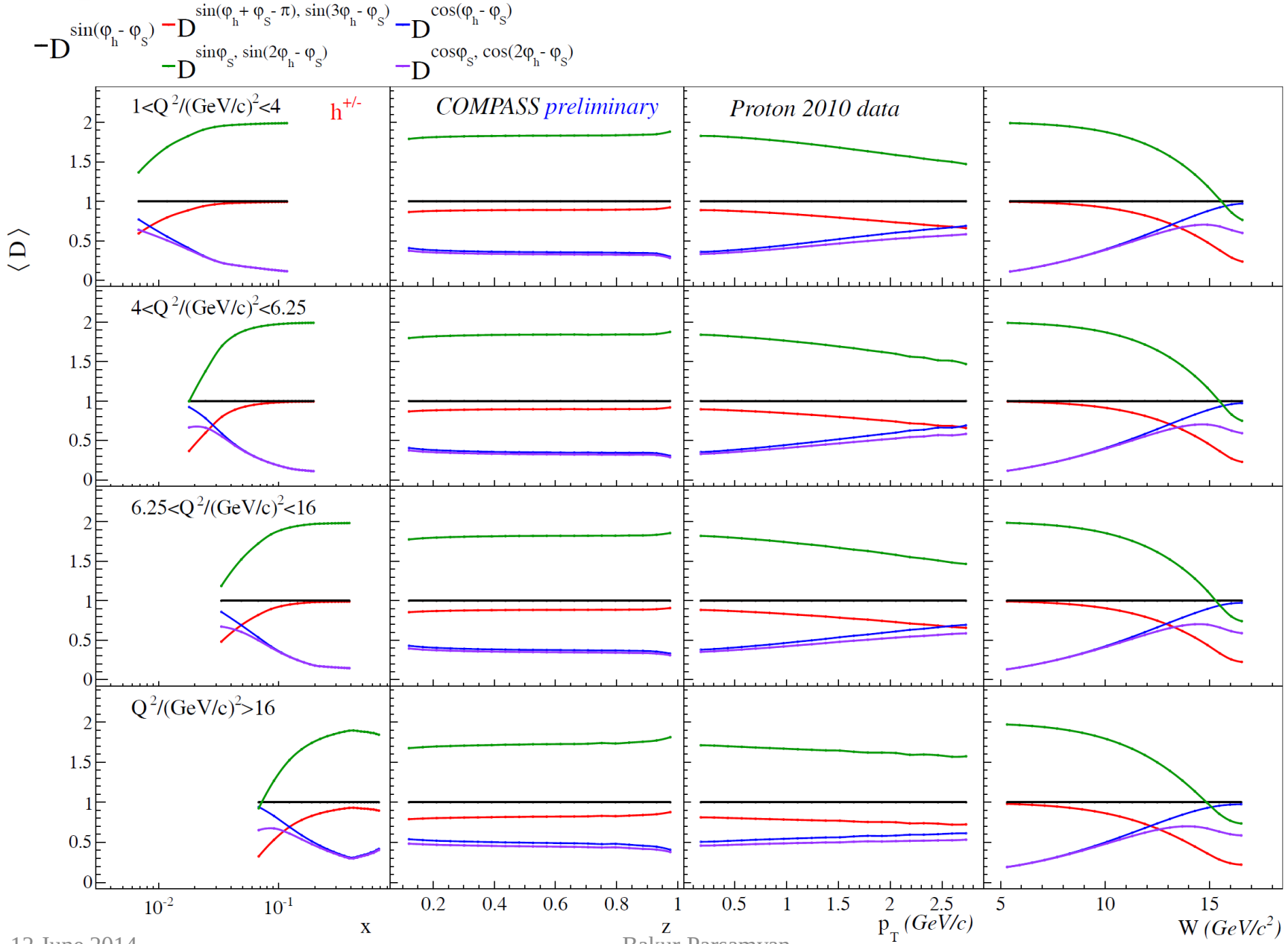


Mean asymmetries in DY-ranges

NEW! These results are being shown for the first time



Depolarization factors



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SIDIS x-section: from lp to $\gamma^* p$ (P_L=0)

Kotzinian et al.
hep-ph/9808368 (1998)
hep-ph/9908466 (1999)
M. Diehl and S. Sapeta,
Eur. Phys. J. C 41 (2005) 515

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

$$\left[1+\cos\varphi_h\times\sqrt{2\varepsilon(1+\varepsilon)}A_{UU}^{\cos\varphi_h}+\cos(2\varphi_h)\times\varepsilon A_{UU}^{\cos(2\varphi_h)}+\lambda\sin\varphi_h\times\sqrt{2\varepsilon(1-\varepsilon)}A_{LU}^{\sin\varphi_h}+\right.$$

$$\frac{P_T}{\sqrt{1-\sin^2\theta\sin^2\varphi_S}}\left[\sin\varphi_S\times\left(\cos\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+\right.$$

$$\sin(\varphi_h-\varphi_S)\times\left(\cos\theta A_{UT}^{\sin(\varphi_h-\varphi_S)}+\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UL}^{\sin\varphi_h}\right)+$$

$$\sin(\varphi_h+\varphi_S)\times\left(\cos\theta\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}+\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UL}^{\sin\varphi_h}\right)+$$

$$\sin(2\varphi_h-\varphi_S)\times\left(\cos\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}+\frac{1}{2}\sin\theta\varepsilon A_{UL}^{\sin 2\varphi_h}\right)+$$

$$\sin(3\varphi_h-\varphi_S)\times\left(\cos\theta\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right)+$$

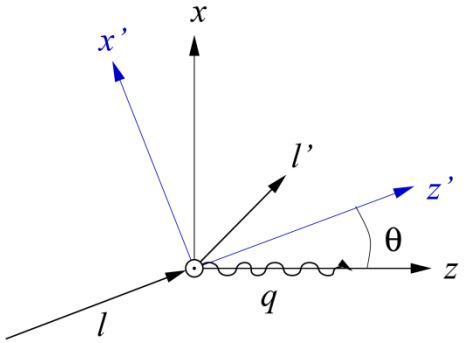
$$\left.\left.\sin(2\varphi_h+\varphi_S)\times\left(\frac{1}{2}\sin\theta\varepsilon A_{UL}^{\sin 2\varphi_h}\right)\right]+\right.$$

$$\frac{P_T\lambda}{\sqrt{1-\sin^2\theta\sin^2\varphi_S}}\left[\cos\varphi_S\times\left(\cos\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}+\sin\theta\sqrt{(1-\varepsilon^2)}A_{LL}\right)+\right.$$

$$\cos(\varphi_h-\varphi_S)\times\left(\cos\theta\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}+\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LL}^{\cos\varphi_h}\right)+$$

$$\cos(2\varphi_h-\varphi_S)\times\left(\cos\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)+$$

$$\left.\left.\cos(\varphi_h+\varphi_S)\times\left(\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LL}^{\cos\varphi_h}\right)\right]\right]$$



lepton plane

$$\sin\theta=\gamma\sqrt{\frac{1-y-\frac{1}{4}\gamma^2y^2}{1+\gamma^2}},\ \gamma=\frac{2Mx}{Q};$$

$$\theta\xrightarrow[\text{Bjorken limit}]{}0\Rightarrow S_T\simeq P_T,\ S_L\simeq P_L$$

SIDIS x-section: from *lp* to $\gamma^* p$ (P_L=0)

Kotzinian et al.
hep-ph/9808368 (1998)
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M. Diehl and S. Sapeta,
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$$\left[1+\cos\varphi_h\times\sqrt{2\varepsilon(1+\varepsilon)}A_{UU}^{\cos\varphi_h}+\cos(2\varphi_h)\times\varepsilon A_{UU}^{\cos(2\varphi_h)}+\lambda\sin\varphi_h\times\sqrt{2\varepsilon(1-\varepsilon)}A_{LU}^{\sin\varphi_h}+\right.$$

$$\frac{P_T}{\sqrt{1-\sin^2\theta\sin^2\varphi_S}}\left[\sin\varphi_S\times\left(\cos\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+\right.$$

$$\sin(\varphi_h-\varphi_S)\times\left(\cos\theta A_{UT}^{\sin(\varphi_h-\varphi_S)}+\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UL}^{\sin\varphi_h}\right)+$$

$$\sin(\varphi_h+\varphi_S)\times\left(\cos\theta\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}+\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UL}^{\sin\varphi_h}\right)+$$

$$\sin(2\varphi_h-\varphi_S)\times\left(\cos\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}+\frac{1}{2}\sin\theta\varepsilon A_{UL}^{\sin 2\varphi_h}\right)+$$

$$\sin(3\varphi_h-\varphi_S)\times\left(\cos\theta\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right)+$$

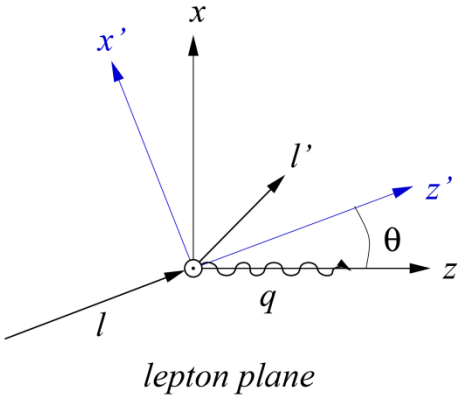
$$\left.\left.\sin(2\varphi_h+\varphi_S)\times\left(\frac{1}{2}\sin\theta\varepsilon A_{UL}^{\sin 2\varphi_h}\right)\right]+\right.$$

$$\frac{P_T\lambda}{\sqrt{1-\sin^2\theta\sin^2\varphi_S}}\left[\cos\varphi_S\times\left(\cos\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}+\sin\theta\sqrt{(1-\varepsilon^2)}A_{LL}\right)+\right.$$

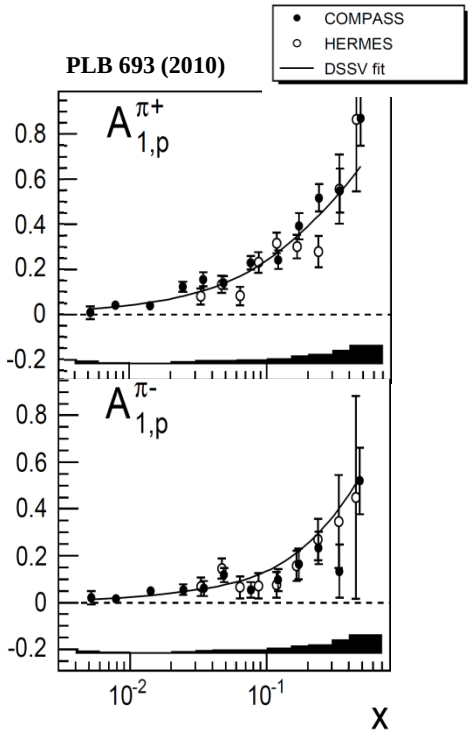
$$\cos(\varphi_h-\varphi_S)\times\left(\cos\theta\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}+\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LL}^{\cos\varphi_h}\right)+$$

$$\cos(2\varphi_h-\varphi_S)\times\left(\cos\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)+$$

$$\left.\left.\cos(\varphi_h+\varphi_S)\times\left(\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LL}^{\cos\varphi_h}\right)\right]\right]$$



lepton plane



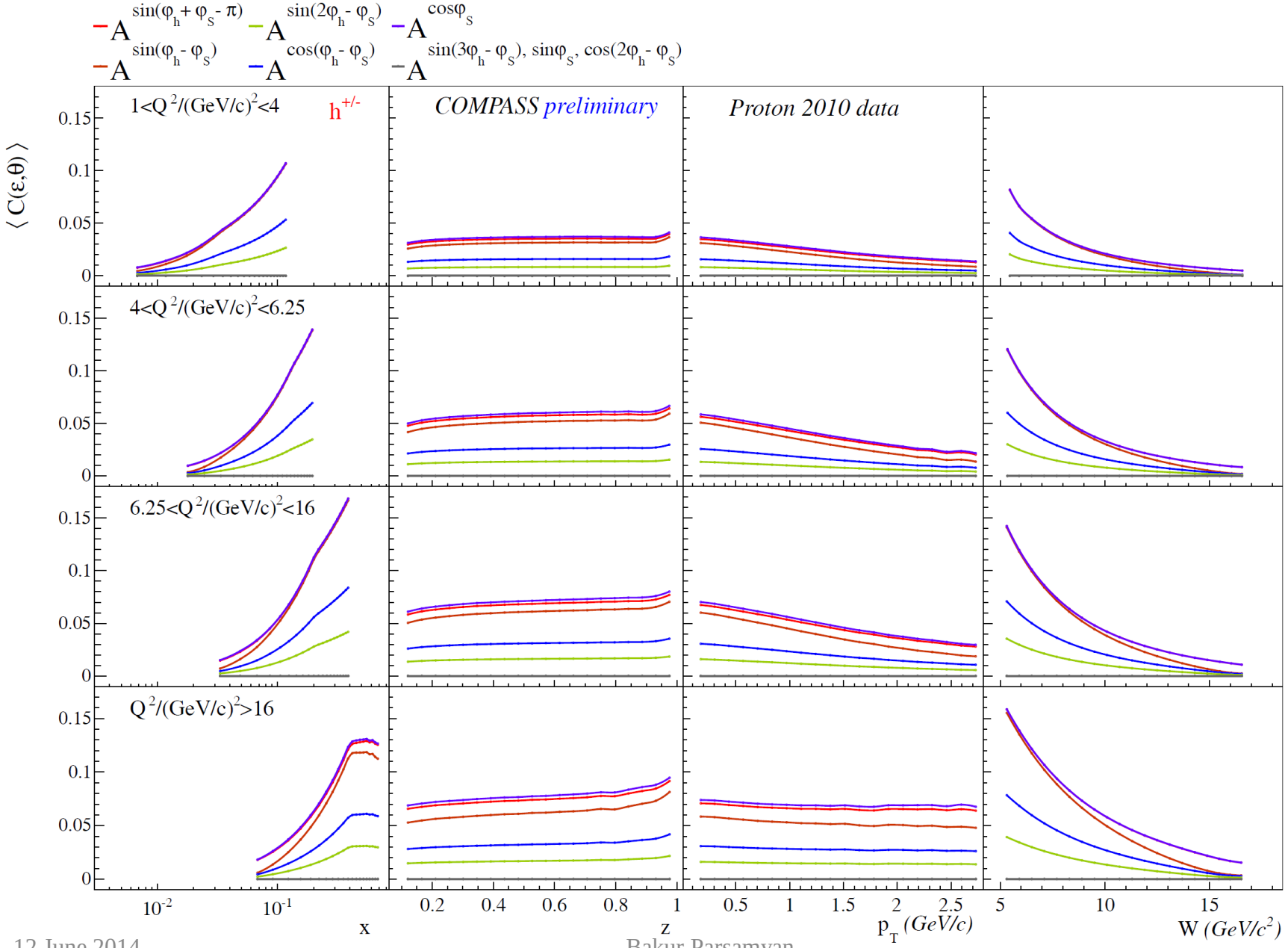
Mixing of the "T" and "L" amplitudes

$$TSA_{fit} = \cos\theta \cdot TSA_{real} + C(\varepsilon,\theta) \cdot LSA$$

TSA	$C(\varepsilon,\theta)$ - factor	Contributing LSA
$A_{UT}^{\sin(\phi_h-\phi_s)}$	$\sin\theta \dfrac{\sqrt{2\varepsilon(1+\varepsilon)}}{2}$	$A_{UL}^{\sin\phi_h}$
$A_{UT}^{\sin(\phi_h+\phi_s)}$	$\sin\theta \dfrac{\sqrt{2\varepsilon(1+\varepsilon)}}{2\varepsilon}$	$A_{UL}^{\sin\phi_h}$
$A_{UT}^{\sin(2\phi_h-\phi_s)}$	$\sin\theta \dfrac{\varepsilon}{2\sqrt{2\varepsilon(1+\varepsilon)}}$	$A_{UL}^{\sin2\phi_h}$
$A_{LT}^{\cos(\phi_h-\phi_s)}$	$\sin\theta \dfrac{\sqrt{2\varepsilon(1-\varepsilon)}}{2\sqrt{(1-\varepsilon^2)}}$	$A_{LL}^{\cos\phi_h}$
$A_{LT}^{\cos\phi_s}$	$\sin\theta \dfrac{\sqrt{(1-\varepsilon^2)}}{\sqrt{2\varepsilon(1-\varepsilon)}}$	A_{LL}
$A_{UT}^{\sin(3\phi_h-\phi_s)}, A_{UT}^{\sin\phi_s}, A_{LT}^{\cos(2\phi_h-\phi_s)}$	–	–

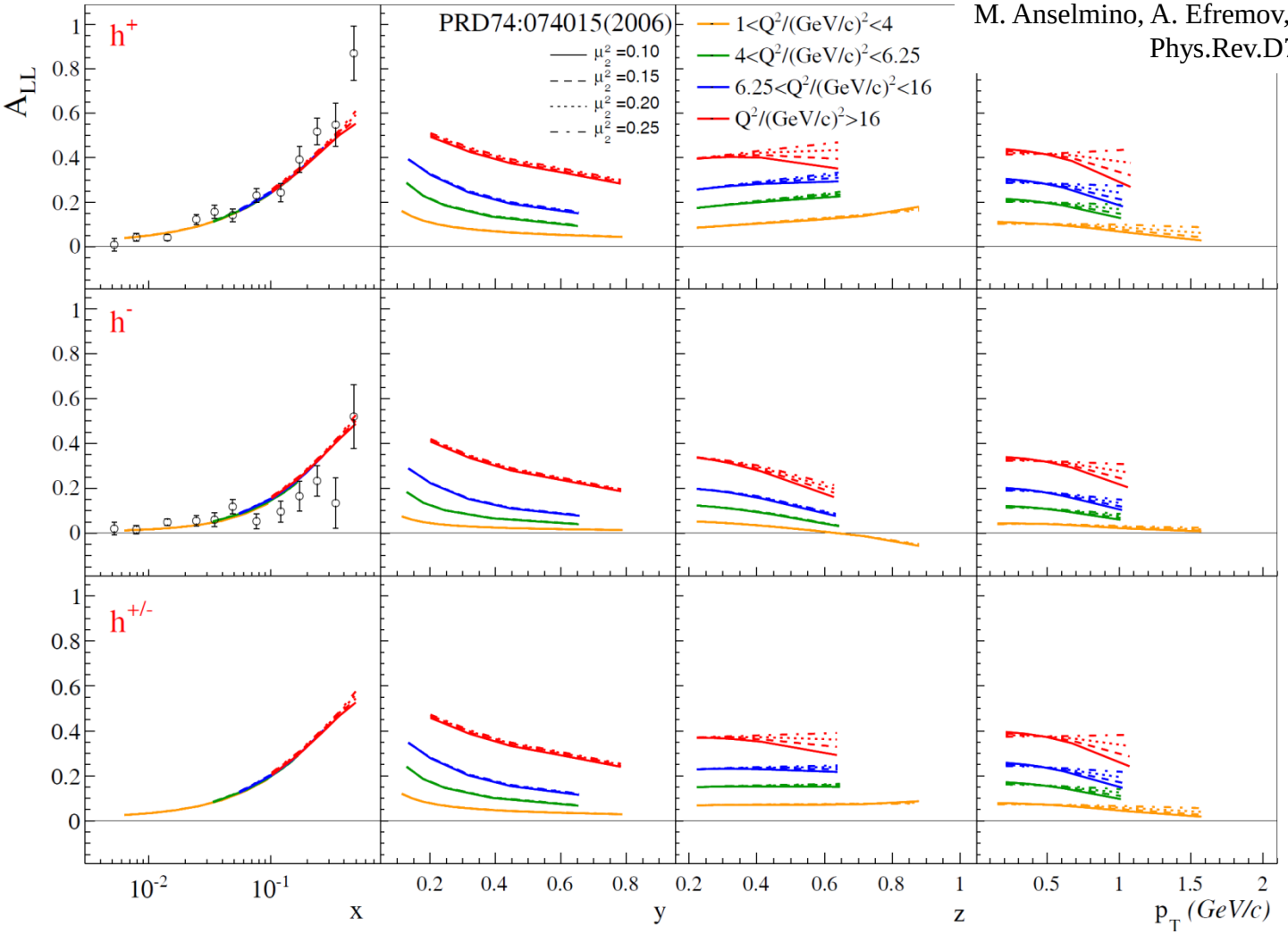
The sinθ is small at COMPASS kinematics.
The maximum reached value is ~ 0.18 and the mean is around 0.05 (cosθ > 0.98).

$C(\varepsilon, \theta)$ - factors for different asymmetries



A_{LL} evaluated according to the PRD **74,** 074015 (2006)

COMPASS Proton 2007 (PLB 693(2010))



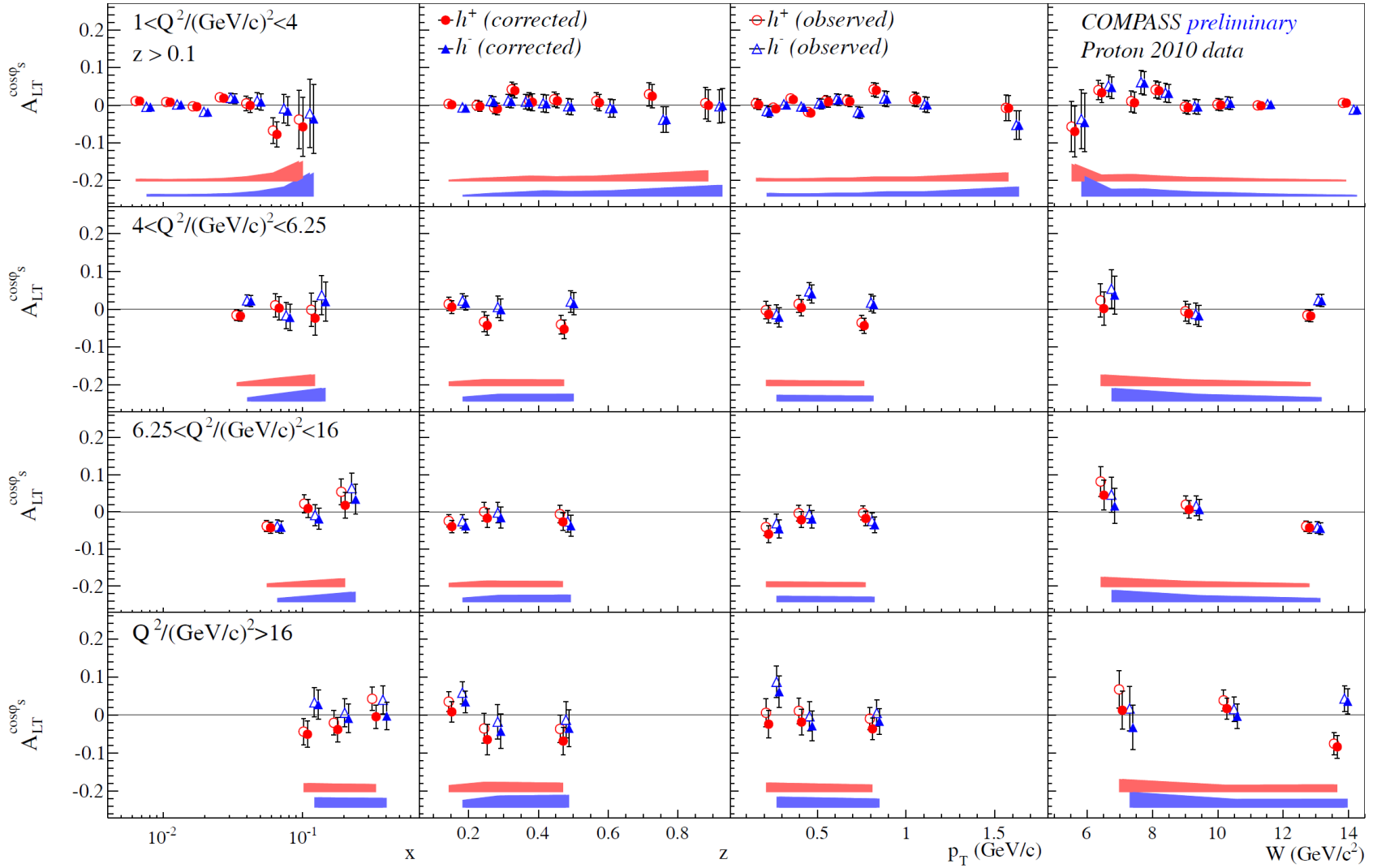
M. Anselmino, A. Efremov, A. Kotzinian, and B. Parsamyan
Phys.Rev.D74:074015 (2006)

Asymmetry is evaluated in COMPASS specific mean kinematic points extracted from the data. Good level of agreement, which allows us to use the predicted *x*- , *z*- and p_T - dependencies for the $A_{LT}^{\cos(\varphi_S)}$-*correction.*

$A_{LT}^{\cos\varphi_S}$ corrected for A_{LL}-contribution

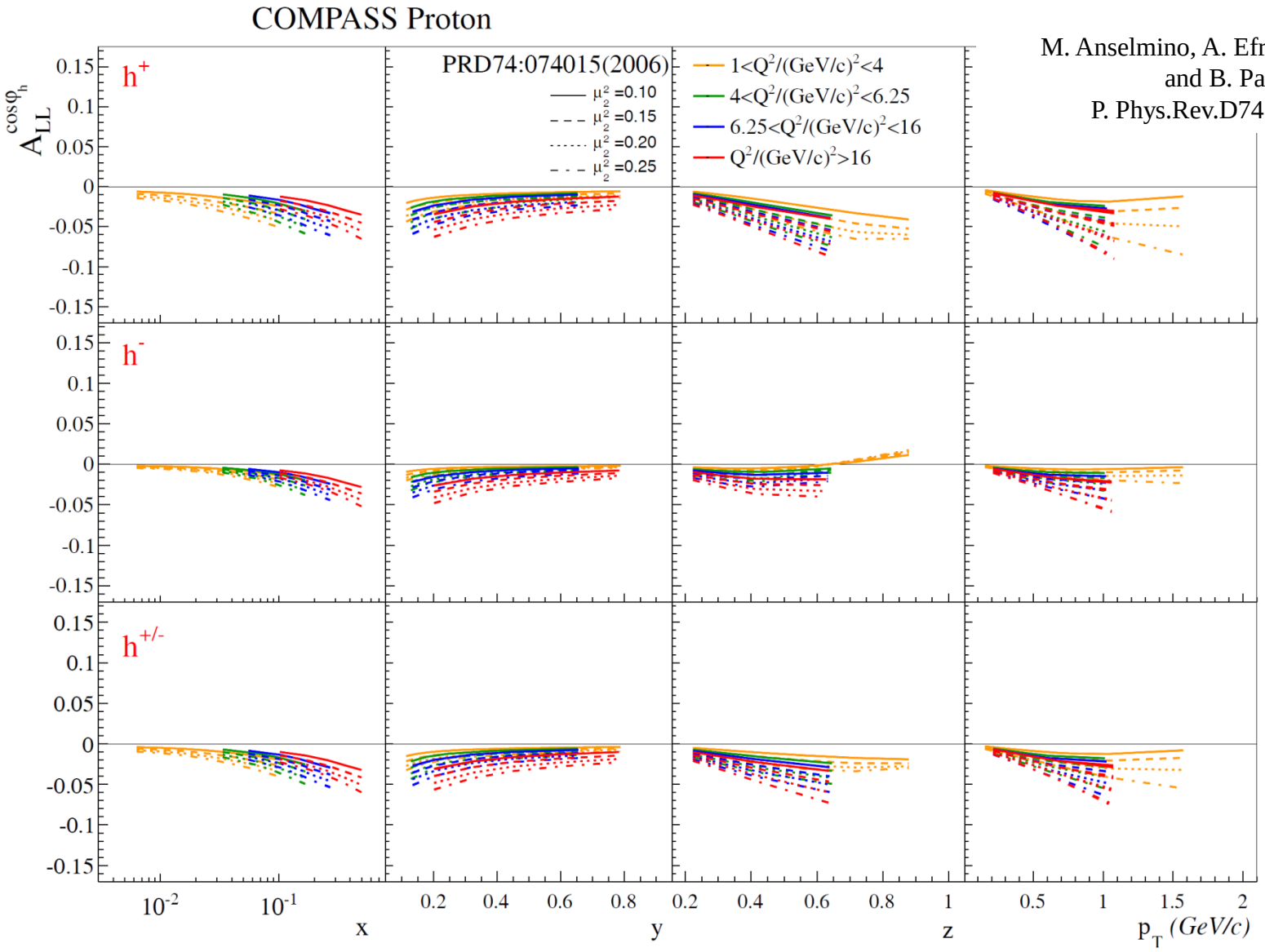
using A_{LL} from PRD **74,** 074015(2006)

$$A_{LT,observed}^{\cos\varphi_S} \approx \left(\cos\theta A_{LT}^{\cos\varphi_S} + \sin\theta \frac{\sqrt{\left(1-\varepsilon^2\right)}}{\sqrt{2\varepsilon\left(1-\varepsilon\right)}} A_{LL} \right)$$



As expected, at large *x* the corrections become sizable.

$A_{LL}^{\cos\varphi_h}$ evaluated according to the PRD 74, 074015 (2006)

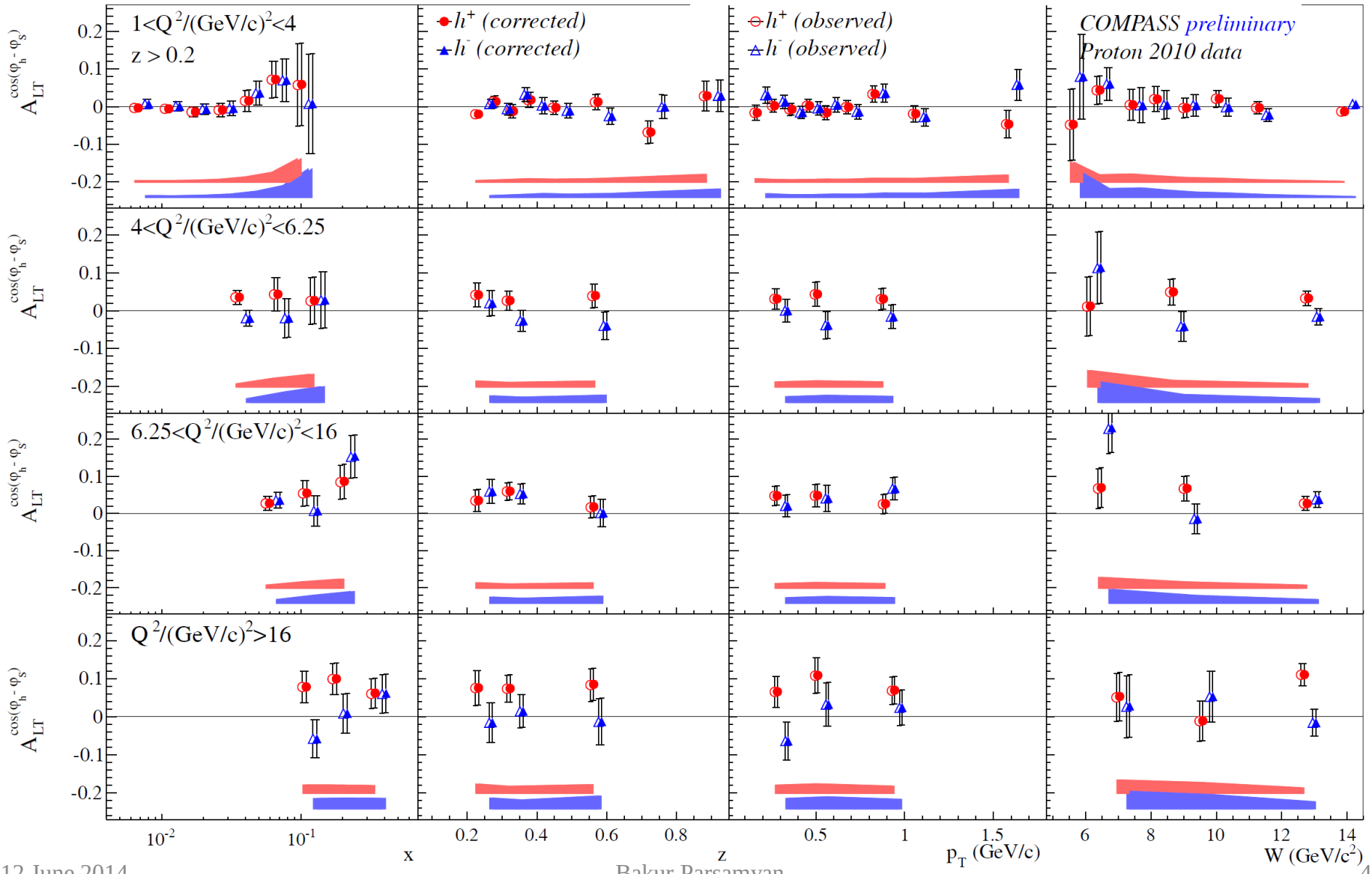


M. Anselmino, A. Efremov, A. Kotzinian, and B. Parsamyan
P. Phys.Rev.D74:074015 (2006)

Asymmetry is evaluated in COMPASS specific mean kinematic points extracted from the proton data.

$A_{LT}^{\cos(\varphi_h - \varphi_S)}$ corrected for $A_{LL}^{\cos\varphi_h}$-contribution

M. Anselmino, A. Efremov, A. Kotzinian, and B. Parsamyan
Phys.Rev.D74:074015 (2006)

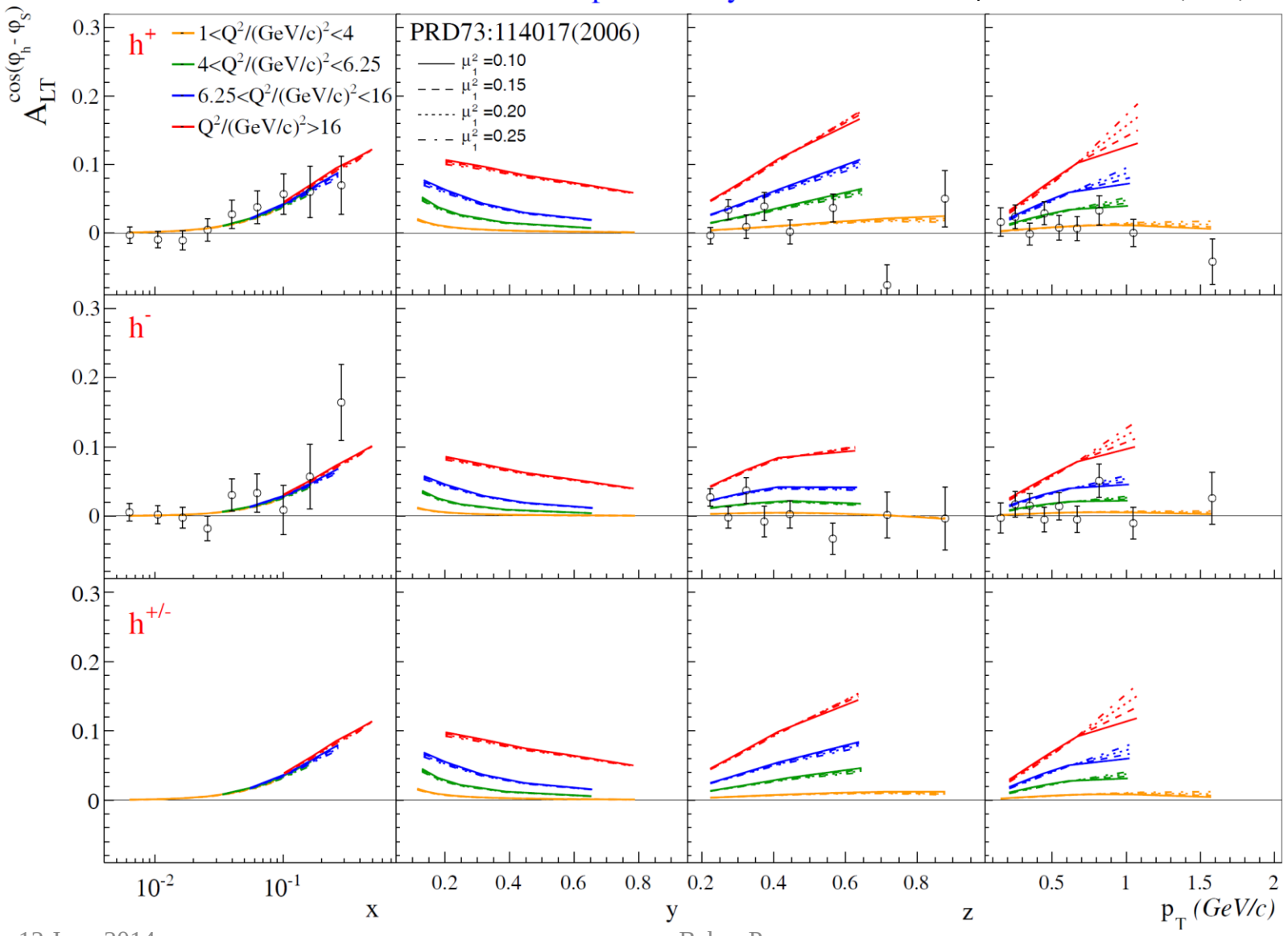


Outline

- Introduction
  - Brief review of COMPASS results with TSAs
- COMPASS – "SIDIS-DY bridge"
- New results!
  - Asymmetries
  - Re-evaluation of $A_{LT}^{\cos\varphi_S}$ and $A_{LT}^{\cos(\varphi_h - \varphi_s)}$: from the lp to $\gamma^* p$ cross-section
  - $A_{LT}^{\cos(\varphi_h - \varphi_s)}$: Comparison with predictions
  - Multi-D map of kinematical distributions
- Conclusions

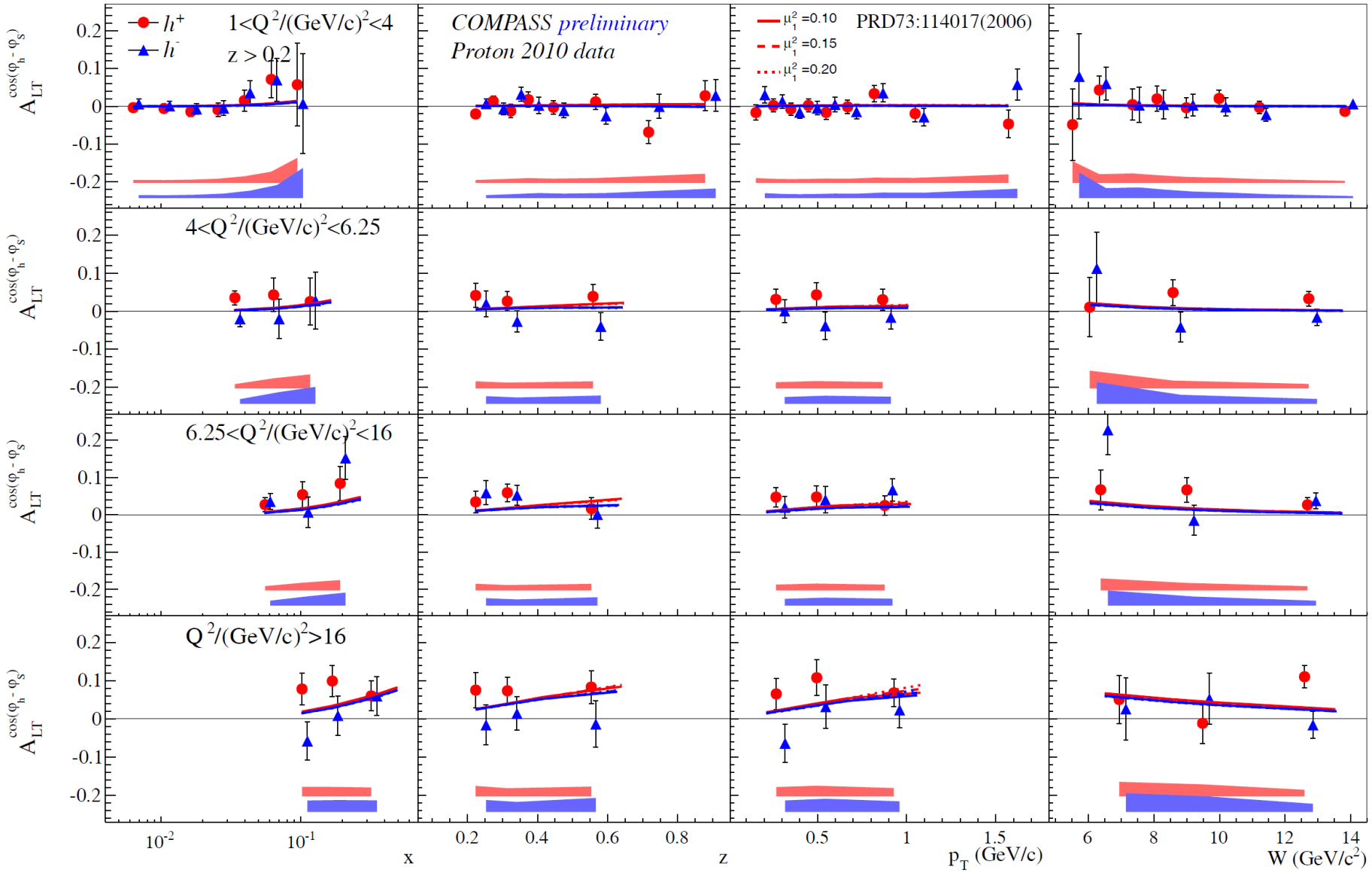
$A_{LT}^{\cos(\varphi_h-\varphi_S)}$ in DY Q^2-bins: PRD 73, 114017(2006)

A. Kotzinian, B. Parsamyan, A. Prokudin
Phys.Rev.D73:114017 (2006)



$A_{LT}^{\cos(\varphi_h-\varphi_S)}$ in DY Q^2-bins:

predictions i.a.w. PRD 73, 114017(2006)



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  - **Multi-D map of kinematical distributions**
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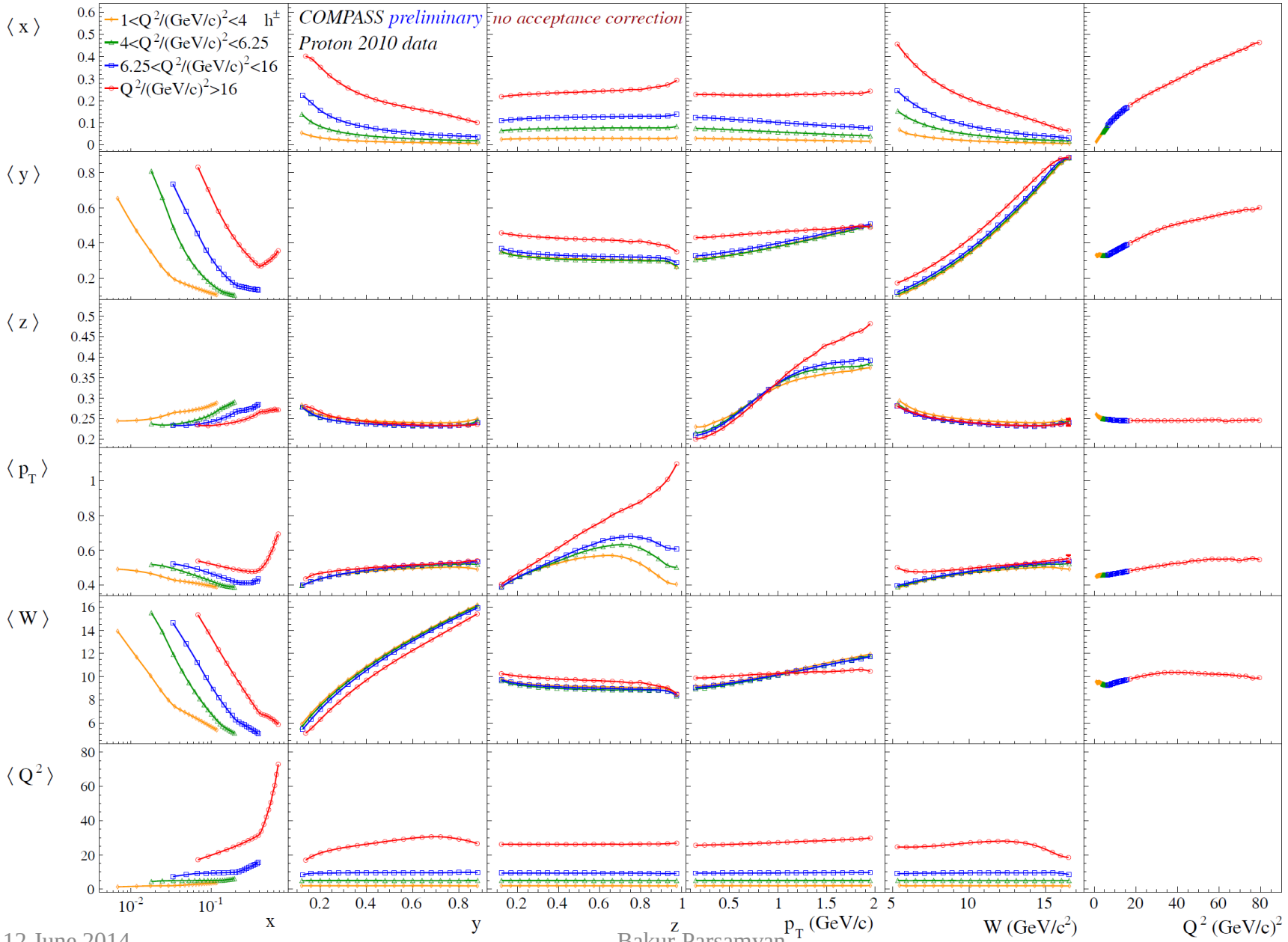
Multi-D map of kinematical distributions



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  - Multi-D map of kinematical distributions
- **Conclusions**

Conclusions

- First input for the future global SIDIS-DY studies is provided
  - All eight SIDIS TSAs were extracted from COMPASS proton-2010 data in four "Drell-Yan" Q^2-bins.
- Several asymmetries show a non-zero trend in different kinematical regions
  - i.e. Sivers, Collins, $A_{LT}^{\cos(\varphi_h-\varphi_S)}$, $A_{UT}^{\sin\varphi_S}$
  - Predictions for the $A_{LT}^{\cos(\varphi_h-\varphi_S)}$ are in good agreement with the experimental results within the given statistical accuracy
- Interesting input to the "Q^2-evolution" related studies
  - Essentially, no strong Q^2- dependence observed within given statistical accuracy

- More refined multi-dimensional analysis is ongoing..! More news soon!

Thank you!

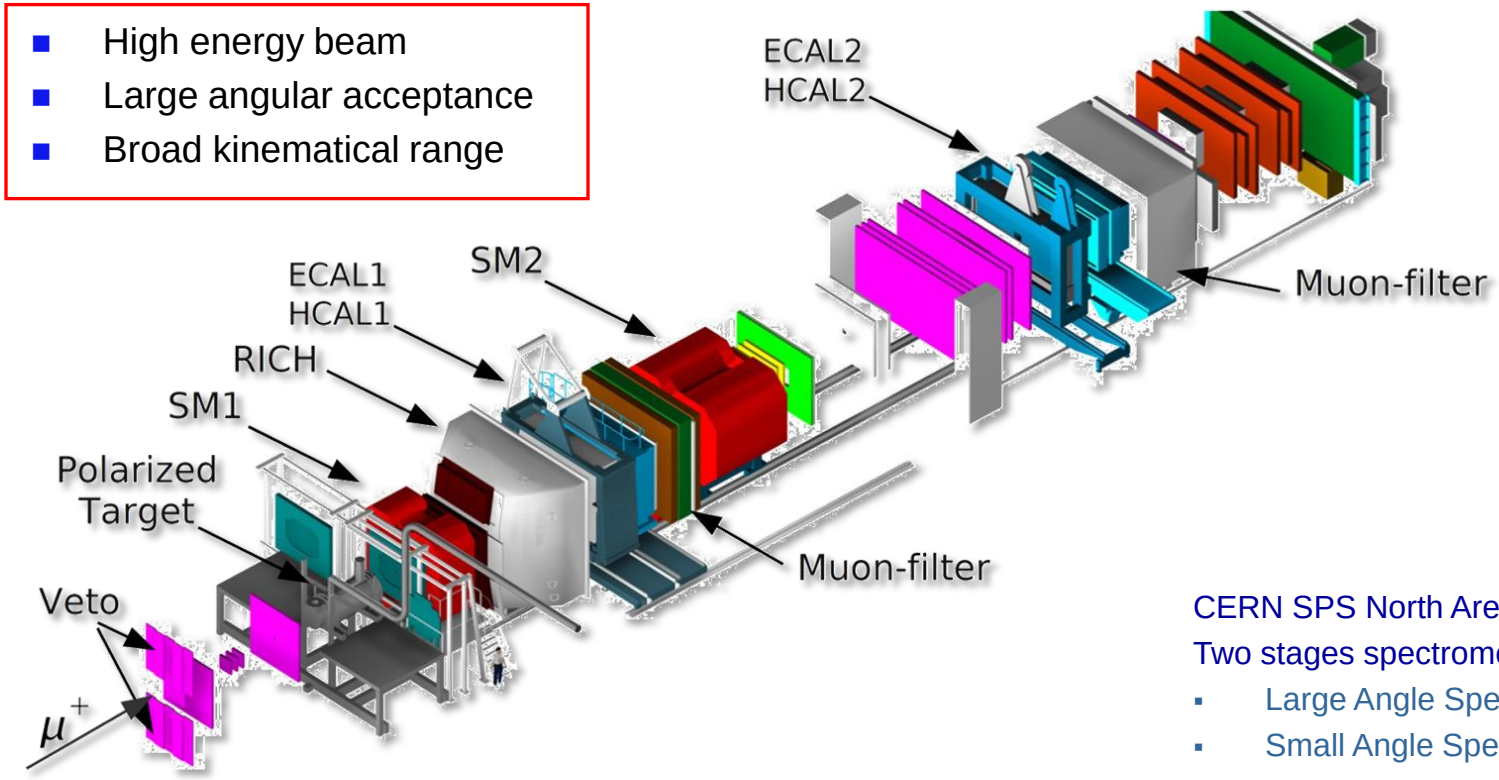
Sorry Christopher.. I did my best..!

Spare slides

COMPASS experimental setup

COmmon Muon Proton Apparatus for Structure and Spectroscopy

- High energy beam
- Large angular acceptance
- Broad kinematical range



Longitudinally polarized μ^+ beam (160 Gev/c).

Longitudinally or Transversely polarized ^{6}LiD or NH_3 target

Momentum, tracking and calorimetric measurements, PID

CERN SPS North Area.

Two stages spectrometer

- Large Angle Spectrometer (SM1)
- Small Angle Spectrometer (SM2)

Hadron & Muon high energy beams.

Beam rates: 10^8 muons/s, $5 \cdot 10^7$ hadrons/s.

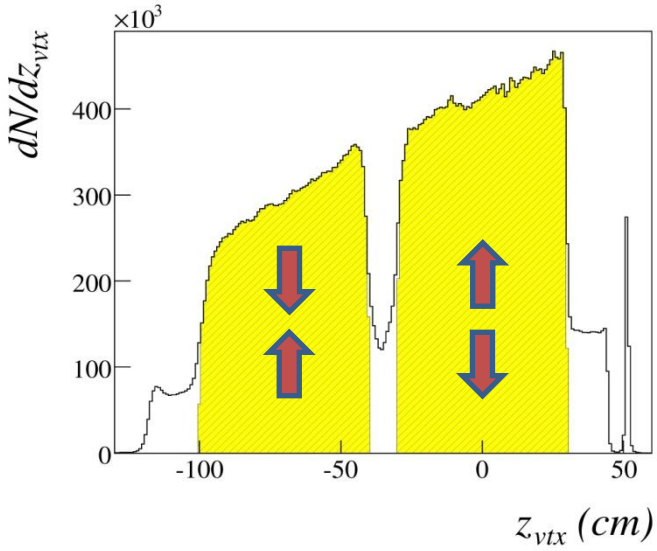
COMPASS Polarized target system

solid state target operated in frozen spin mode

Years 2002-2004

Deuteron - ^{6}LiD:

- Two 60 cm long ^{6}LiD cells with opposite polarization
- Polar angle acceptance – 70 mrad
- Target Polarization ±50%
- dilution factor f = 0.38

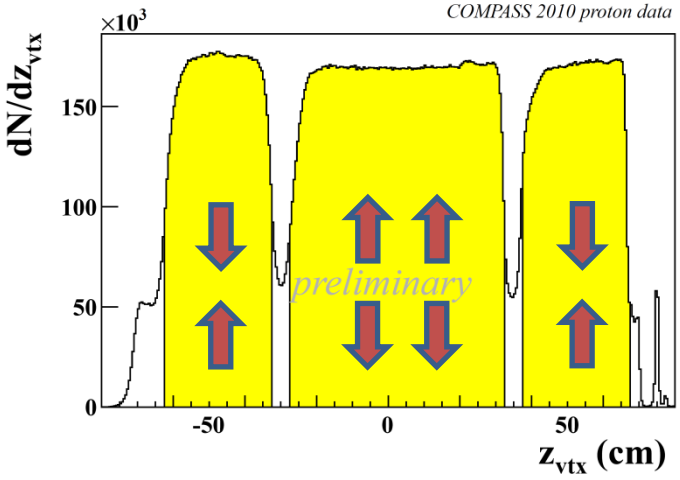


Data is collected simultaneously for the two target spin orientations
Polarization reversal after each ~4-5 days

Years 2007 and 2010

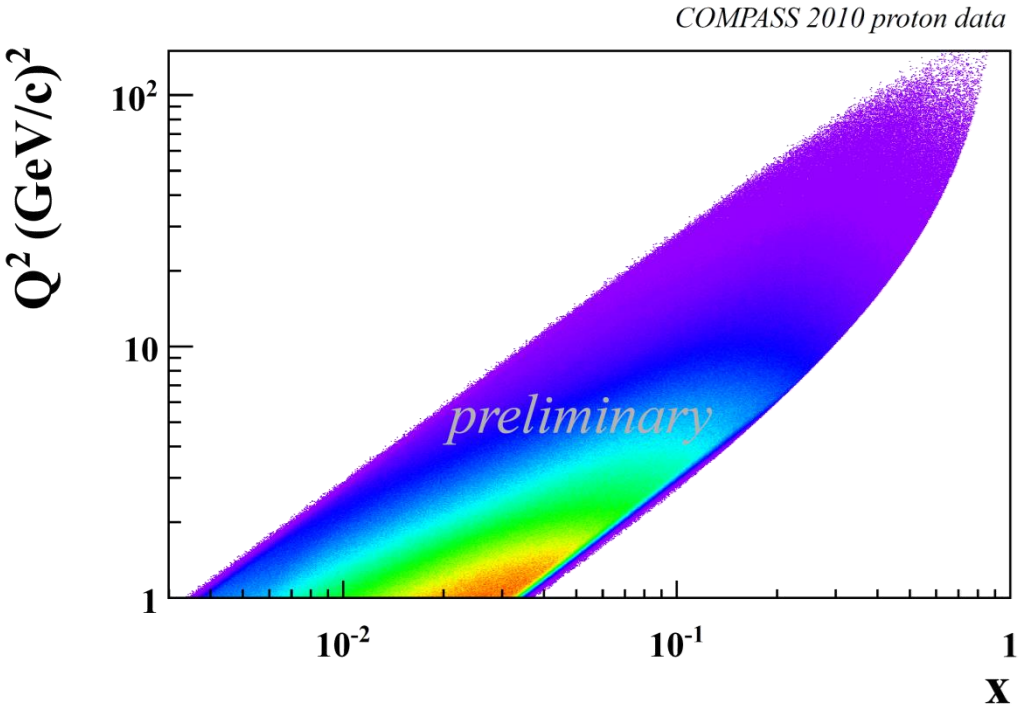
Proton - NH_3:

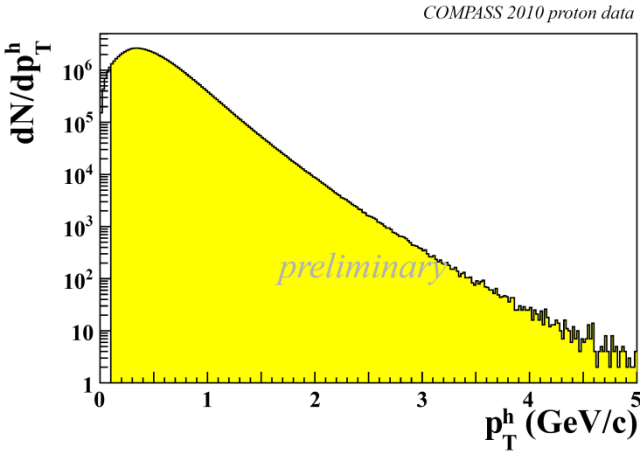
- Three cells system (30 cm,60cm, 30cm)
- Polar angle acceptance – 180 mrad (new magnet in 2006)
- Target Polarization ±90%
- dilution factor f = 0.14

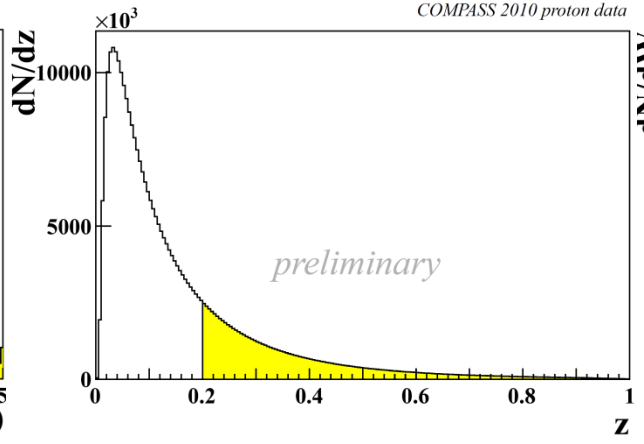


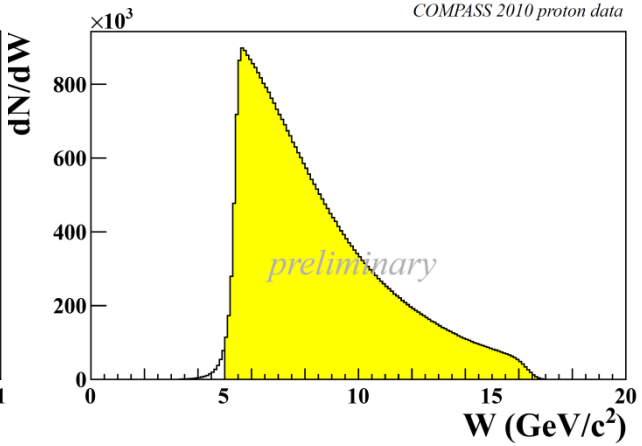
Data selection

- DIS cuts :
  - $Q^2 > 1\ GeV^2$
  - $0.1 < y < 0.9$
  - $W > 5\ GeV$
- Hadron cuts :
  - $z > 0.2$
  - $P_{hT} > 0.1\ GeV/c$



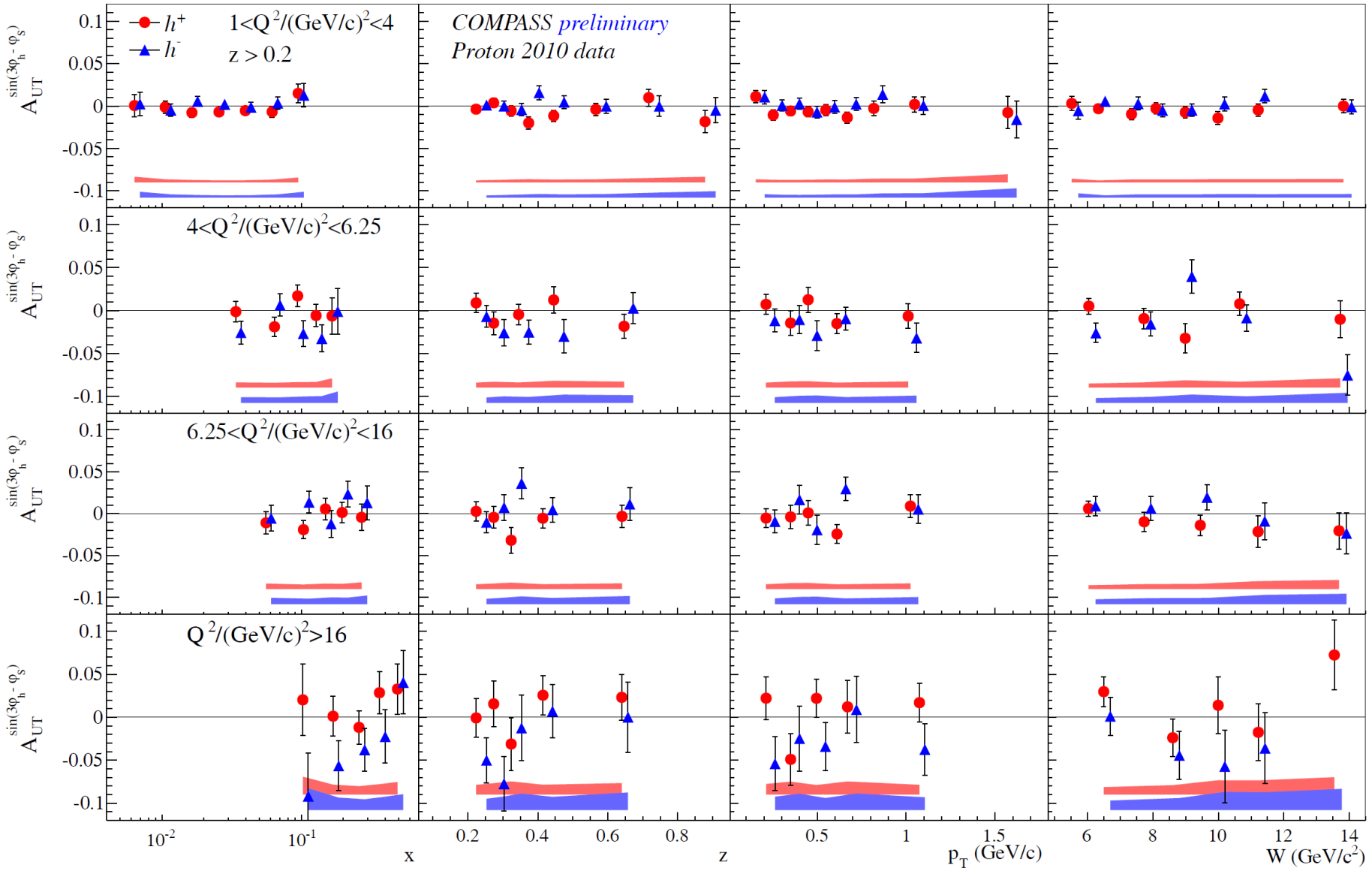






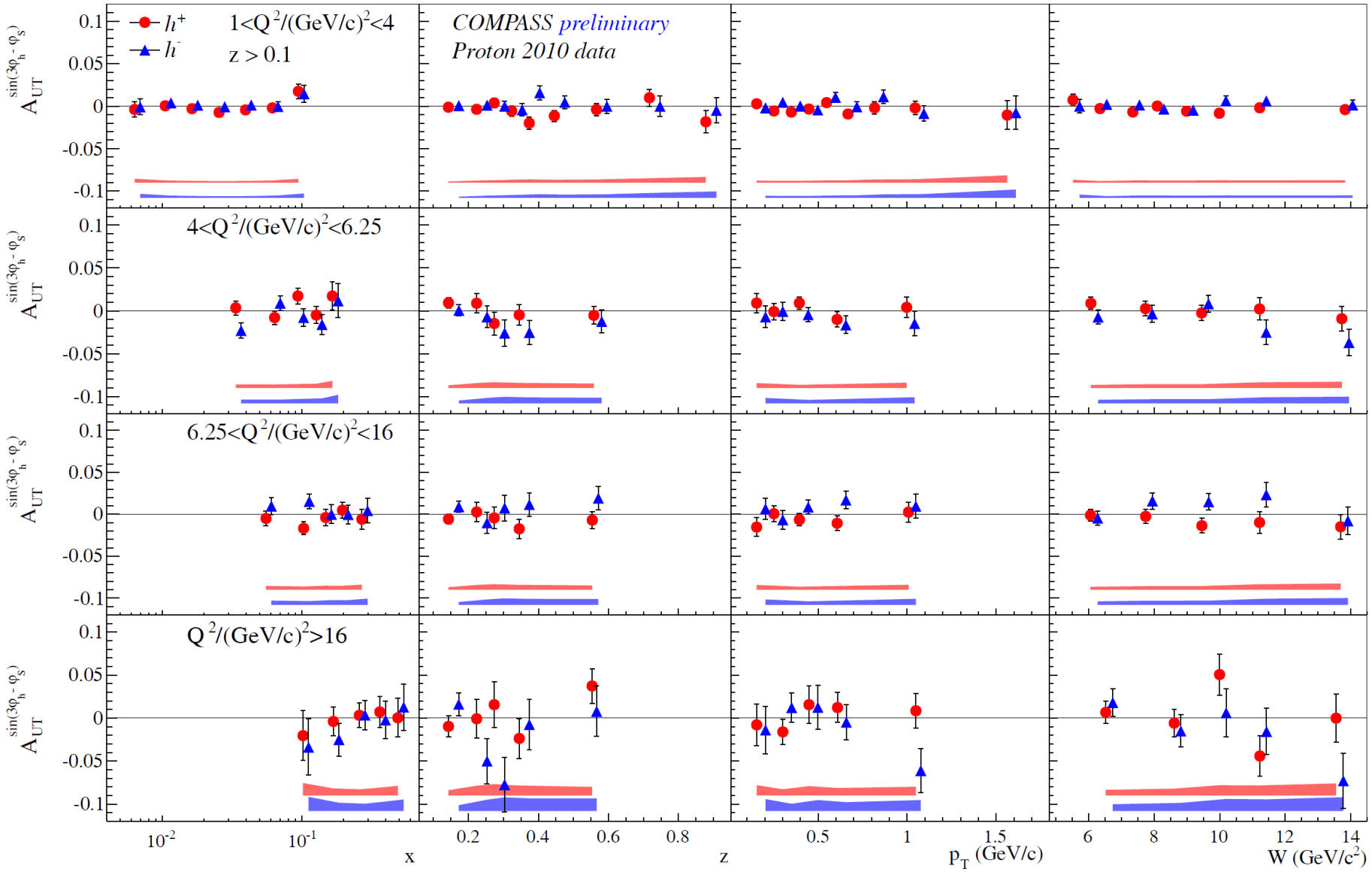
$A_{UT}^{\sin(3\varphi_h-\varphi_S)}$ in DY-ranges: z > 0.2

NEW! These results are being shown for the first time



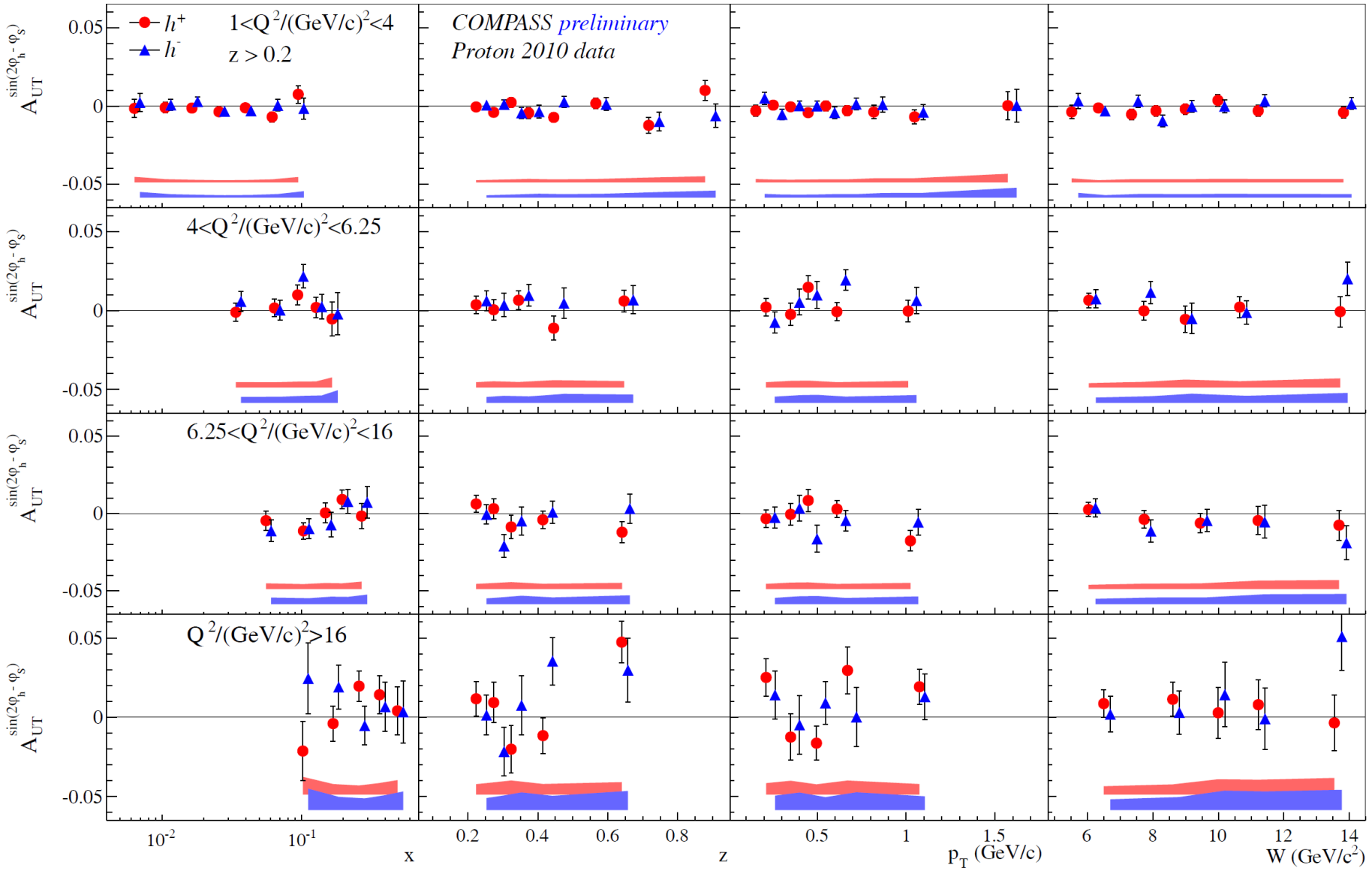
$A_{UT}^{\sin(3\varphi_h-\varphi_S)}$ in DY-ranges: z > 0.1

NEW! These results are being shown for the first time



$A_{UT}^{\sin(2\varphi_h-\varphi_S)}$ in DY-ranges: z > 0.2

NEW! These results are being shown for the first time



$A_{UT}^{\sin(2\varphi_h-\varphi_S)}$ in DY-ranges: z > 0.1

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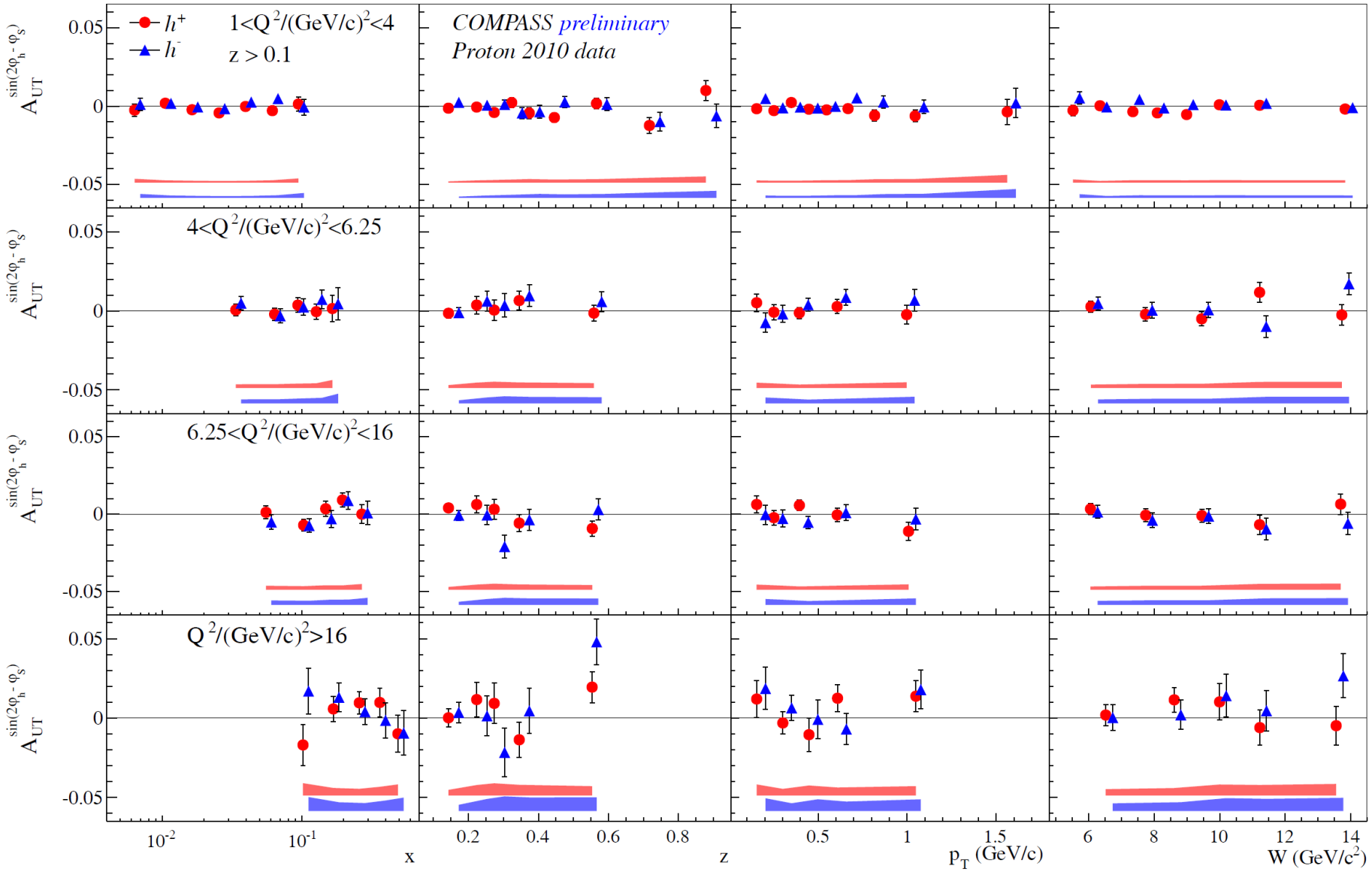
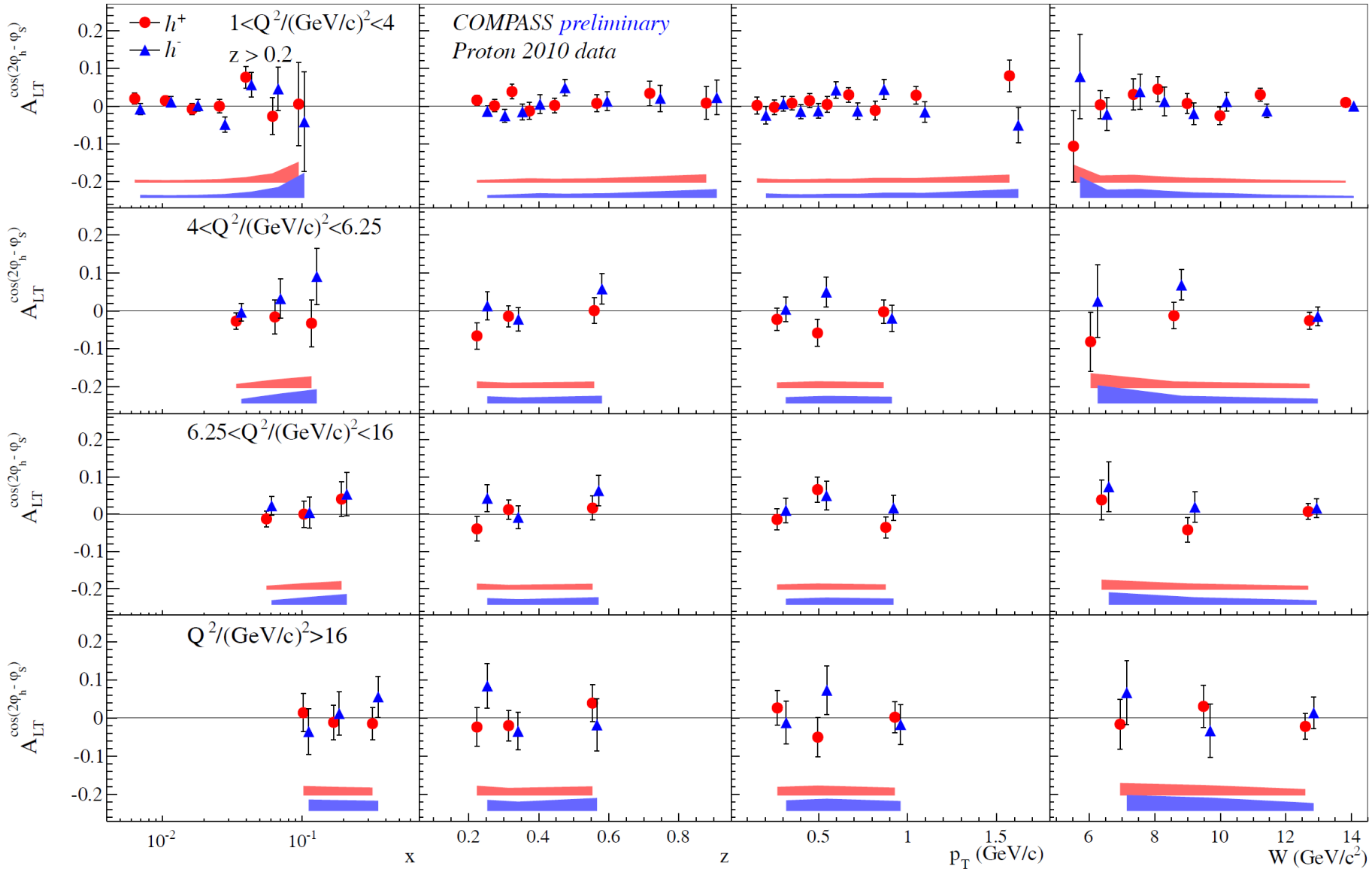


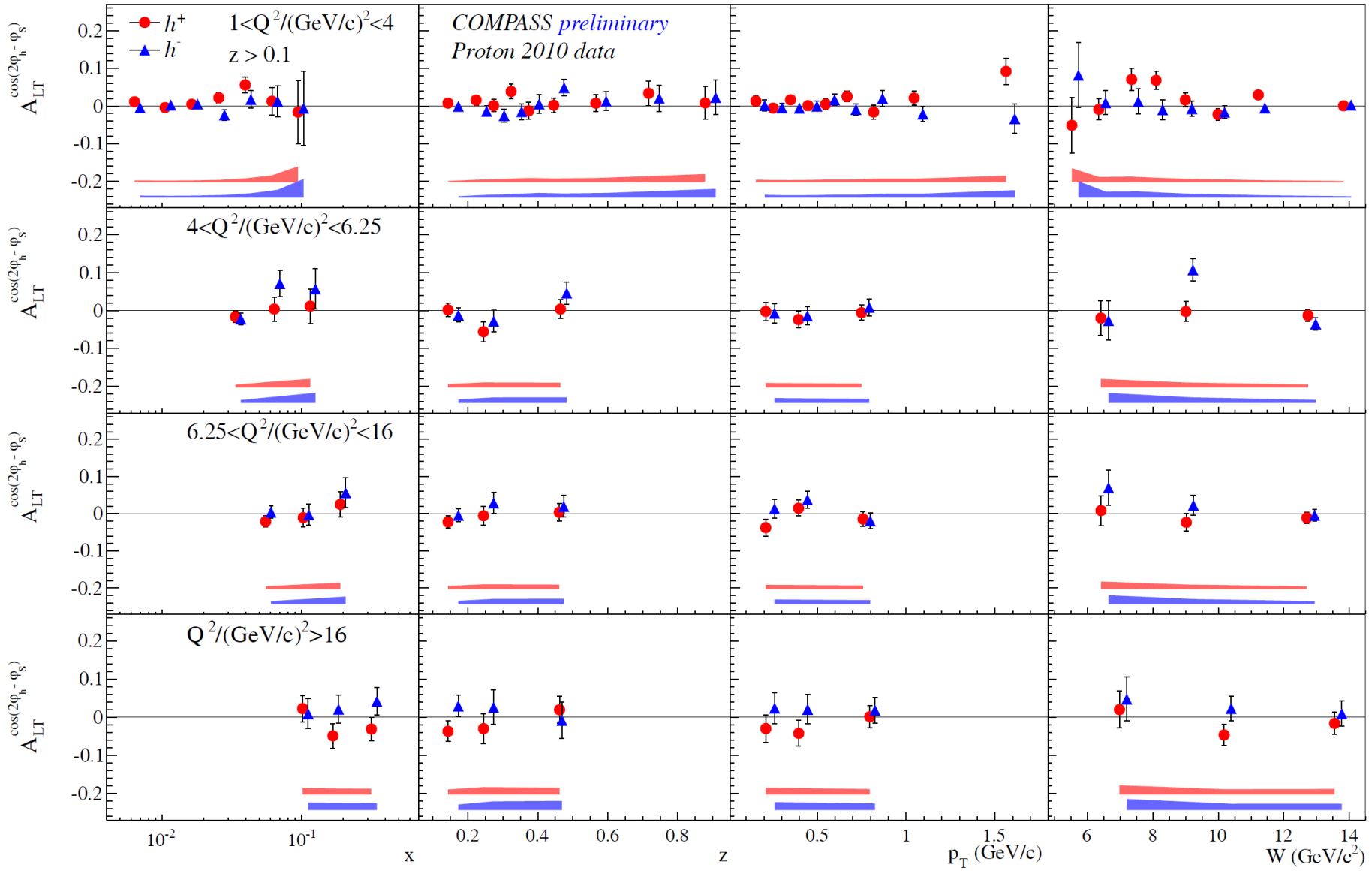
$A_{LT}^{\cos(2\varphi_h-\varphi_S)}$ in DY-ranges: z > 0.2

NEW! These results are being shown for the first time

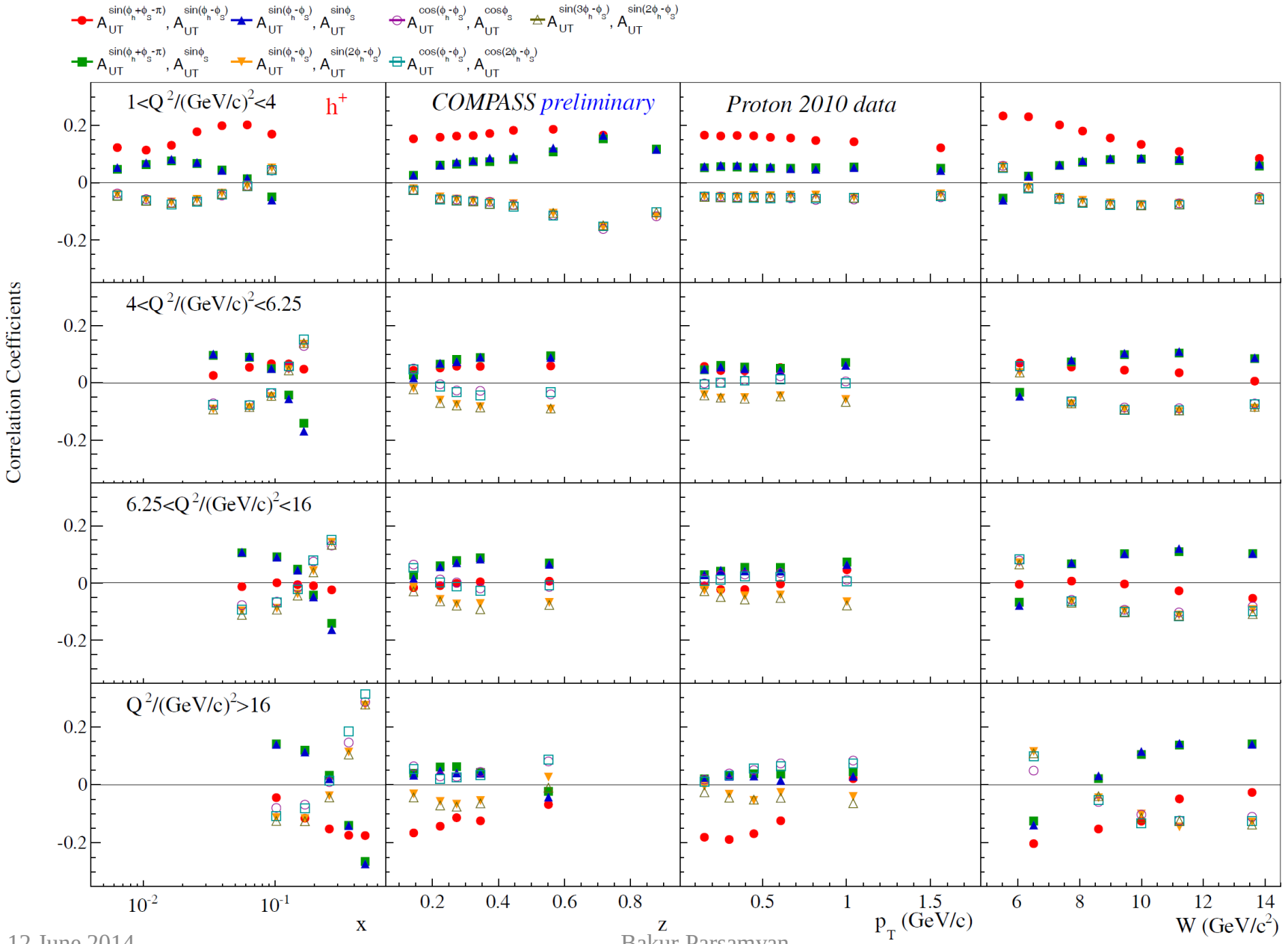


$A_{LT}^{\cos(2\varphi_h-\varphi_S)}$ in DY-ranges: z > 0.1

NEW! These results are being shown for the first time



Correlation Coefficients



SIDIS x-section: from *lp* to $\gamma^* p$ (P_L=0)

Kotzinian et al.
hep-ph/9808368 (1998)
hep-ph/9908466 (1999)
M. Diehl and S. Sapeta,
Eur. Phys. J. C 41 (2005) 515

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

$$\left[1 + \cos\varphi_h \times \sqrt{2\varepsilon(1+\varepsilon)}\,A_{UU}^{\cos\varphi_h} + \cos(2\varphi_h) \times \varepsilon A_{UU}^{\cos(2\varphi_h)} + \lambda \sin\varphi_h \times \sqrt{2\varepsilon(1-\varepsilon)}\,A_{LU}^{\sin\varphi_h} + \right.$$

$$\frac{P_T}{\sqrt{1-\sin^2\theta\sin^2\varphi_S}} \left[\sin\varphi_S \times \left(\underline{\cos\theta}\sqrt{2\varepsilon(1+\varepsilon)}\,A_{UT}^{\sin\varphi_S}\right) + \right.$$

$$\sin(\varphi_h - \varphi_S) \times \left(\underline{\cos\theta}\,A_{UT}^{\sin(\varphi_h-\varphi_S)} + \underline{\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1+\varepsilon)}\,A_{UL}^{\sin\varphi_h}}\right) +$$

$$\sin(\varphi_h + \varphi_S) \times \left(\underline{\cos\theta\varepsilon}\,A_{UT}^{\sin(\varphi_h+\varphi_S)} + \underline{\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1+\varepsilon)}\,A_{UL}^{\sin\varphi_h}}\right) +$$

$$\sin(2\varphi_h - \varphi_S) \times \left(\underline{\cos\theta}\sqrt{2\varepsilon(1+\varepsilon)}\,A_{UT}^{\sin(2\varphi_h-\varphi_S)} + \underline{\frac{1}{2}\sin\theta\varepsilon}\,A_{UL}^{\sin 2\varphi_h}\right) +$$

$$\sin(3\varphi_h - \varphi_S) \times \left(\underline{\cos\theta\varepsilon}\,A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right) +$$

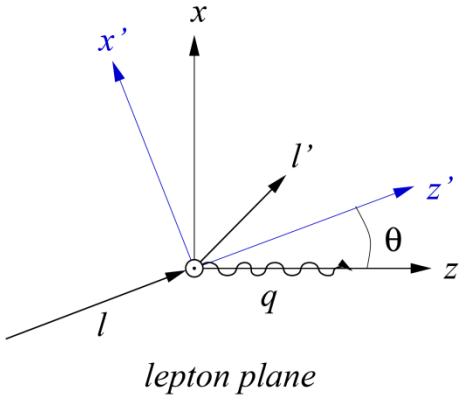
$$\left.\left. \sin(2\varphi_h + \varphi_S) \times \left(\underline{\frac{1}{2}\sin\theta\varepsilon}\,A_{UL}^{\sin 2\varphi_h}\right) \right] + \right.$$

$$\frac{P_T\lambda}{\sqrt{1-\sin^2\theta\sin^2\varphi_S}} \left[\cos\varphi_S \times \left(\underline{\cos\theta}\sqrt{2\varepsilon(1-\varepsilon)}\,A_{LT}^{\cos\varphi_S} + \underline{\sin\theta}\sqrt{(1-\varepsilon^2)}\,A_{LL}\right) + \right.$$

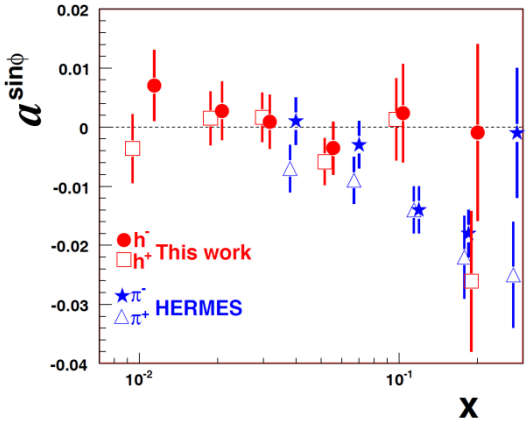
$$\cos(\varphi_h - \varphi_S) \times \left(\underline{\cos\theta}\sqrt{(1-\varepsilon^2)}\,A_{LT}^{\cos(\varphi_h-\varphi_S)} + \underline{\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1-\varepsilon)}}\,A_{LL}^{\cos\varphi_h}\right) +$$

$$\cos(2\varphi_h - \varphi_S) \times \left(\underline{\cos\theta}\sqrt{2\varepsilon(1-\varepsilon)}\,A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right) +$$

$$\left.\left. \cos(\varphi_h + \varphi_S) \times \left(\underline{\frac{1}{2}\sin\theta}\sqrt{2\varepsilon(1-\varepsilon)}\,A_{LL}^{\cos\varphi_h}\right) \right] \right]$$



Eur.Phys.J.C70:39-49,2010



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

$$\left[1+\cos\varphi_h\times\sqrt{2\varepsilon(1+\varepsilon)}A_{UU}^{\cos\varphi_h}+\cos(2\varphi_h)\times\varepsilon A_{UU}^{\cos(2\varphi_h)}+\lambda\sin\varphi_h\times\sqrt{2\varepsilon(1-\varepsilon)}A_{LU}^{\sin\varphi_h}+\right.$$

$$\frac{P_T}{\sqrt{1-\sin^2\theta\sin^2\varphi_S}}\left[\sin\varphi_S\times\left(\cos\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+\right.$$

$$\sin(\varphi_h-\varphi_S)\times\left(\cos\theta A_{UT}^{\sin(\varphi_h-\varphi_S)}+\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UL}^{\sin\varphi_h}\right)+$$

$$\sin(\varphi_h+\varphi_S)\times\left(\cos\theta\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}+\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UL}^{\sin\varphi_h}\right)+$$

$$\sin(2\varphi_h-\varphi_S)\times\left(\cos\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}+\frac{1}{2}\sin\theta\varepsilon A_{UL}^{\sin 2\varphi_h}\right)+$$

$$\sin(3\varphi_h-\varphi_S)\times\left(\cos\theta\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right)+$$

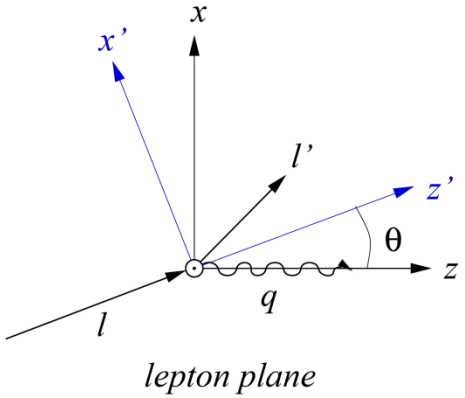
$$\left.\left.\sin(2\varphi_h+\varphi_S)\times\left(\frac{1}{2}\sin\theta\varepsilon A_{UL}^{\sin 2\varphi_h}\right)\right]+\right.$$

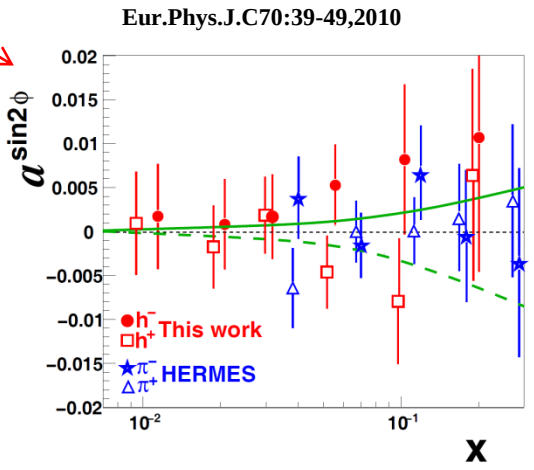
$$\frac{P_T\lambda}{\sqrt{1-\sin^2\theta\sin^2\varphi_S}}\left[\cos\varphi_S\times\left(\cos\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}+\sin\theta\sqrt{(1-\varepsilon^2)}A_{LL}\right)+\right.$$

$$\cos(\varphi_h-\varphi_S)\times\left(\cos\theta\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}+\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LL}^{\cos\varphi_h}\right)+$$

$$\cos(2\varphi_h-\varphi_S)\times\left(\cos\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)+$$

$$\left.\left.\cos(\varphi_h+\varphi_S)\times\left(\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LL}^{\cos\varphi_h}\right)\right]\right]$$





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Kotzinian et al.
hep-ph/9808368 (1998)
hep-ph/9908466 (1999)
M. Diehl and S. Sapeta,
Eur. Phys. J. C 41 (2005) 515

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

$$\left[1+\cos\varphi_h\times\sqrt{2\varepsilon(1+\varepsilon)}A_{UU}^{\cos\varphi_h}+\cos(2\varphi_h)\times\varepsilon A_{UU}^{\cos(2\varphi_h)}+\lambda\sin\varphi_h\times\sqrt{2\varepsilon(1-\varepsilon)}A_{LU}^{\sin\varphi_h}+\right.$$

$$\frac{P_T}{\sqrt{1-\sin^2\theta\sin^2\varphi_S}}\left[\sin\varphi_S\times\left(\cos\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\varphi_S}\right)+\right.$$

$$\sin(\varphi_h-\varphi_S)\times\left(\cos\theta A_{UT}^{\sin(\varphi_h-\varphi_S)}+\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UL}^{\sin\varphi_h}\right)+$$

$$\sin(\varphi_h+\varphi_S)\times\left(\cos\theta\varepsilon A_{UT}^{\sin(\varphi_h+\varphi_S)}+\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UL}^{\sin\varphi_h}\right)+$$

$$\sin(2\varphi_h-\varphi_S)\times\left(\cos\theta\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\varphi_h-\varphi_S)}+\frac{1}{2}\sin\theta\varepsilon A_{UL}^{\sin 2\varphi_h}\right)+$$

$$\sin(3\varphi_h-\varphi_S)\times\left(\cos\theta\varepsilon A_{UT}^{\sin(3\varphi_h-\varphi_S)}\right)+$$

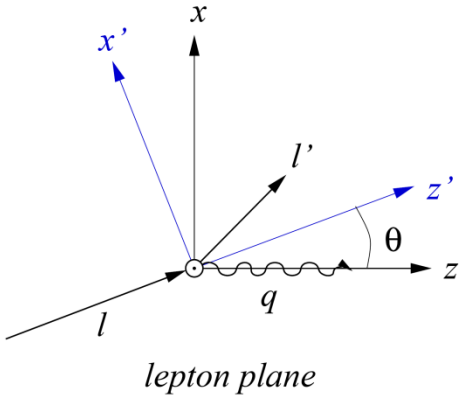
$$\left.\left.\sin(2\varphi_h+\varphi_S)\times\left(\frac{1}{2}\sin\theta\varepsilon A_{UL}^{\sin 2\varphi_h}\right)\right]+\right.$$

$$\frac{P_T\lambda}{\sqrt{1-\sin^2\theta\sin^2\varphi_S}}\left[\cos\varphi_S\times\left(\cos\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\varphi_S}+\sin\theta\sqrt{(1-\varepsilon^2)}A_{LL}\right)+\right.$$

$$\cos(\varphi_h-\varphi_S)\times\left(\cos\theta\sqrt{(1-\varepsilon^2)}A_{LT}^{\cos(\varphi_h-\varphi_S)}+\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LL}^{\cos\varphi_h}\right)+$$

$$\cos(2\varphi_h-\varphi_S)\times\left(\cos\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\varphi_h-\varphi_S)}\right)+$$

$$\left.\left.\cos(\varphi_h+\varphi_S)\times\left(\frac{1}{2}\sin\theta\sqrt{2\varepsilon(1-\varepsilon)}A_{LL}^{\cos\varphi_h}\right)\right]\right]$$



lepton plane

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