Azimuthal asymmetries on proton at COMPASS: Q^2- dependence

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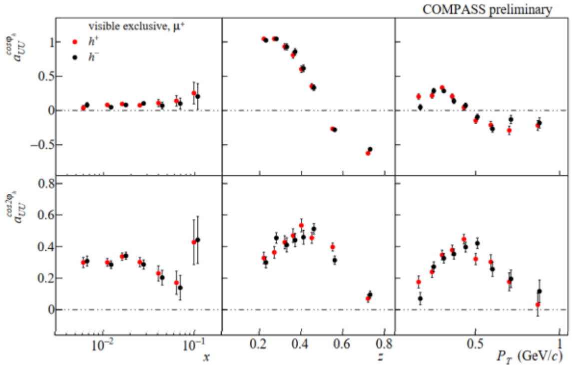
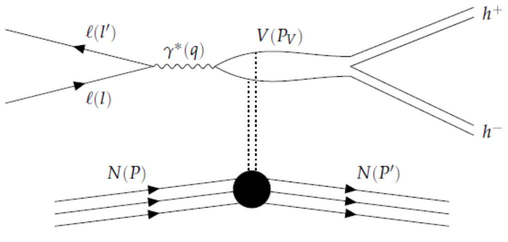
Azimuthal asymmetries at COMPASS (proton 2016)

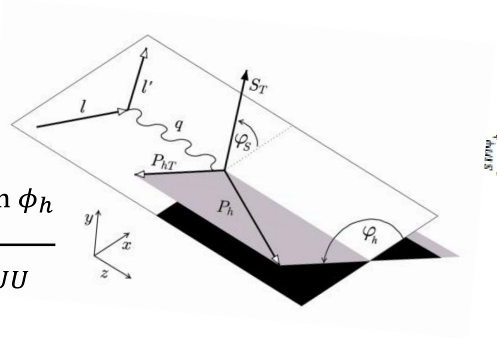
$$\frac{d^5\sigma}{dx\,dy\,dz\,d\varphi_h dP_T^2} = \frac{2\pi\alpha^2}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\cdot\left(F_{UU,T}+\varepsilon F_{UU,L}+\sqrt{2\varepsilon(1+\varepsilon)}F_{UU}^{\cos\varphi_h}\cos\varphi_h+\varepsilon F_{UU}^{\cos 2\varphi_h}\cos 2\varphi_h+\lambda_l\sqrt{2\varepsilon(1-\varepsilon)}F_{LU}^{\sin\varphi_h}\sin\varphi_h\right)$$

Exclusive hadrons: *discarded* (visible part) or *subtracted* (not visible part, Monte Carlo)





Fit of the **amplitude of the modulation in the azimuthal angle** of the hadrons
- as a function of x, z or P_T (1D)
- with a simultaneous binning (3D)

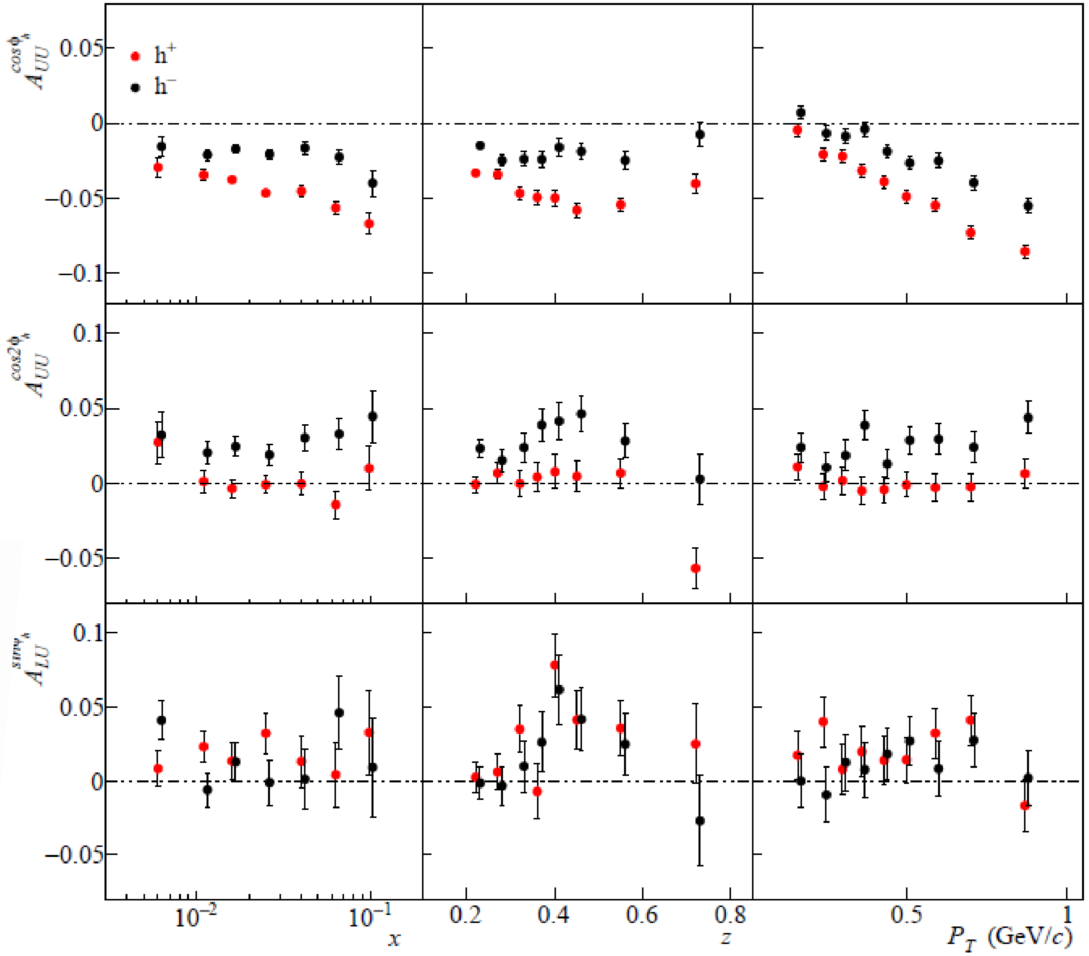


Azimuthal asymmetries: defined as the following ratios

$$A_{UU}^{\cos\phi_h} = \frac{F_{UU}^{\cos\phi_h}}{F_{UU}} \qquad A_{UU}^{\cos 2\phi_h} = \frac{F_{UU}^{\cos 2\phi_h}}{F_{UU}} \qquad A_{LU}^{\sin\phi_h} = \frac{F_{LU}^{\sin\phi_h}}{F_{UU}}$$

- **Strong kinematic dependences**
- **Interesting differences** between positive and negative hadrons, as observed in previous measurements by COMPASS on deuteron and by HERMES

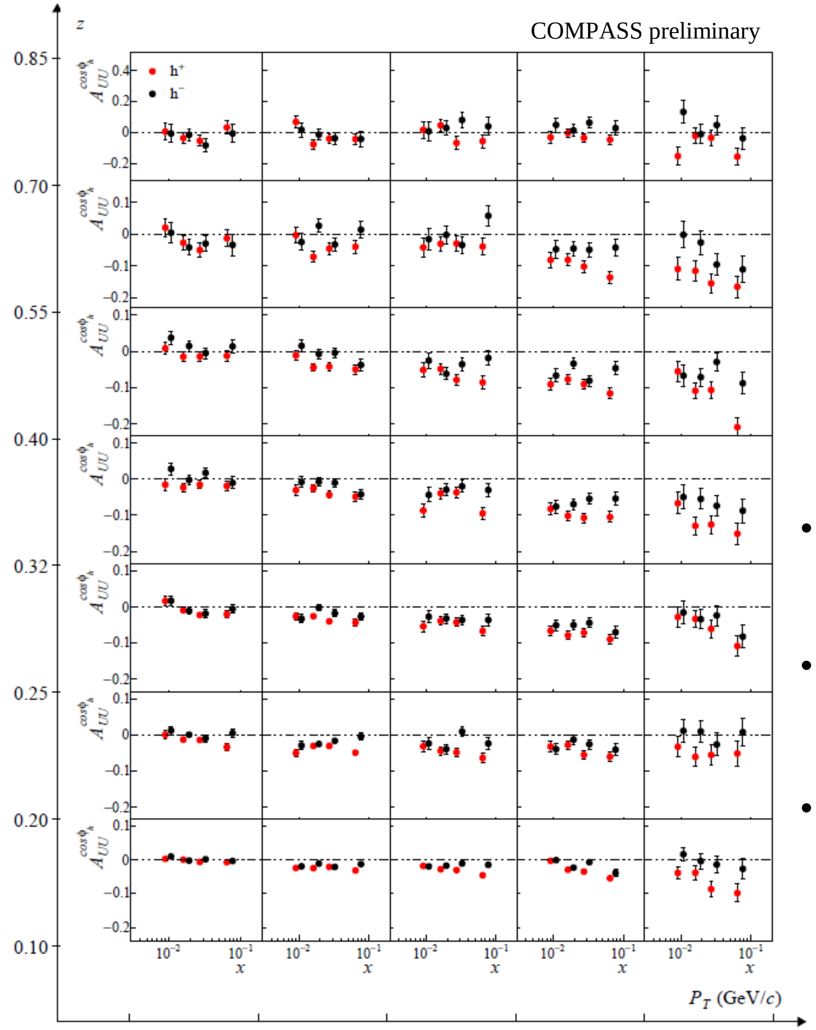
COMPASS preliminary



The error bars correspond to the statistical uncertainty only. $\sigma_{syst} \sim \sigma_{stat}$ (1D)

Q^2- dependence of $A_{UU}^{cos\phi_h}$

The error bars correspond to the statistical uncertainty only. $\sigma_{syst} \sim\ 0.5\ \sigma_{stat}$ (3D)



3D azimuthal asymmetries for positive and negative hadrons

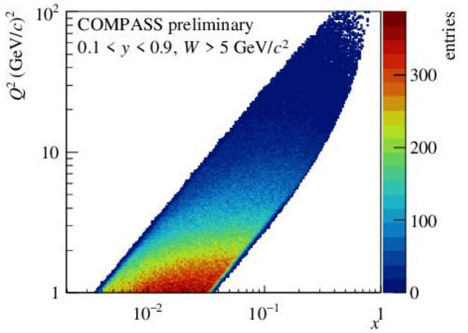
Clear signal, strong dependence on P_T;
compatible with zero at high z.
In agreement with COMPASS deuteron results.

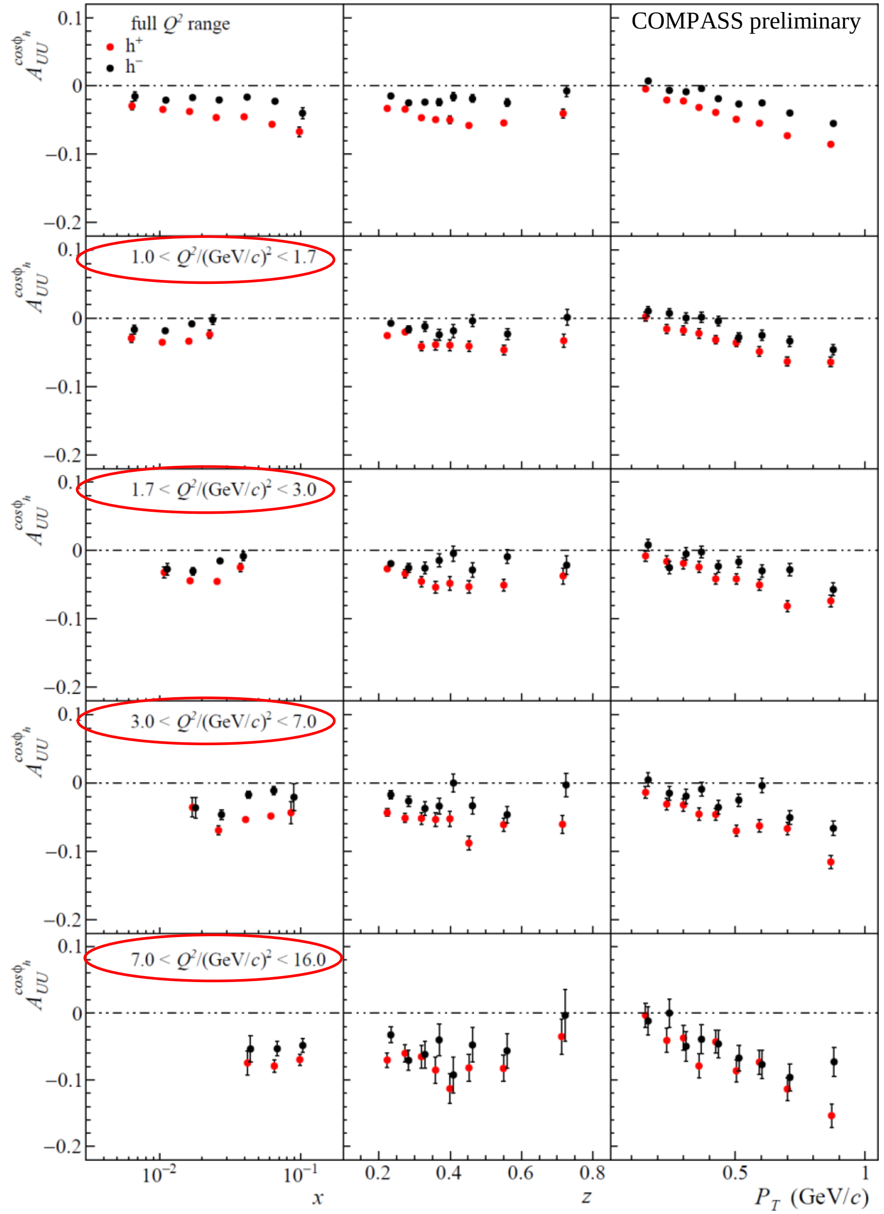
Expectation from Cahn effect:

$$A_{UU|Cahn}^{\cos\phi_h} = -\frac{2zP_T\langle k_T^2\rangle}{Q\ \langle P_T^2\rangle}$$

Binning in Q^2

- The $A_{UU}^{cos\phi_h}$ asymmetry is observed to increase with Q^2 ***unexpected!***
- The difference between positive and negative hadrons decreases with Q^2.
- **Almost no Q^2 dependence for $A_{UU}^{cos2\phi_h}$**





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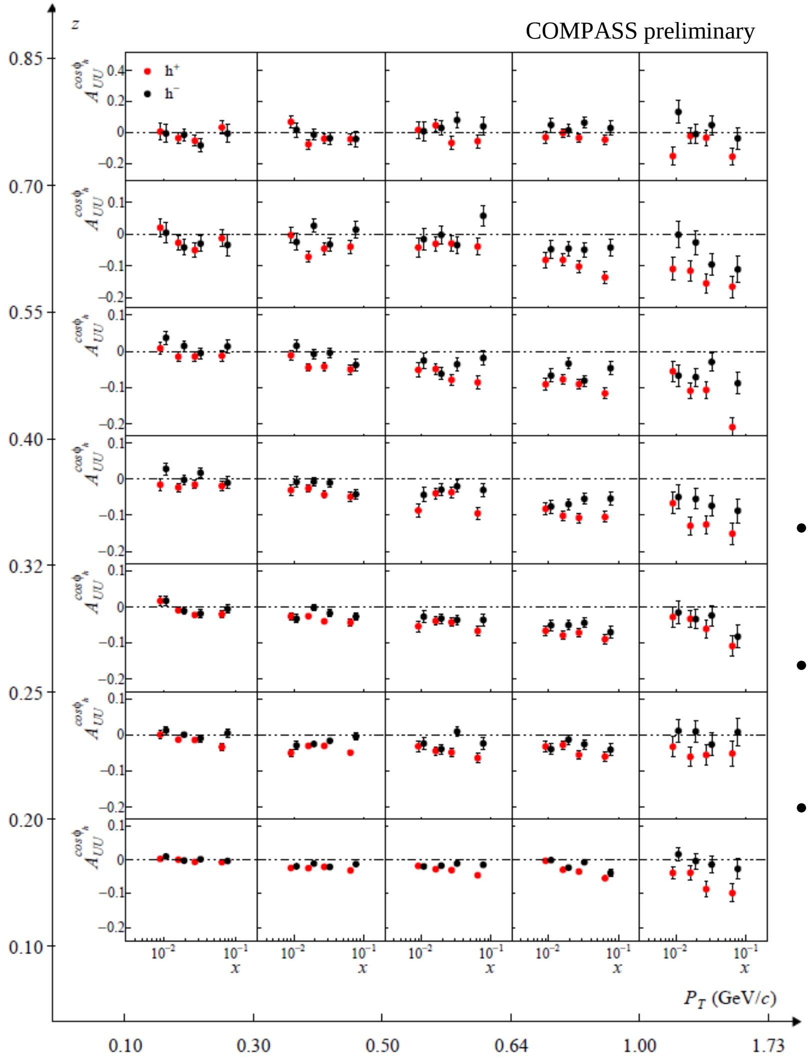

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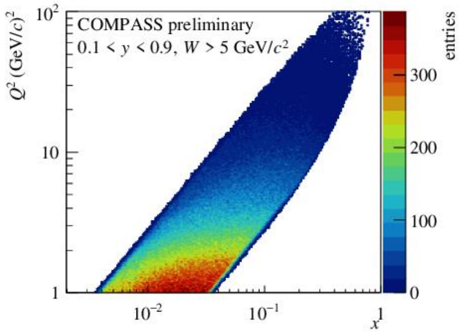

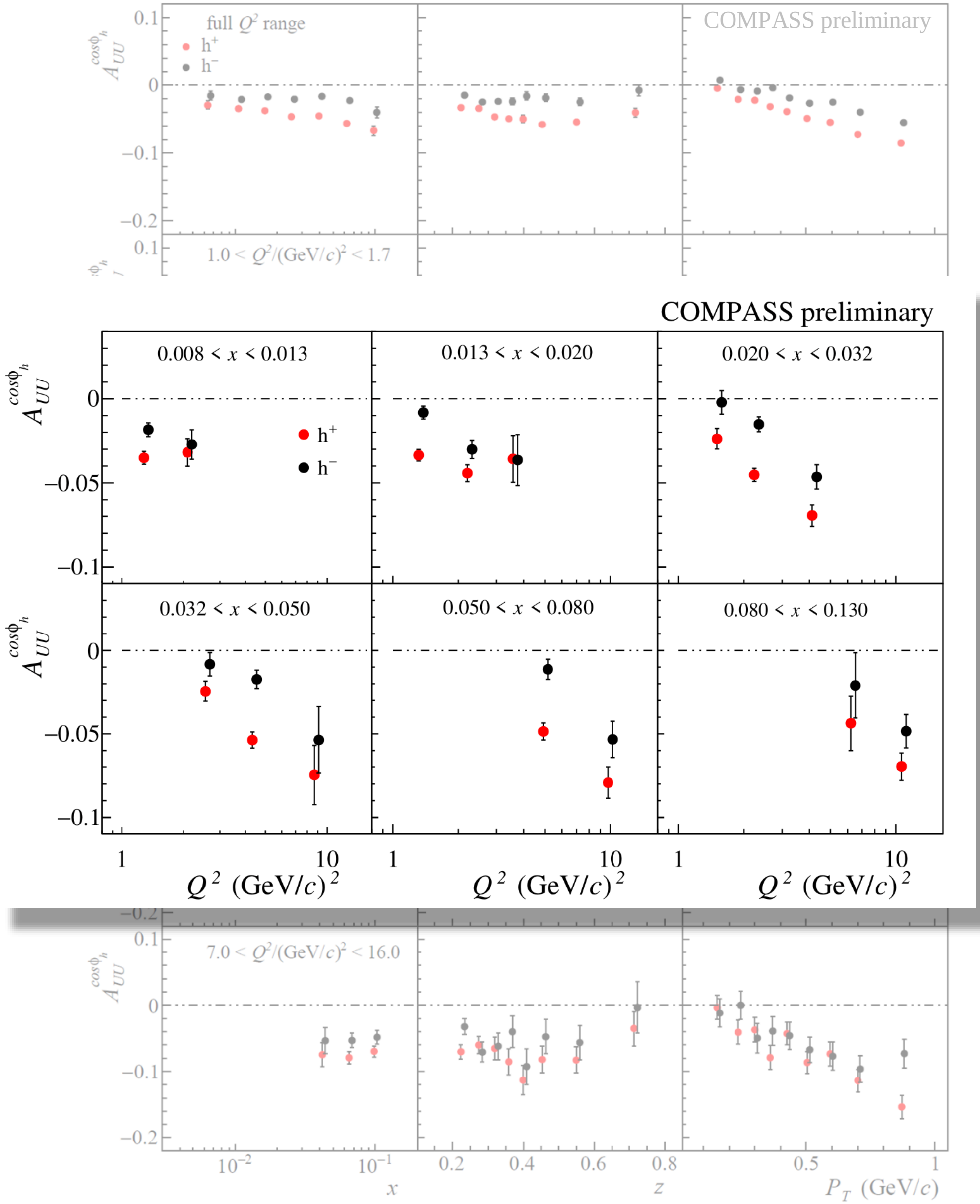

Conclusions and Perspectives

Azimuthal asymmetries

Very interesting observables to access the nucleon structure in unpolarized SIDIS

- **COMPASS** has produced results using a **deuteron** (published 2014) and **proton** target (new)

- Intriguing investigations of their properties:
  rich kinematic dependences, h^+h^- differences, …

A lot to be understood and/or addressed

- Difference between positive and negative hadrons in azimuthal asymmetries
- Kinematic dependences (sometimes *counterintuitive* for azimuthal asymmetries)
- Role of twist-3 contributions beyond Cahn
- Impact of radiative corrections – not included in the results shown here
  may give a relevant contribution to the Q^2 dependence
- Possible role of vector mesons inclusively produced in SIDIS