XX International Workshop on Deep-Inelastic Scattering and Related Subjects

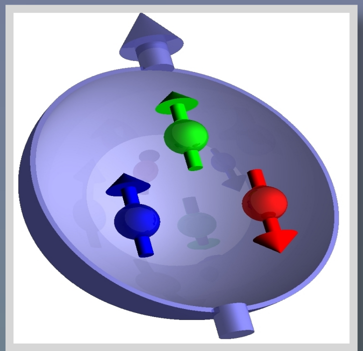
26-30 March 2012, University of Bonn

Longitudinal semi-inclusive double-spin asymmetries at HERMES

Polina Kravchenko

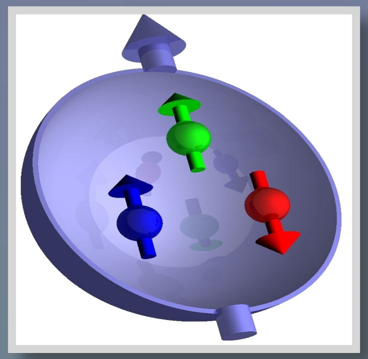
on behalf of the HERMES collaboration

- Motivation
- DSA as an observable for helicity distribution extraction
    - Methods
    - Results
- Summary



- looks simple in static quark model

Proton structure



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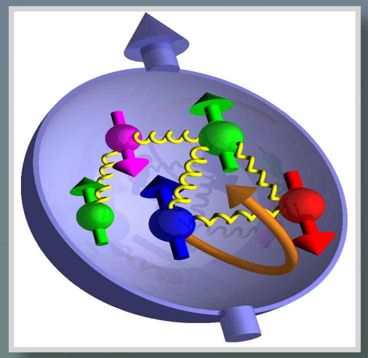

- much more complicated in QCD

Motivation I

Where does the Nucleon Spin come from?

$$S_z = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z^q + L_z^g$$

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Motivation II

Parton Distribution Functions

- unpolarized $q(x)$, $g(x)$
- helicity $\Delta q(x)$, $\Delta g(x)$
- transversity $\Delta_T q(x)$
- Transverse Momentum dependent (TMD) distributions
- Generalized Parton (GPDs) distributions

Focus in this talk: Helicity distributions Δq

Helicity distributions

- What do we know? $\Delta\Sigma \sim 0.3$
- But how do the different $\Delta q(x)$, $q=u,d,s,...$ look like?
- How they can be measured?

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Find a process where one probes
interaction with quark of a given polarization
with respect to the parent nucleon

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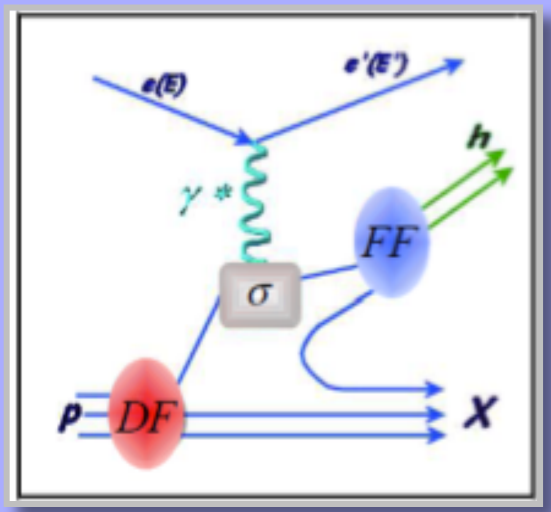

Semi-inclusive Deep-Inelastic Scattering

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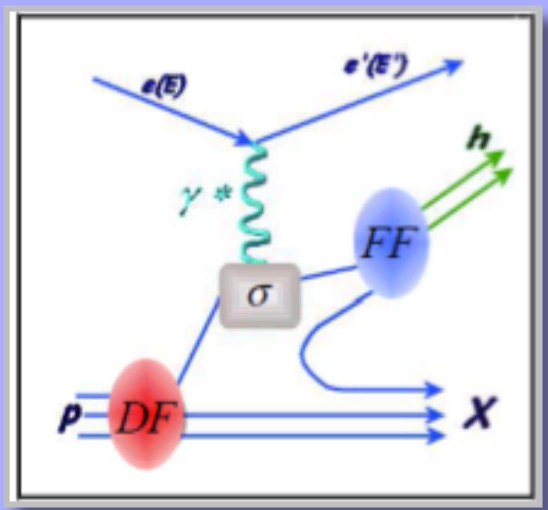

Semi-inclusive Deep-Inelastic Scattering

The possible contributions to the DIS cross section in the semi-inclusive measurement

$$\sigma^h = \sigma^h_{UU} + \lambda_l \sigma^h_{LU} + S_L \sigma^h_{UL} + \lambda_l S_L \sigma^h_{LL} + S_T \sigma^h_{UT} + \lambda_l S_T \sigma^h_{LT}$$

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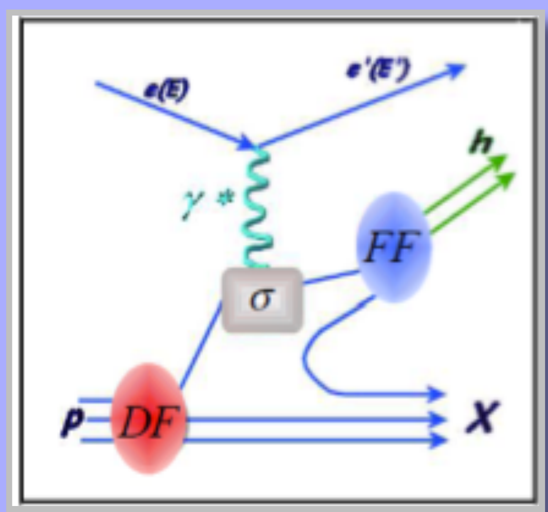

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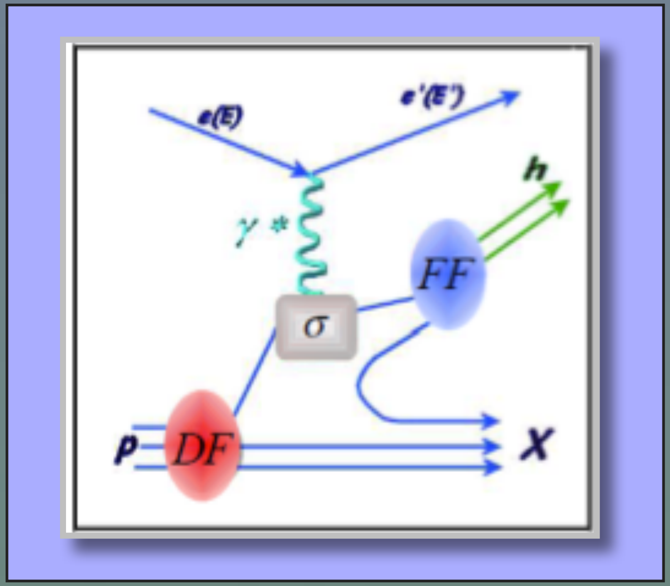
two structure functions appear

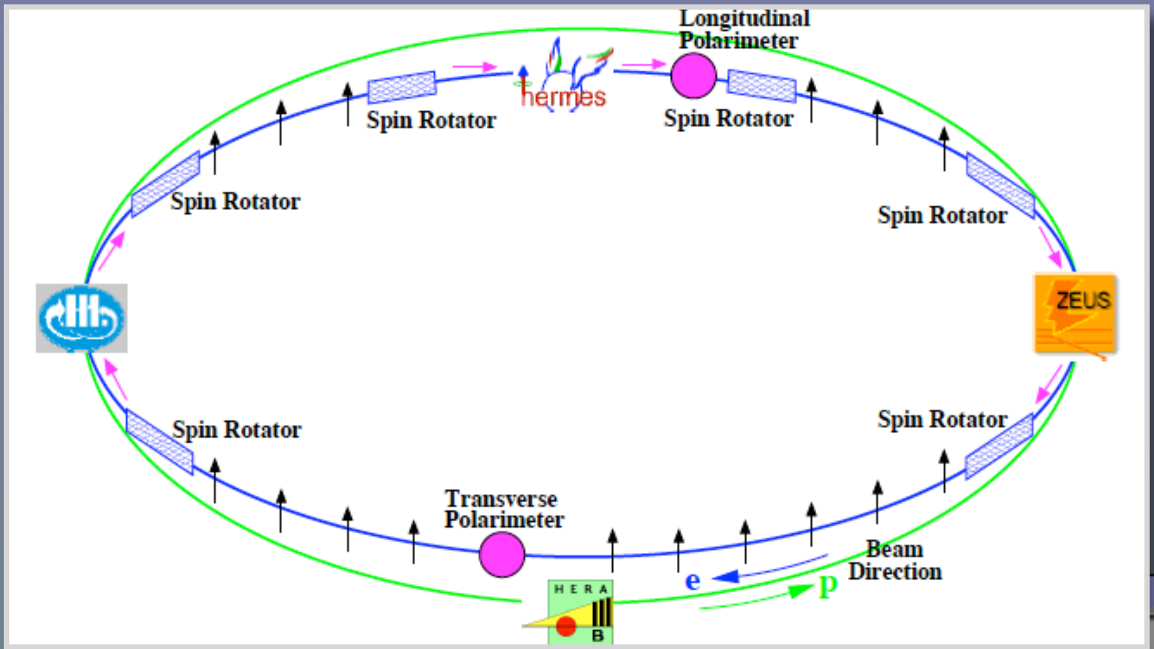
$$S_L \lambda_l \left[\sqrt{1-\epsilon^2} F_{LL} + \sqrt{2\epsilon(1-\epsilon)} cos(\phi) F^{cos\phi}_{LL} \right.$$

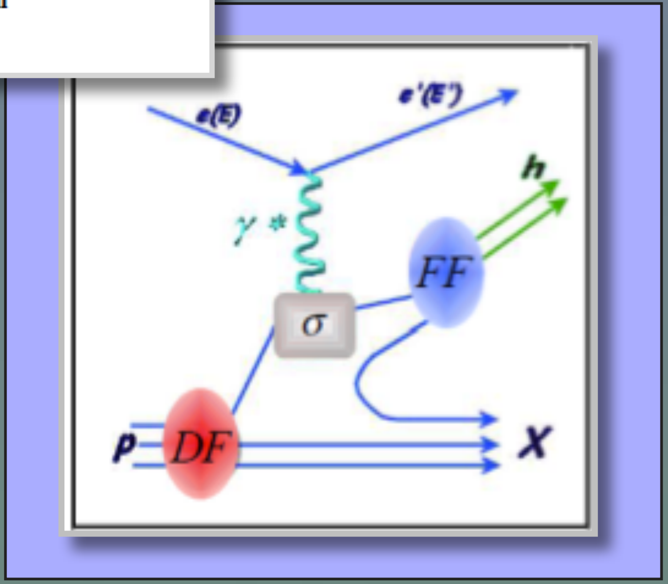
$$F_{LL} \sim C\left[g_L D_1 \right]$$

Helicity distributions $\Delta q(x)$


e(E)
e'(E')
γ *
h
FF
σ
p
DF
X

HERMES experiment

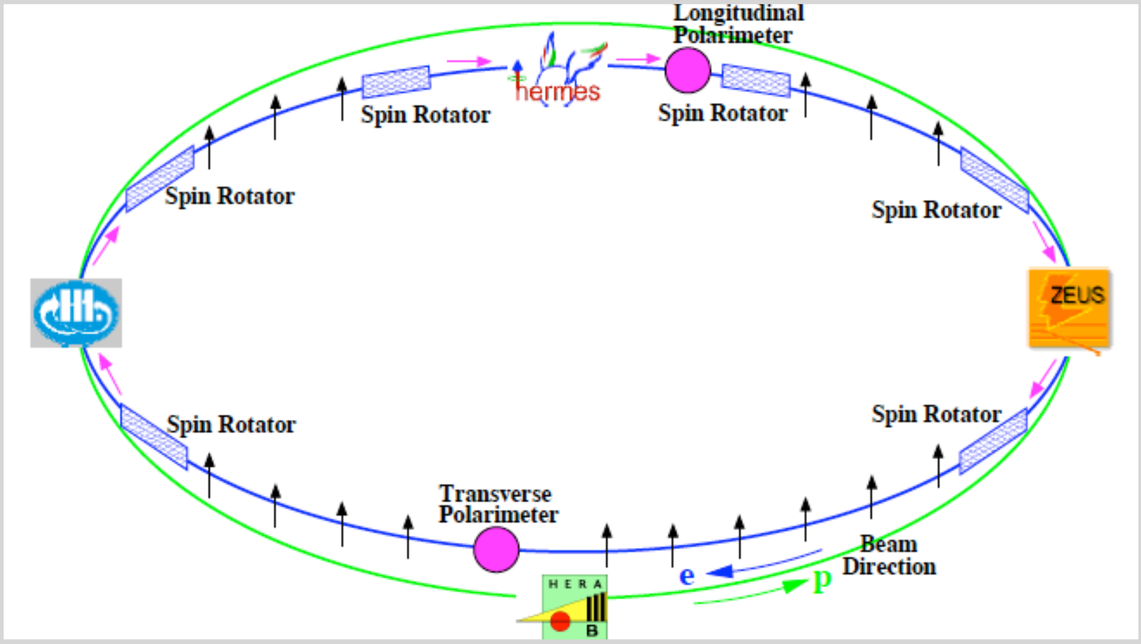


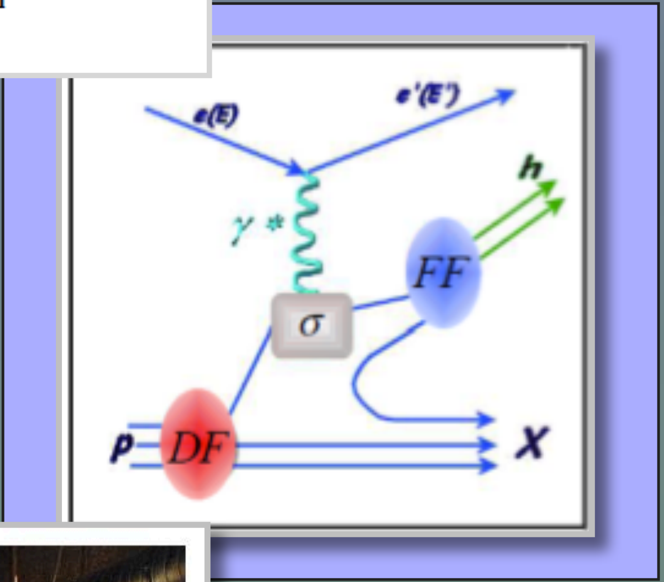


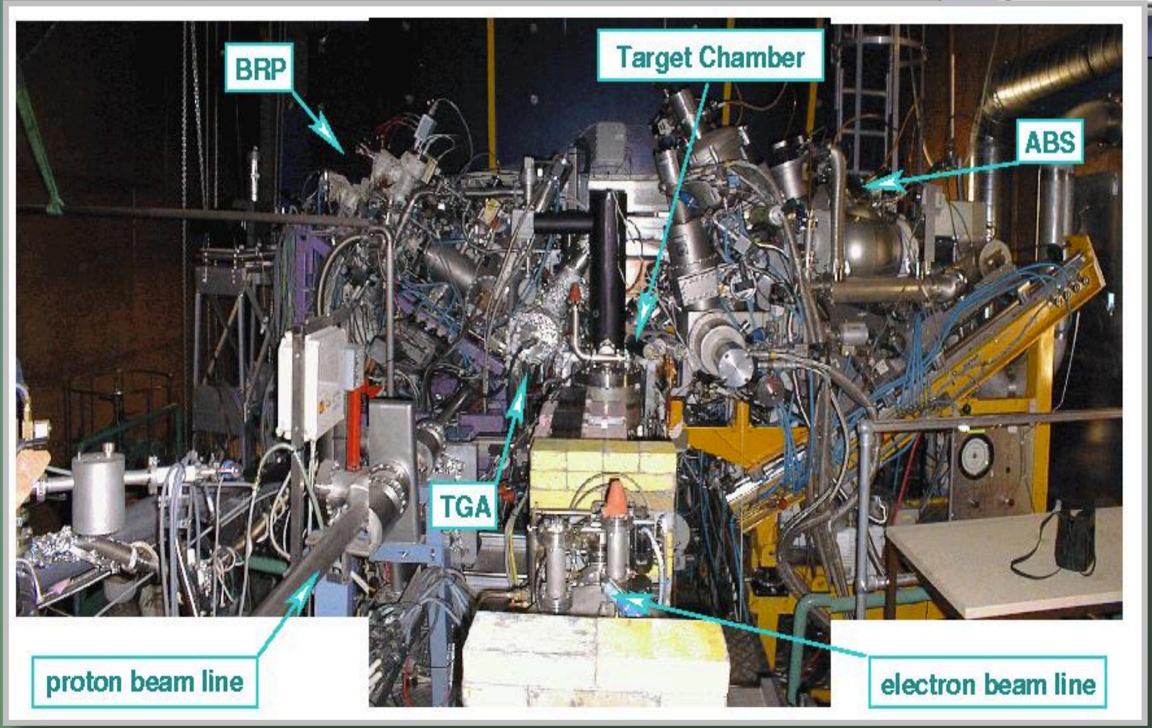
HERA positron beam properties:

- E_e=27.6GeV, I_e<50mA, P_b=0.55
- lifetime=12-14h
- transversely polarized e± in storage ring
- polarization build-up by emission of synchrotron radiation (Sokolov-Ternov effect)
- Spin rotators around HERMES IP

HERMES experiment





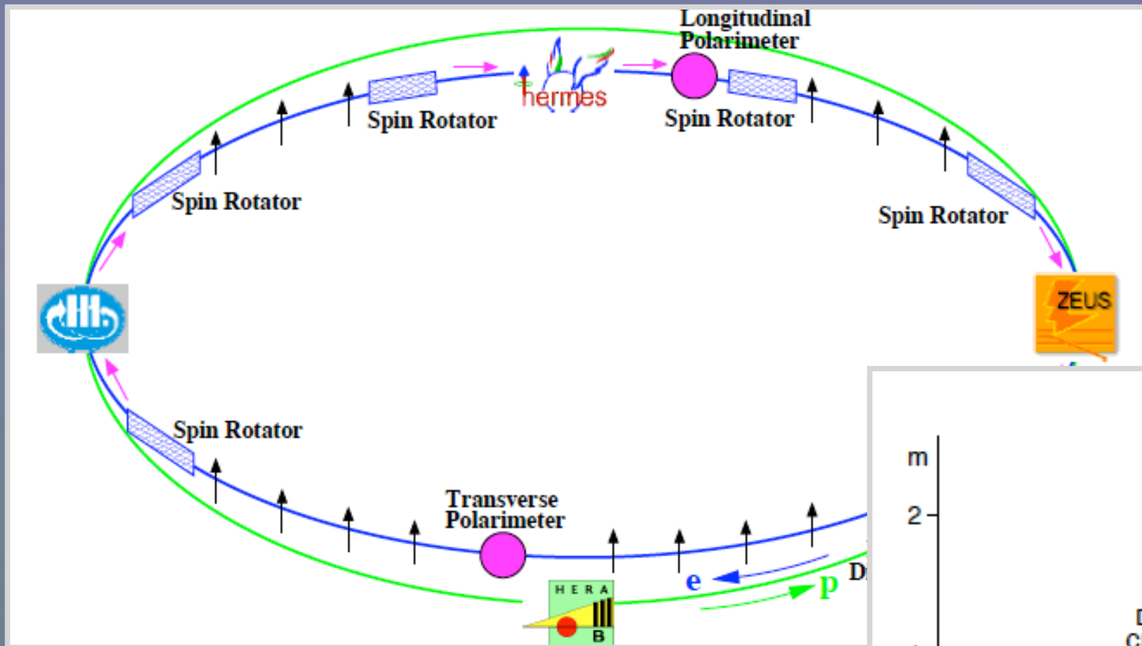


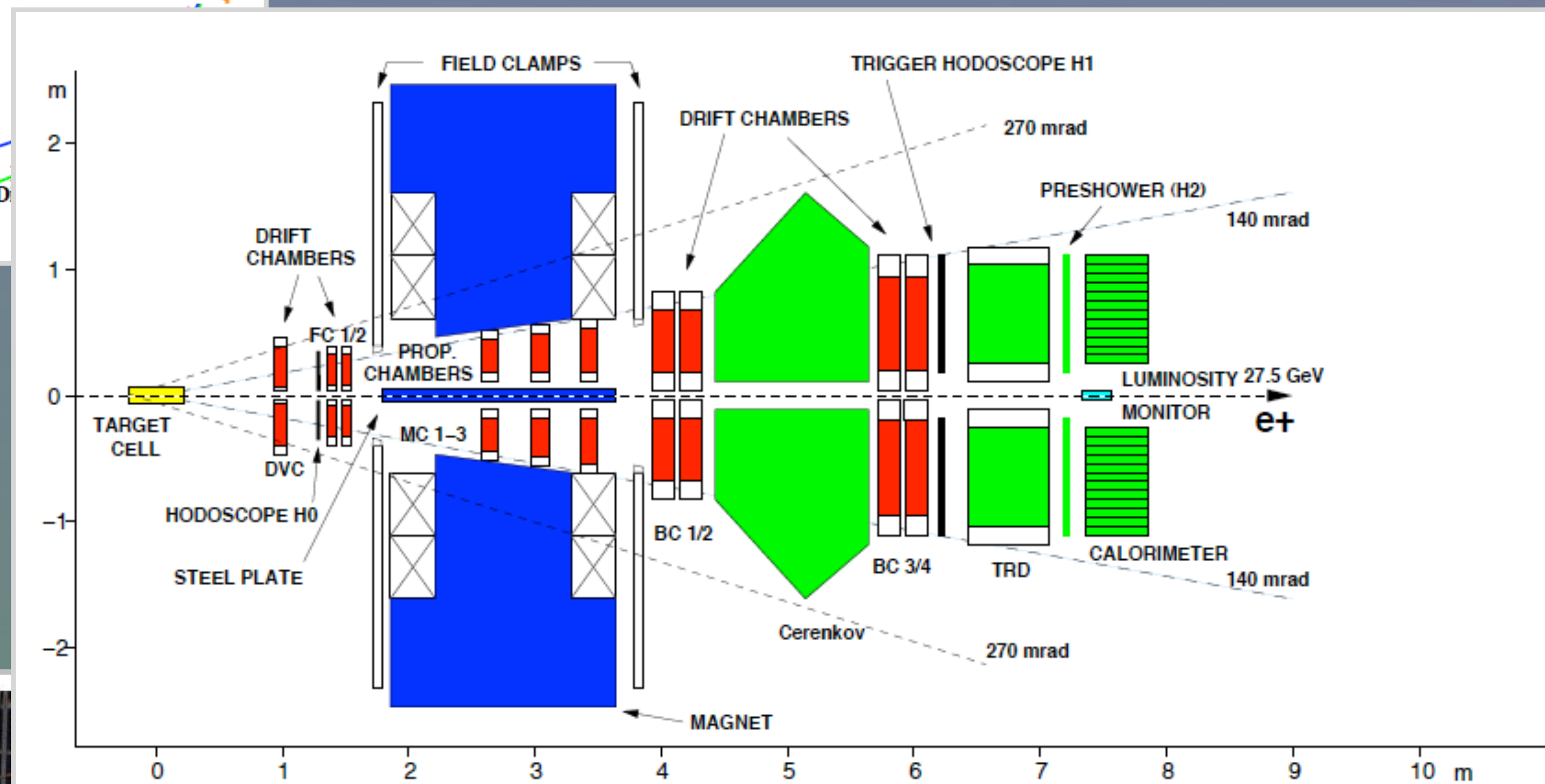
Typical HERMES target properties :

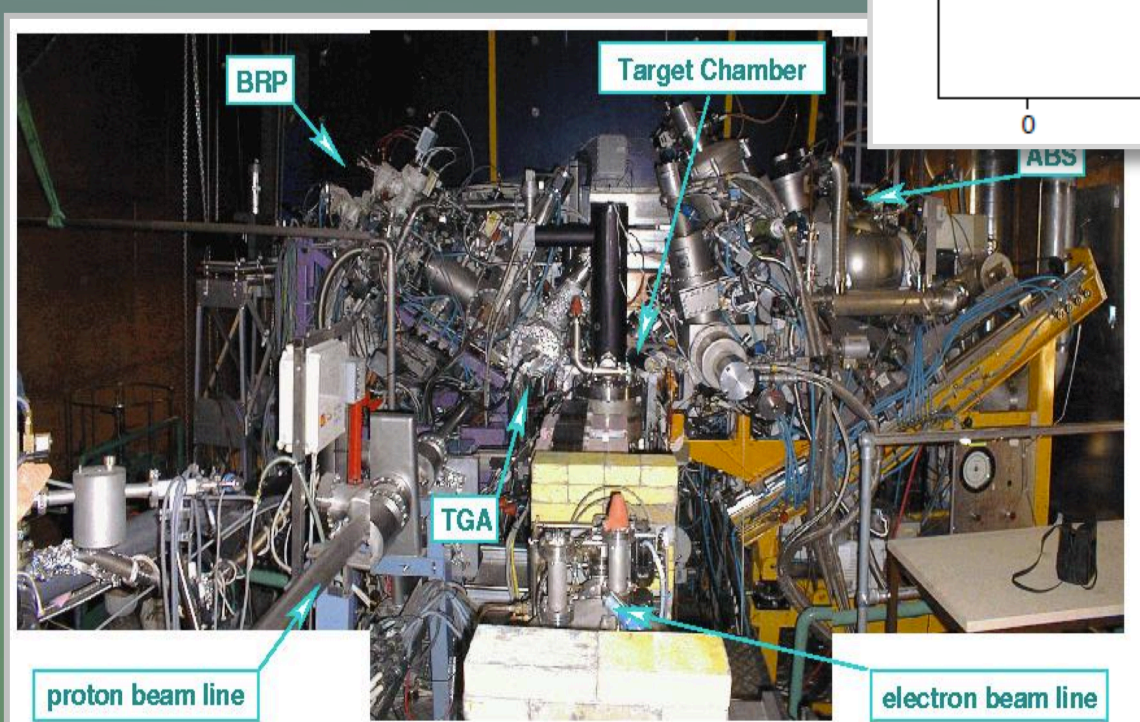
- P_t~0.85; polarized $H^{\uparrow\rightarrow}$, $D^{\rightarrow}$
- dilution factor=1
- Thickness =10^{14}-10^{15} nucl/cm^2
- Temperature=100K

internal to the HERA storage ring

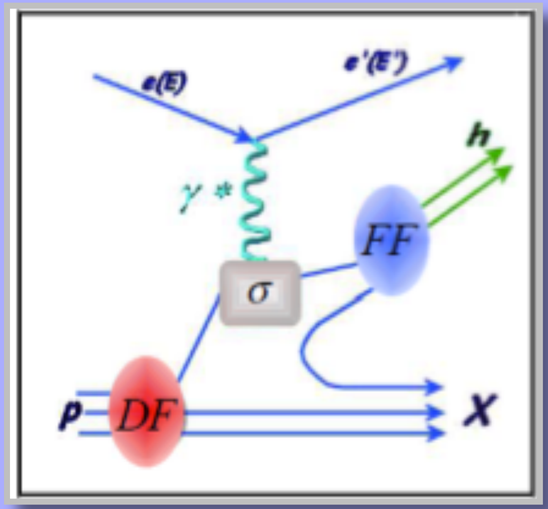
HERMES experiment







- **Tracking:** Drift Vertex Chambers, Front Chambers, Magnet Chambers, Back Chambers
- **Particle Identification:** Čerenkov (RICH) Detector, Transition Radiation Detector, Preshower, Calorimeter
  Luminosity Monitor (Bhabha/Møller scattering)



Semi-inclusive Deep-Inelastic Scattering

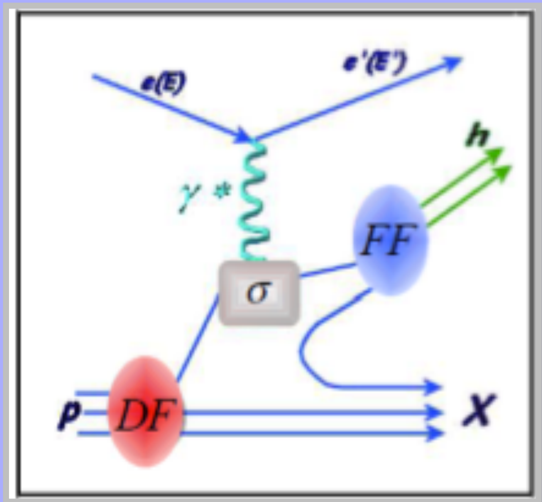
Method (Flavor tagging):
Use correlation between detected hadron and struck quark → **'LO Purity method'**

Observable: semi-inclusive double-spin asymmetry

A. Airapetian et al., PRD 75 (2007)

$$A_1^h(x,Q^2) \overset{LO}{\sim} \frac{\sum_q e_q^2 \Delta q(x,Q^2) \int dz D_q^h(z,Q^2)}{\sum_q e_q^2 q(x,Q^2) \int dz D_q^h(z,Q^2)}$$

$$\sim \sum_q \frac{e_q^2 q(x) \int dz D_q^h(z)}{\sum_{q'} e_{q'}^2 q' \int dz D_{q'}^h(z)} \cdot \frac{\Delta q(x)}{q(x)} \quad \sim P_q^h \frac{\Delta q}{q}$$



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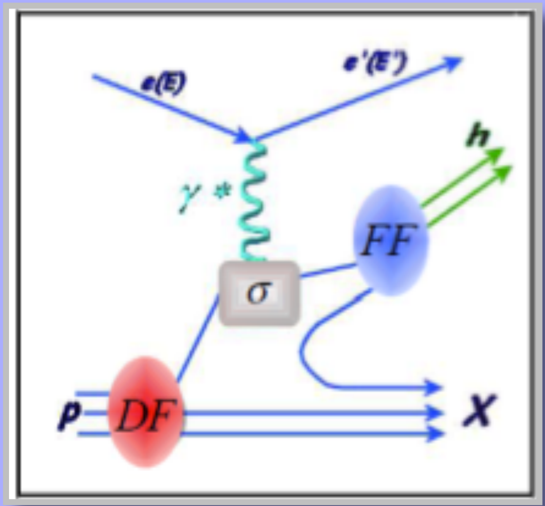
$$\sim \sum_q \frac{e_q^2 q(x) \int dz D \ldots}{\sum_{q'} e_{q'}^2 q' \int dz D_{q'}^h(z)} \quad q(x) \quad \ldots q \quad q$$

What about additional information about fragmentation process?



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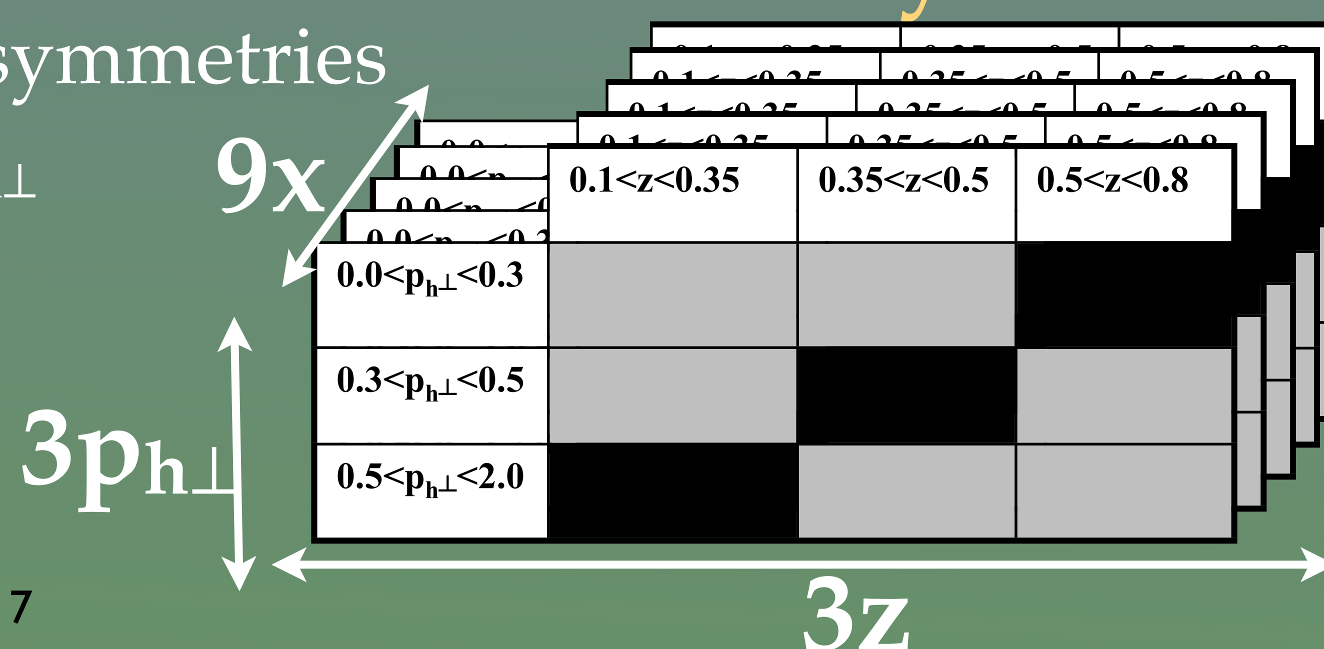
What about additional information about fragmentation process?

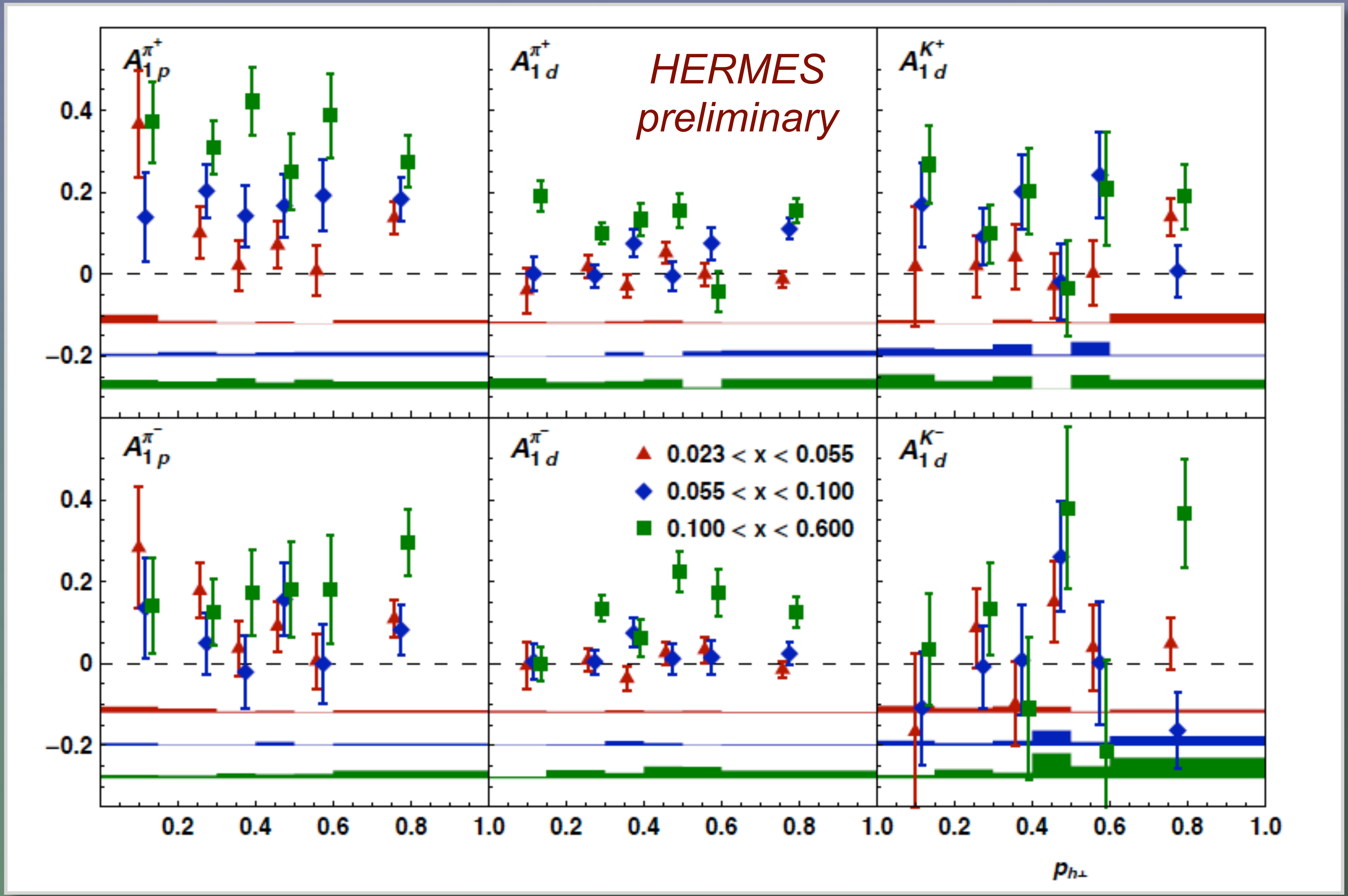
3D binned asymmetries

Provide a dataset of semi-inclusive asymmetries binned simultaneously in x, z, and $p_{h\perp}$



to better isolate different regions of fragmentation

2D binned asymmetry $A_1(x,p_{h\perp})$

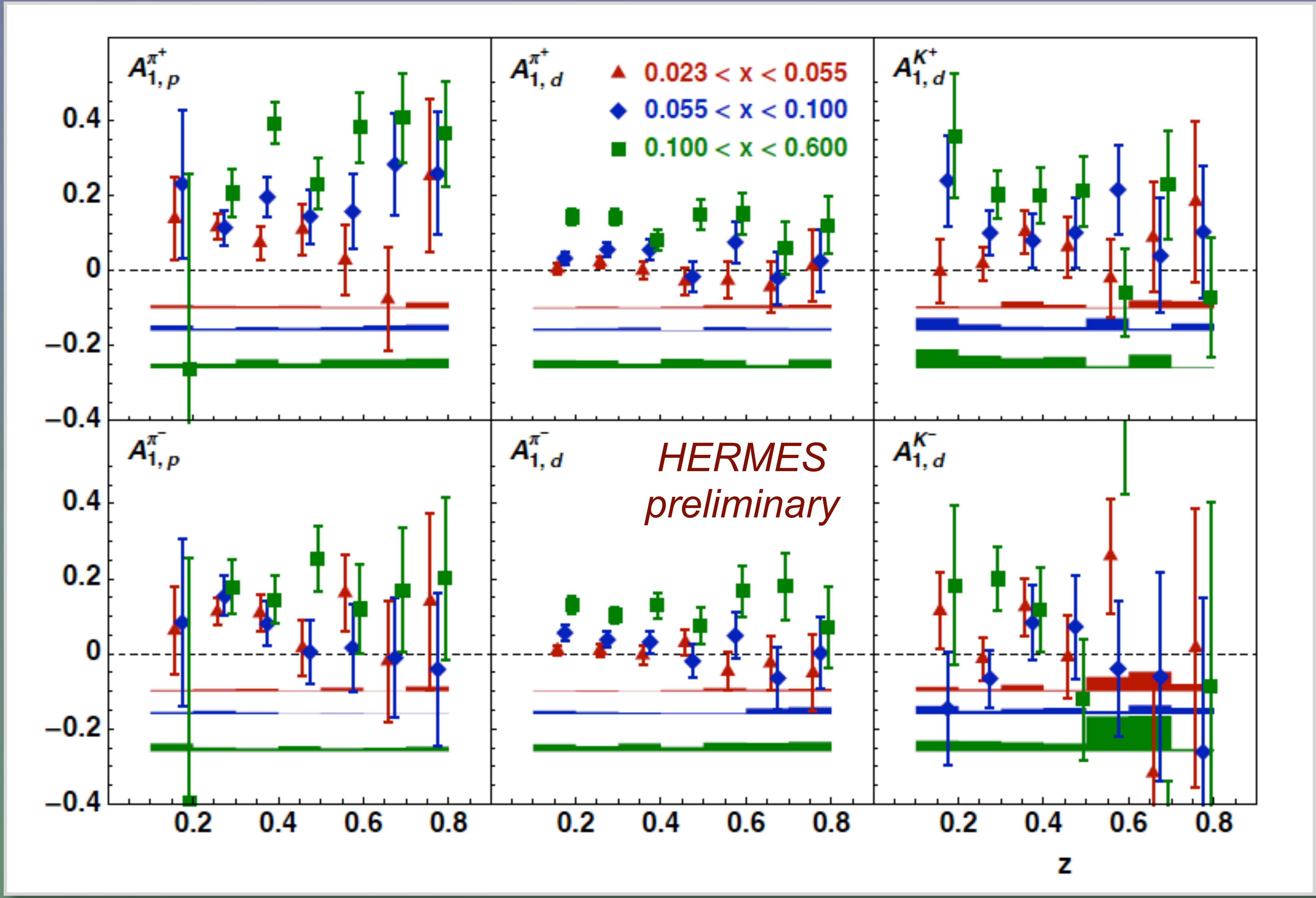


Theoretical prediction

M. Anselmino et al., PRD 74, 074015 (2006)

No significant $p_{h\perp}$ dependence observed

2D binned asymmetry $A_1(x,z)$

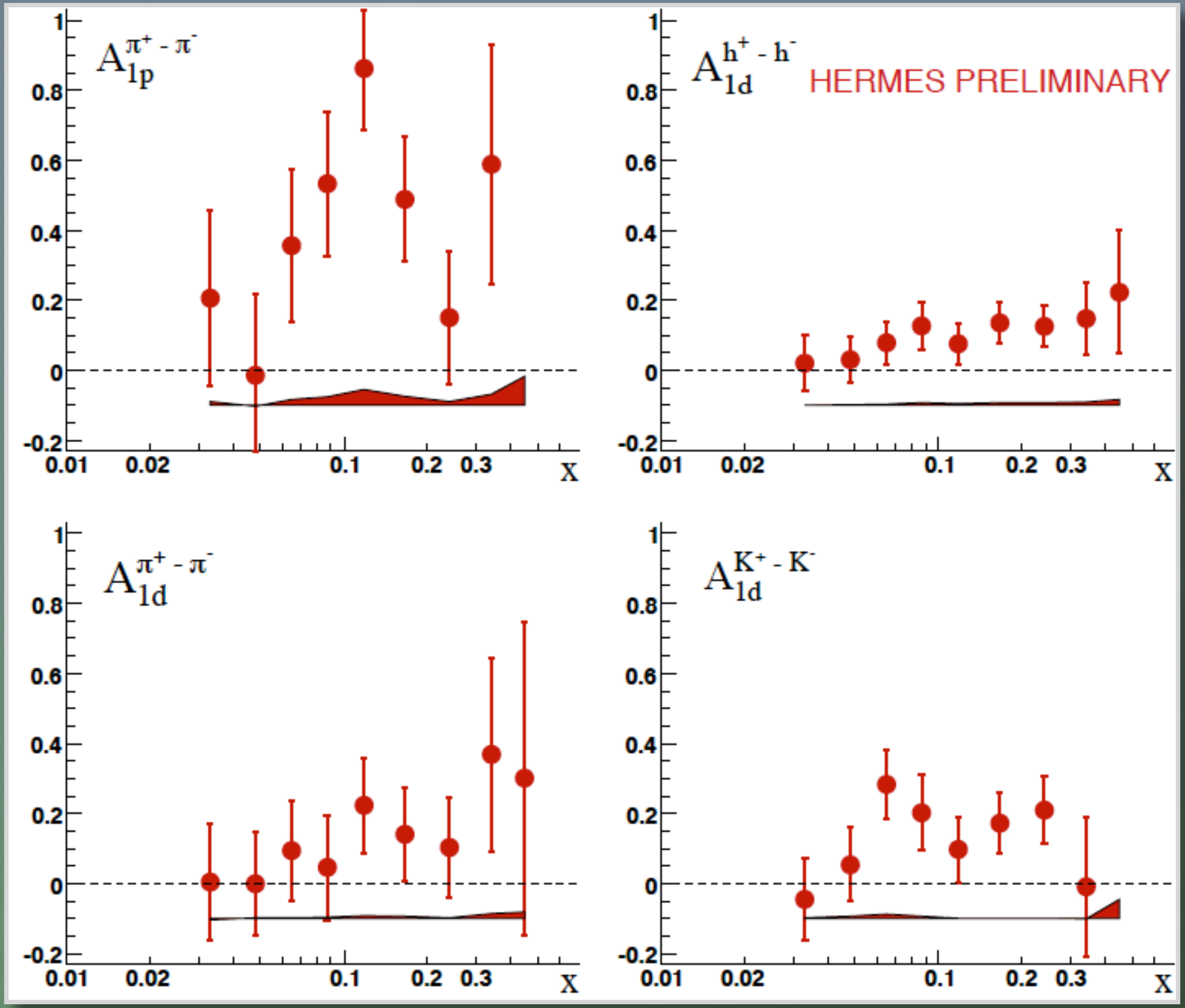


No significant z dependence observed

Hadron charge difference asymmetry

$$A_1^{h^+-h^-} = \frac{(d\sigma_{h^+}^{\overset{\rightarrow}{\Leftarrow}} - d\sigma_{h^-}^{\overset{\rightarrow}{\Leftarrow}}) - (d\sigma_{h^+}^{\overset{\rightarrow}{\Rightarrow}} - d\sigma_{h^-}^{\overset{\rightarrow}{\Rightarrow}})}{(d\sigma_{h^+}^{\overset{\rightarrow}{\Leftarrow}} - d\sigma_{h^-}^{\overset{\rightarrow}{\Leftarrow}}) + (d\sigma_{h^+}^{\overset{\rightarrow}{\Rightarrow}} - d\sigma_{h^-}^{\overset{\rightarrow}{\Rightarrow}})}$$

Provides additional spin-structure information

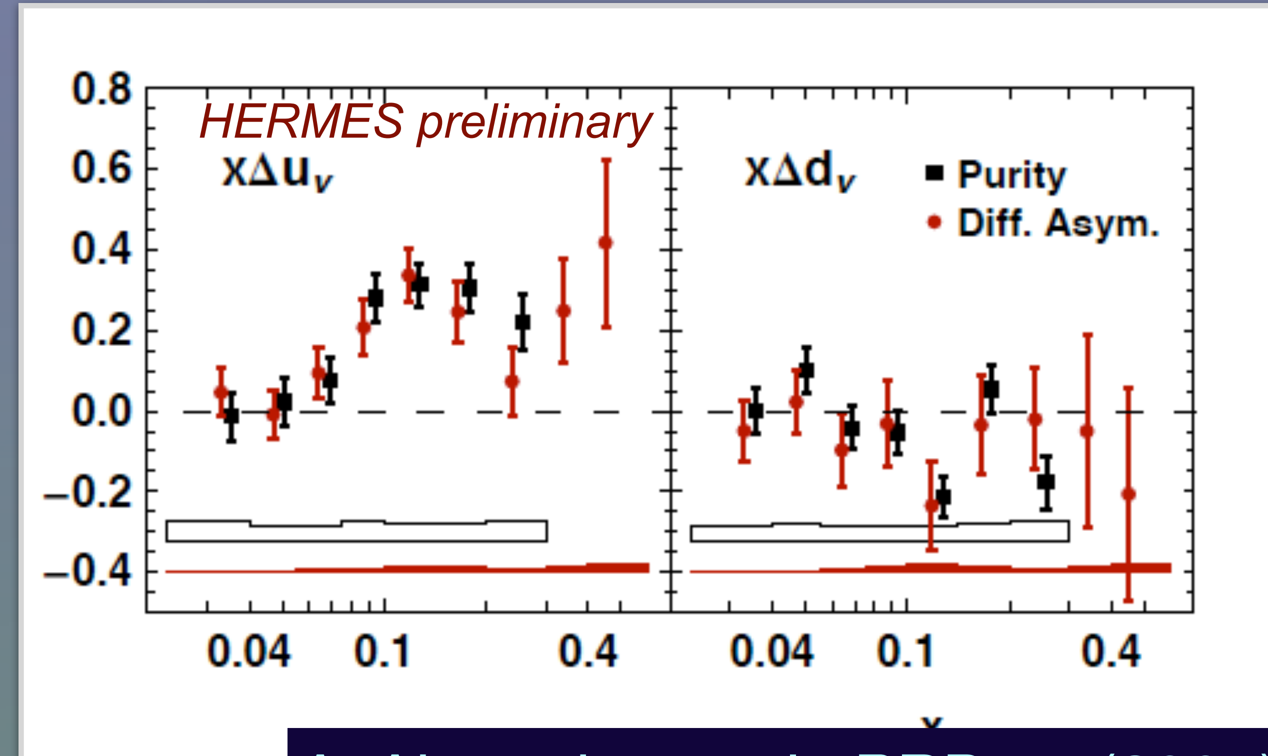


Smaller error bars on the kaon sample due to larger difference in kaon yields

Valence helicity distributions

Separation of quark contributions into valence and sea quark contributions

- LO parton model
- Charge conjugation
- No MC usage
- The contribution of fragmentation functions drop out



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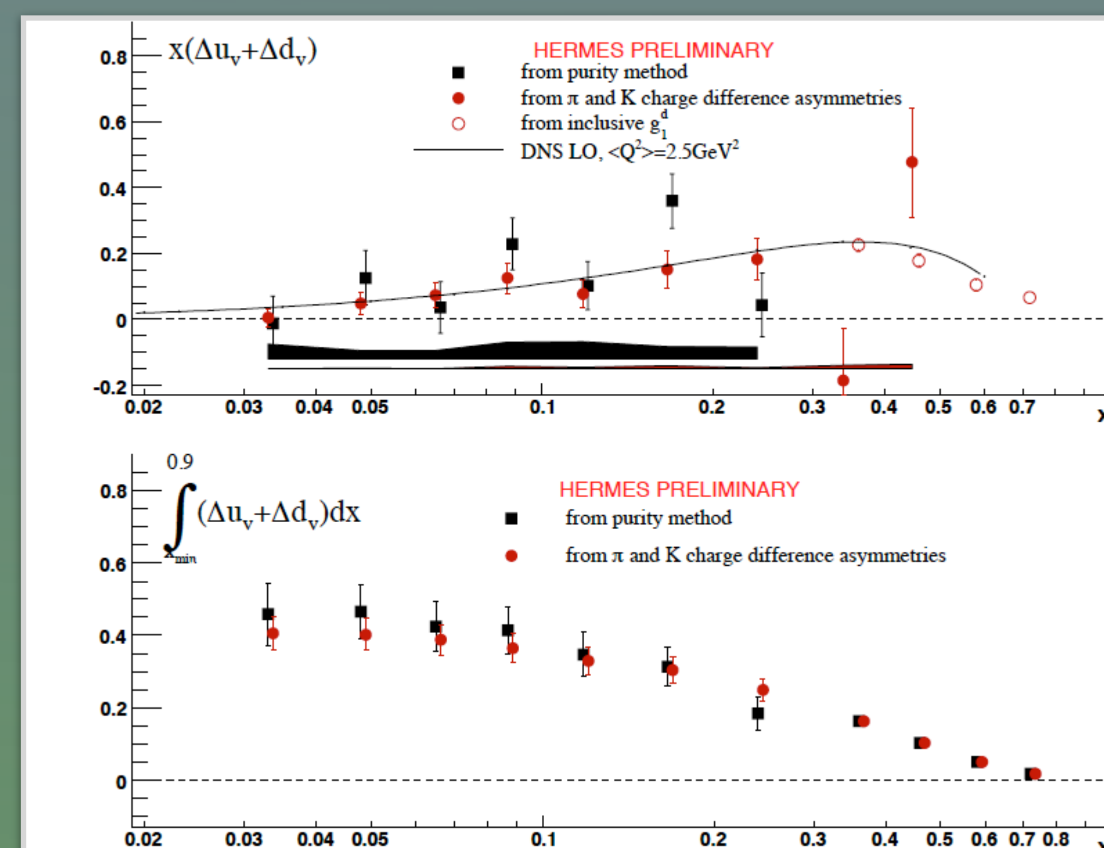


Proton target: $$A_{1p}^{h^+-h^-} = \frac{4\Delta u_v - \Delta d_v}{4u_v - d_v}$$

Deuteron target: $$A_{1d}^{h^+-h^-} = \frac{\Delta u_v + \Delta d_v}{u_v + d_v}$$

Transverse momentum dependence of the quark helicity distributions in SIDIS

The possible contributions to the DIS cross section in the semi-inclusive measurement

$$\sigma^h = \sigma^h_{UU} + \lambda_l \sigma^h_{LU} + S_L \sigma^h_{UL} + \lambda_l S_L \sigma^h_{LL} + S_T \sigma^h_{UT} + \lambda_l S_T \sigma^h_{LT}$$

two structure functions appear

$$S_L \lambda_l \left[\sqrt{1-\epsilon^2} F_{LL} + \sqrt{2\epsilon(1-\epsilon)} cos(\phi) F^{cos\phi}_{LL} \right.$$

ϕ angle is the azimuthal angle of the hadron plane around the virtual-photon direction

$$F^{\cos\phi_h}_{LL} \sim \frac{2M}{Q} C\left[-\frac{\hat{h}\cdot p_T}{M} x g_L^{\perp} D_1 \right]$$

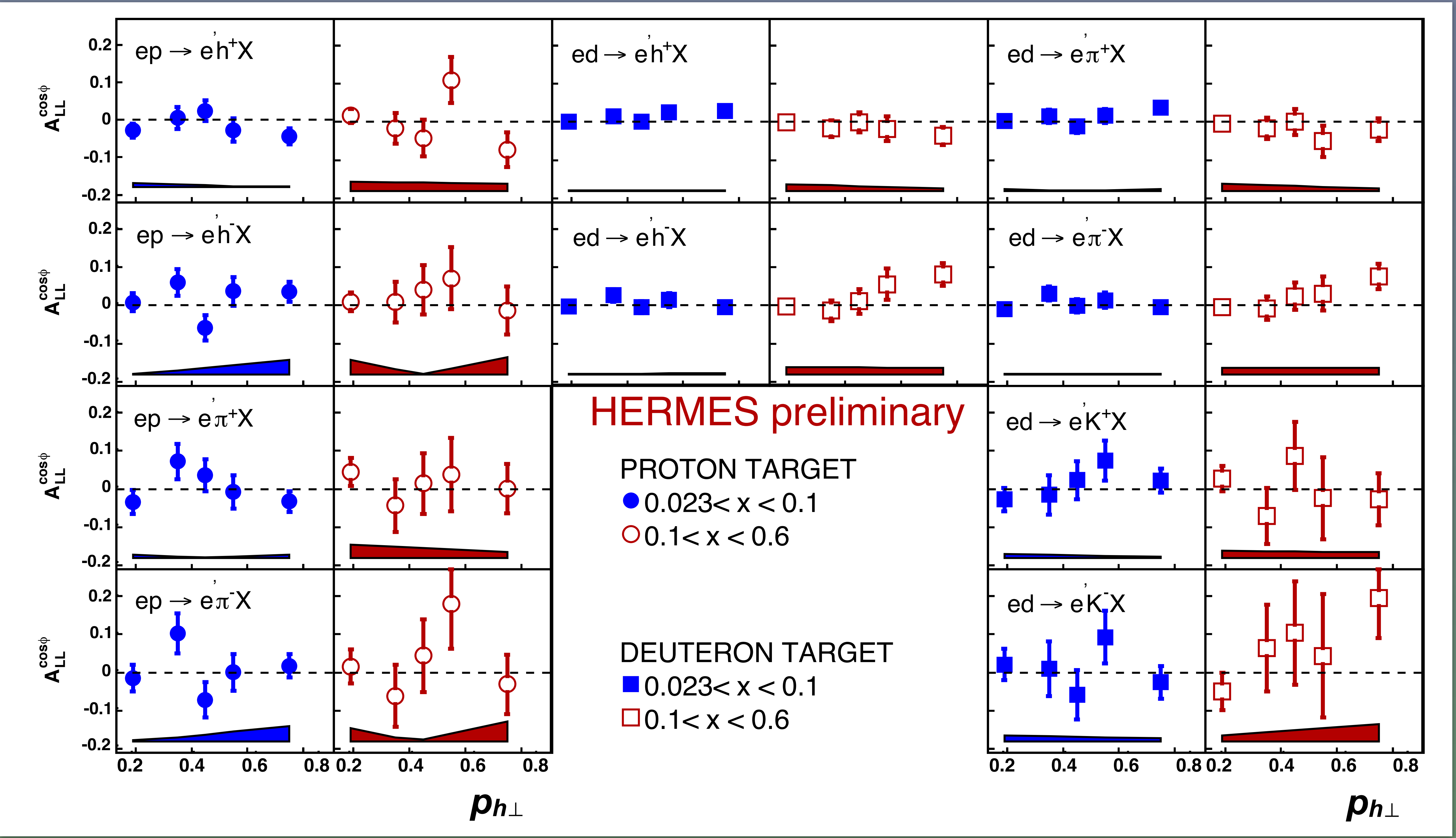
Unintegrated helicity distributions $\Delta q(x,k_\perp)$

To access

$$A^h_{LL} = \frac{1}{\lambda_l S_L} \frac{d\sigma_h^{\overset{\rightarrow}{\Leftarrow}}(\phi) - d\sigma_h^{\overset{\rightarrow}{\Rightarrow}}(\phi)}{d\sigma_h^{\overset{\rightarrow}{\Leftarrow}}(\phi) + d\sigma_h^{\overset{\rightarrow}{\Rightarrow}}(\phi)} = A^h_{LL}(x,y,z,p_{h\perp}) + cos\phi A^{cos\phi}_{LL}(x,y,z,p_{h\perp})$$

NEW!!

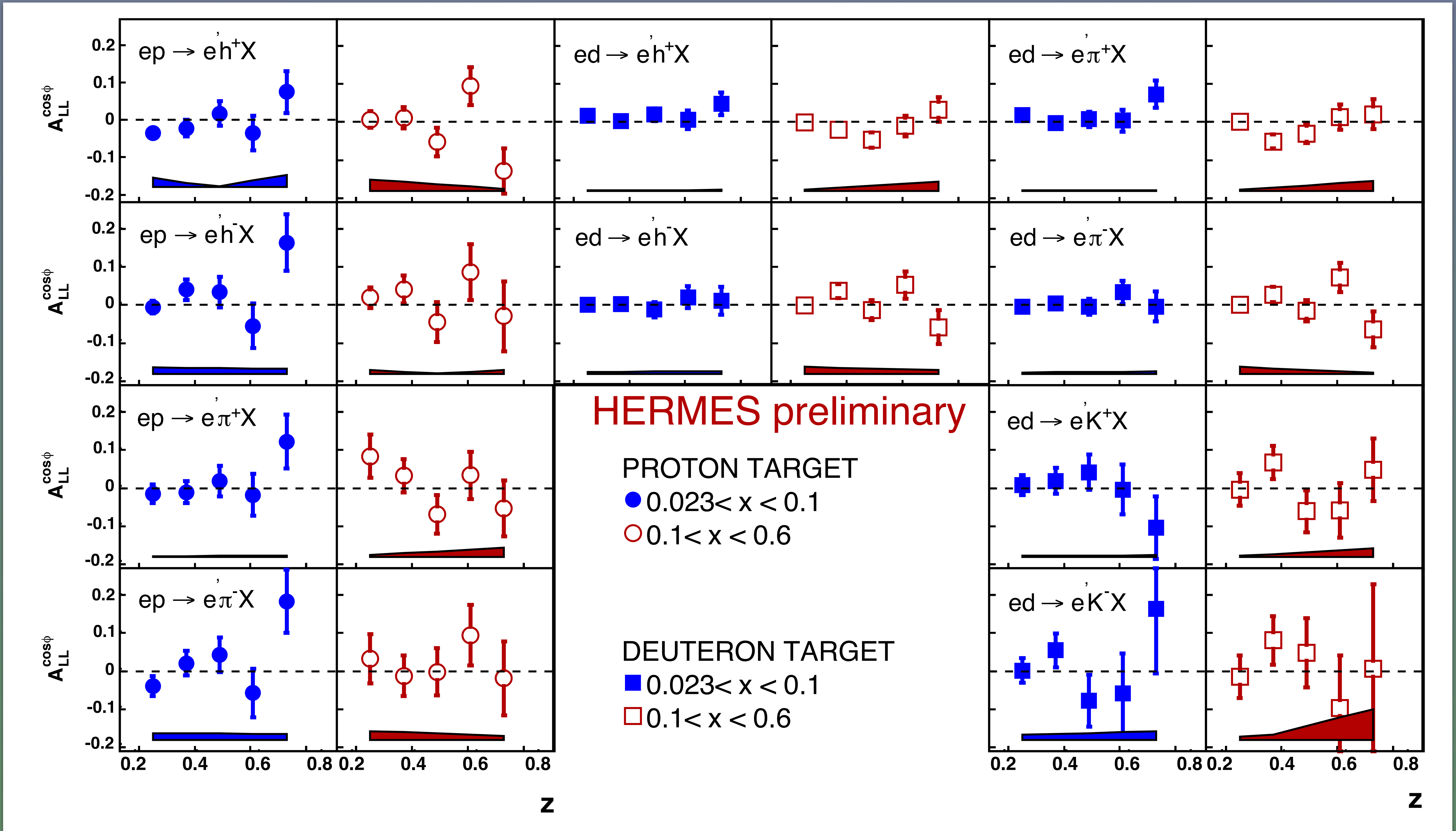
cos ϕ moments of semi-inclusive double spin asymmetry $A_{LL}(p_{h\perp}, x)$



Theoretical prediction M. Anselmino et al., PRD 74, 074015 (2006)

NEW!!

cos ϕ moments of semi-inclusive double spin asymmetry $A_{LL}(z, x)$



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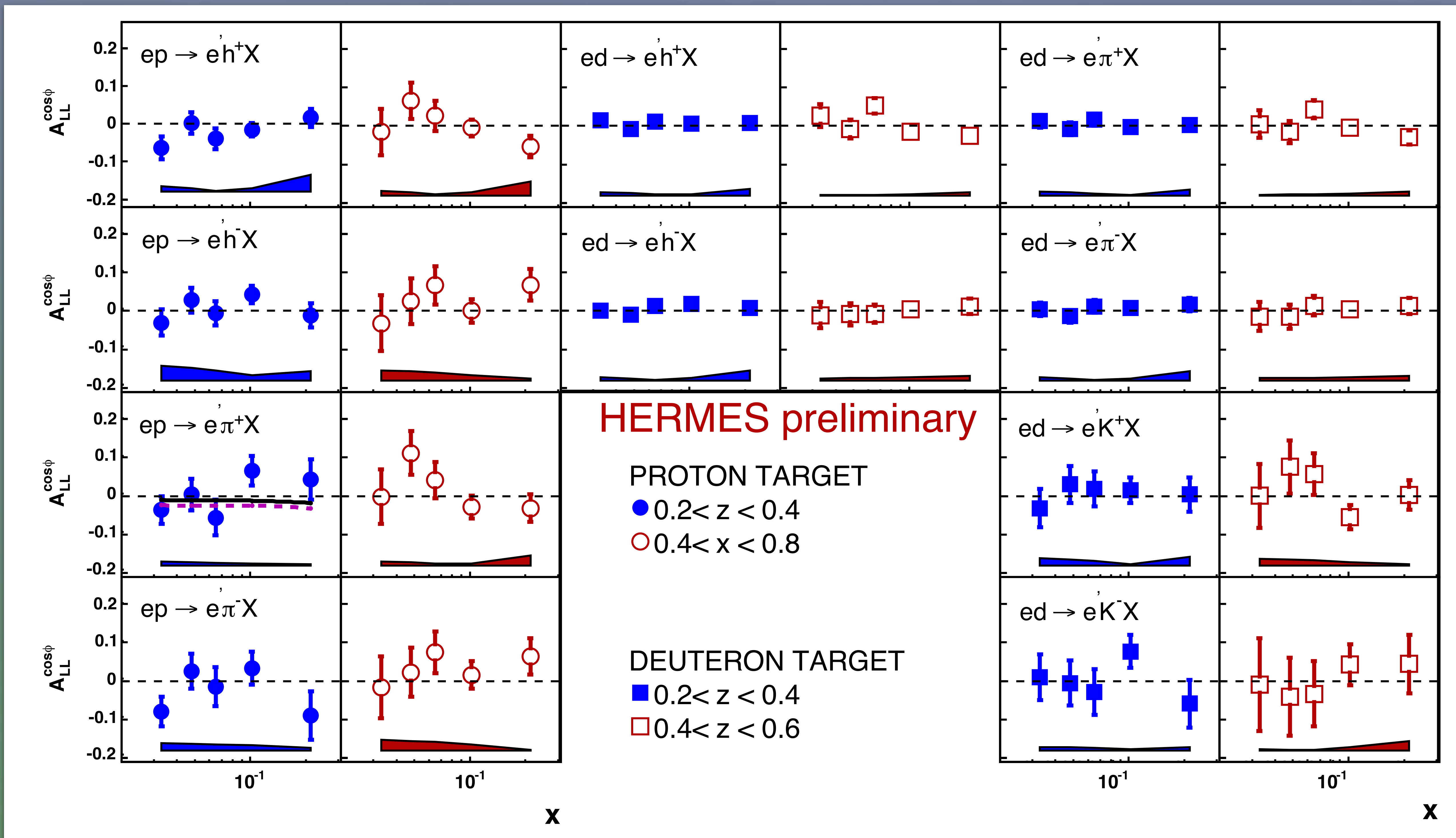
Polina Kravchenko

NEW!!

cos ϕ moments of semi-inclusive double spin asymmetry $A_{LL}(x, z)$



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Summary

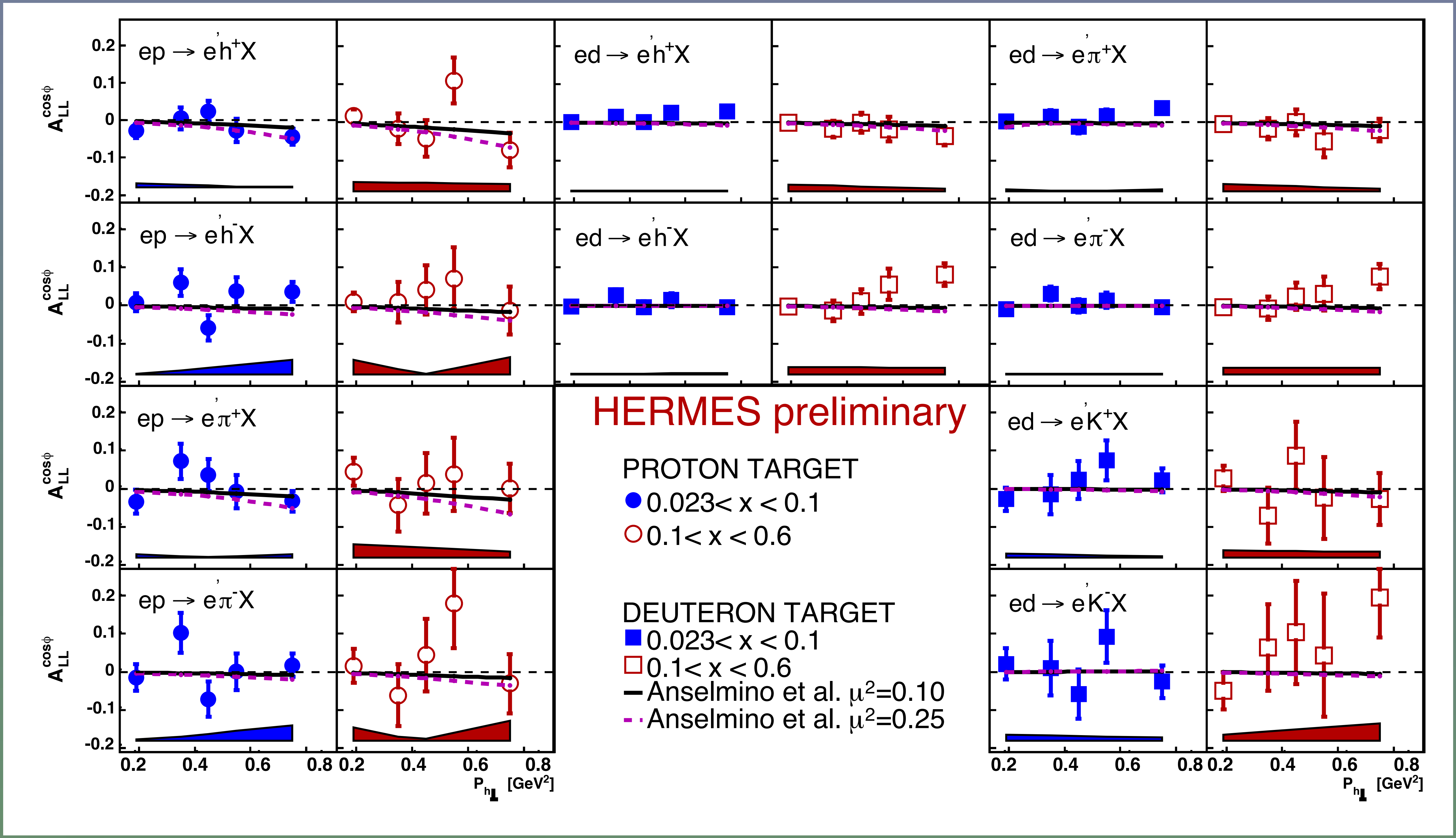
A_1^h asymmetries in x, z and $p_{h\perp}$ are available for flavor separated quark helicity distribution extraction.

Hadron charge difference asymmetries have been measured . Valence helicity densities are presented in comparison with the same quantities from previous HERMES purity extraction.

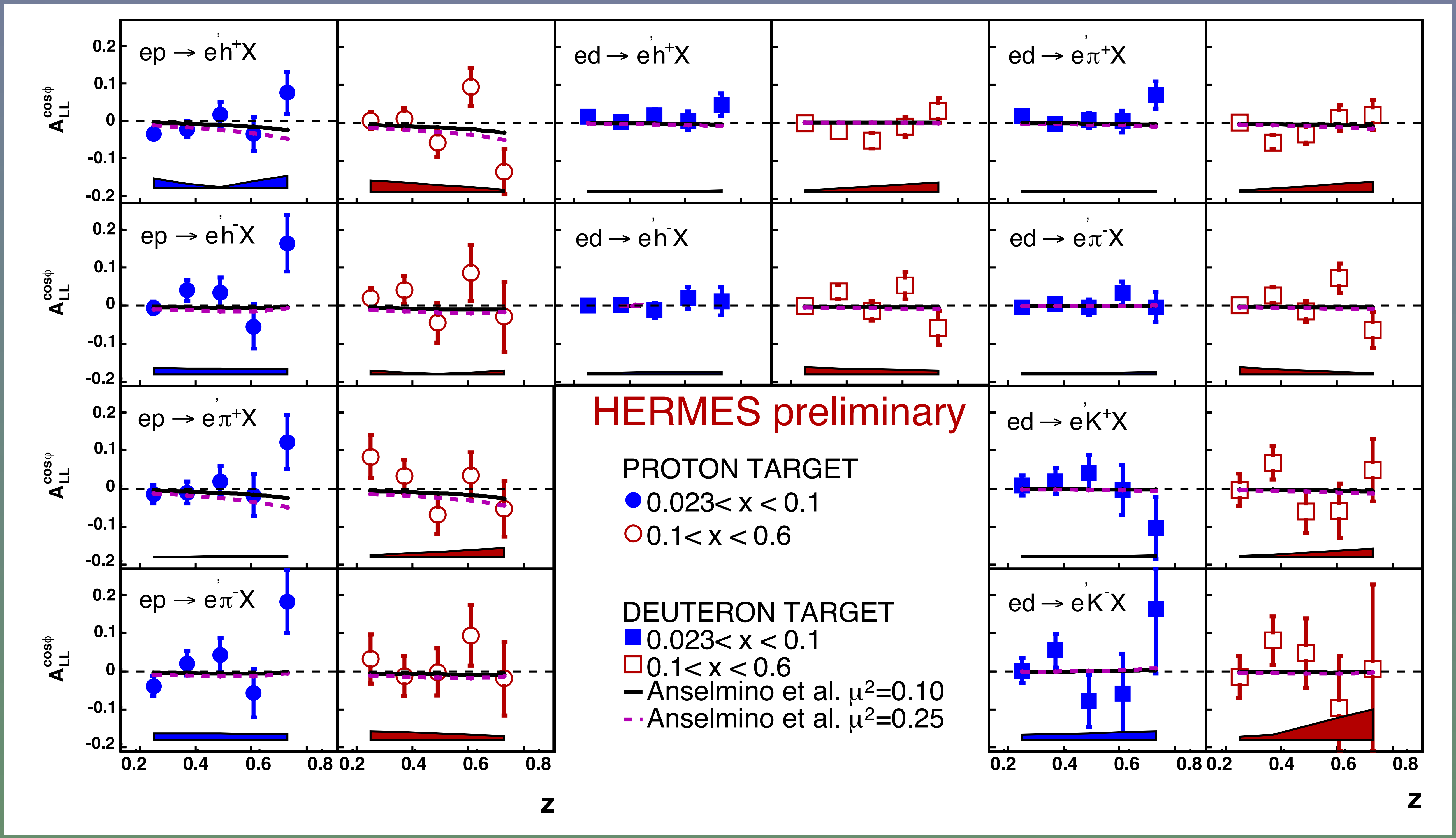
The cos ϕ moments of semi-inclusive double spin asymmetry as a function of x, z and $p_{h\perp}$ are shown and compatible with zero.

Backup slides

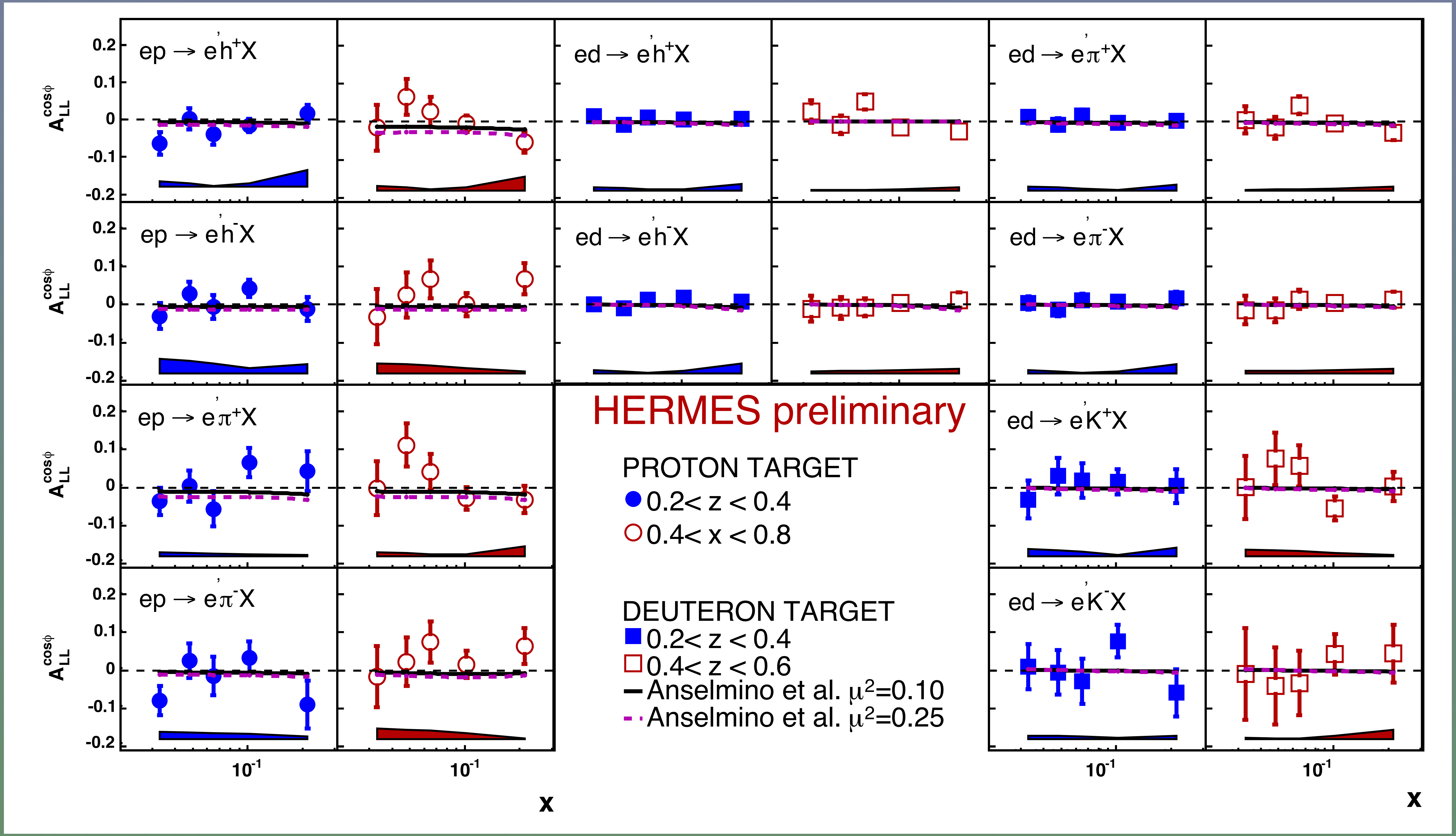
cos ϕ moments of semi-inclusive double spin asymmetry $A_{LL}(p_{h\perp}, x)$



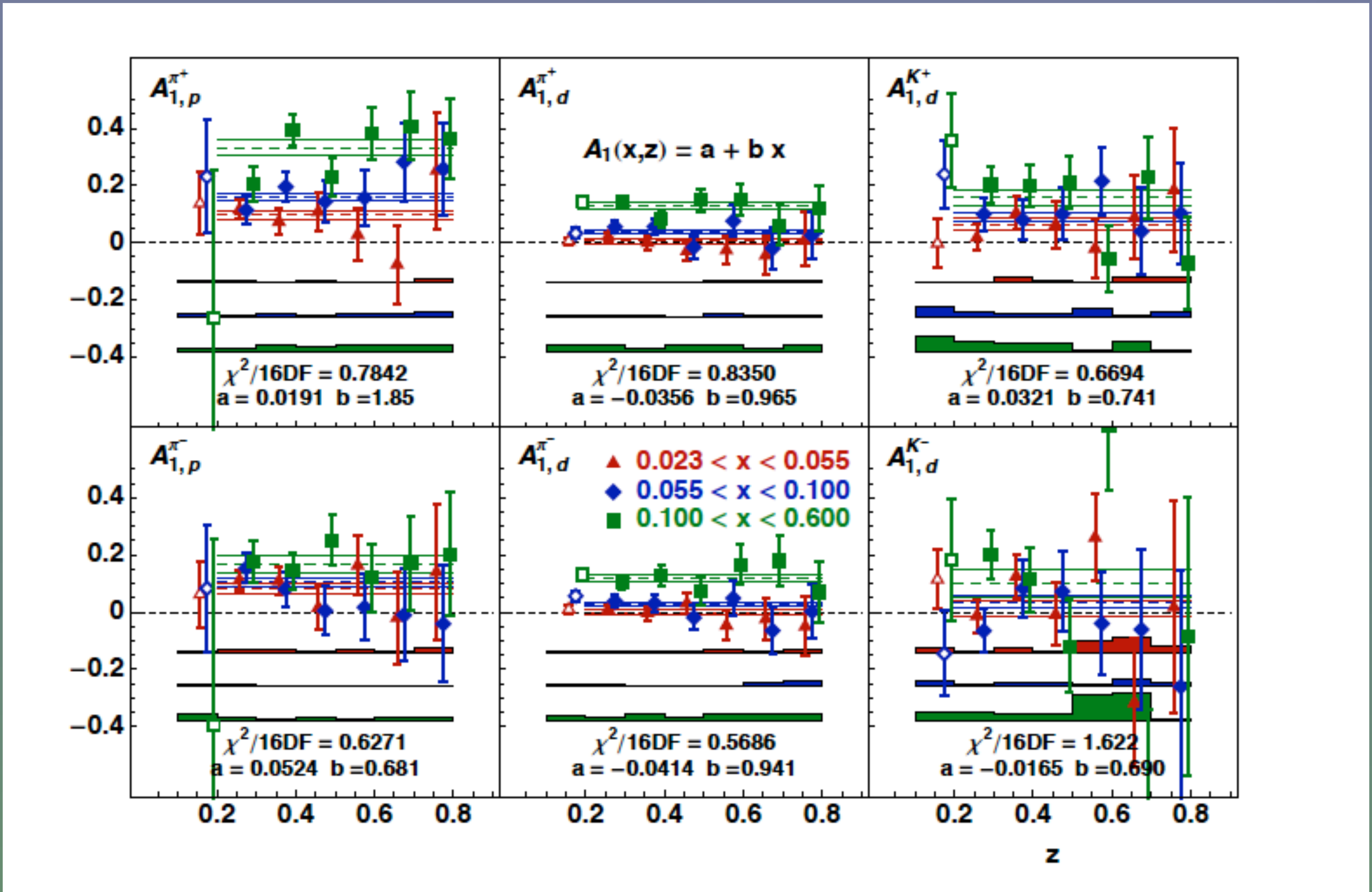
cos ϕ moments of semi-inclusive double spin asymmetry $A_{LL}(z, x)$



$\cos\phi$ moments of semi-inclusive double spin asymmetry $A_{LL}(x, z)$



2D binned asymmetry $A_1(x,z)$



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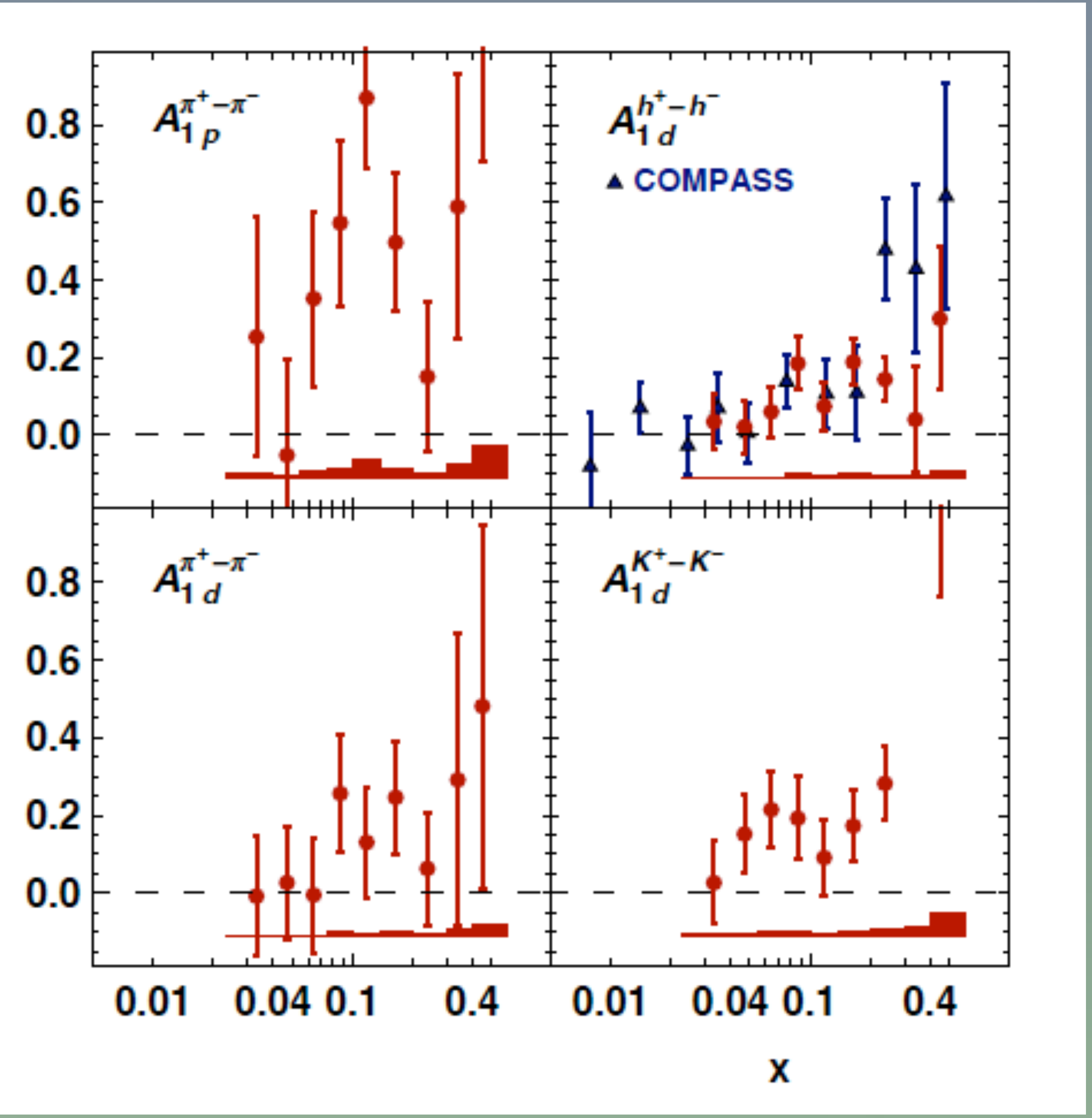
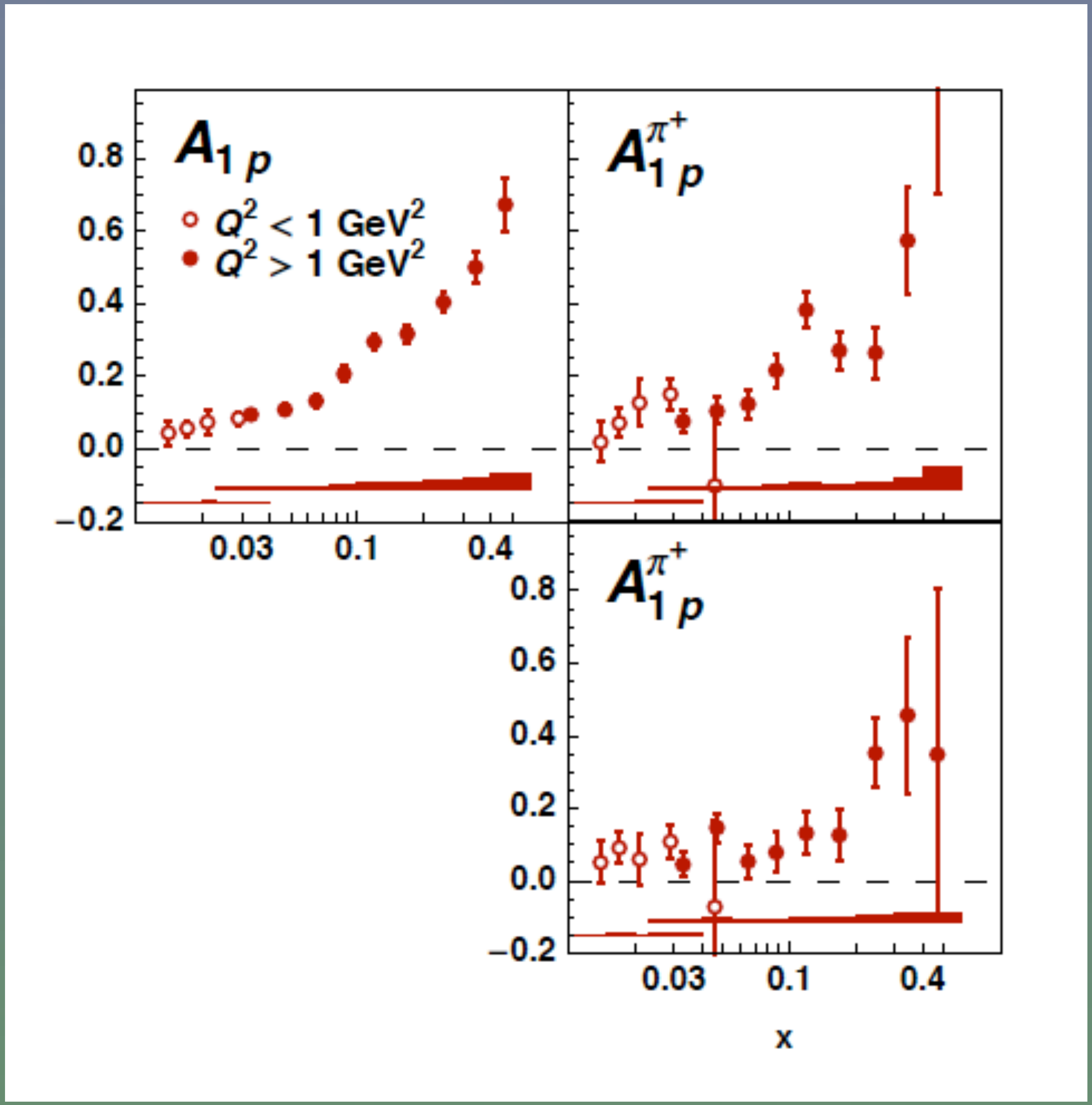


Longitudinal semi-inclusive double-spin asymmetries at HERMES.



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