Single-spin asymmetries with 2 hadron fragmentation:
The Measurement

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On behalf of the HERMES collaboration

Layout:

- **Introduction**
- **Results**
- **Interpretation**

h_1

Introduction - 1π fragmentation

$\mathcal{I}[\cdots] \equiv \int d^2\boldsymbol{p}_T d^2\boldsymbol{k}_T \delta(\boldsymbol{p}_T - \boldsymbol{k}_T - \frac{\boldsymbol{P}_{h\perp}}{z})[\cdots]$

h_1 couples to $H_1^\perp(z, z^2\boldsymbol{k}_T^2)$:

$$d\sigma_{UT}^{\text{Collins}} \propto \sum_q e_q^2 \sin(\phi_h + \phi_S)\mathcal{I}\left[\frac{\boldsymbol{k}_T \cdot \hat{\boldsymbol{P}}_{h\perp}}{M_h} h_1^q H_1^{\perp q}\right]$$

Difficulties:

- extraction of $h_1 H_1^\perp$ difficult, needs weighting with $P_h^\perp$
- Sivers & Collins entangled:

$$d\sigma_{UT}^{\text{Sivers}} \propto \sum_q e_q^2 \sin(\phi_h - \phi_S)\mathcal{I}\left[\frac{\boldsymbol{p}_T \cdot \hat{\boldsymbol{P}}_{h\perp}}{M} f_{1T}^{\perp q} D_1^q\right]$$

Introduction - 2π fragmentation

$\zeta \propto z_1/(z_1+z_2)$

h_1 couples to:

$$H_1^{\perp}(z,\zeta,M_h^2,\boldsymbol{k}_T^2,\boldsymbol{k}_T\cdot\boldsymbol{R}_T) \;\&\; H_1^{\sphericalangle\prime}(z,\zeta,M_h^2,\boldsymbol{k}_T^2,\boldsymbol{k}_T\cdot\boldsymbol{R}_T)$$

Integrate over $\boldsymbol{P}_{h\perp}$:

left with only $H_1^{\sphericalangle}(z,\zeta,M_h^2)$ $\Longrightarrow$ $d\sigma_{UT} \propto \sum_q e_q^2 \sin(\phi_{R\perp}+\phi_S) h_1 H_1^{\sphericalangle}$

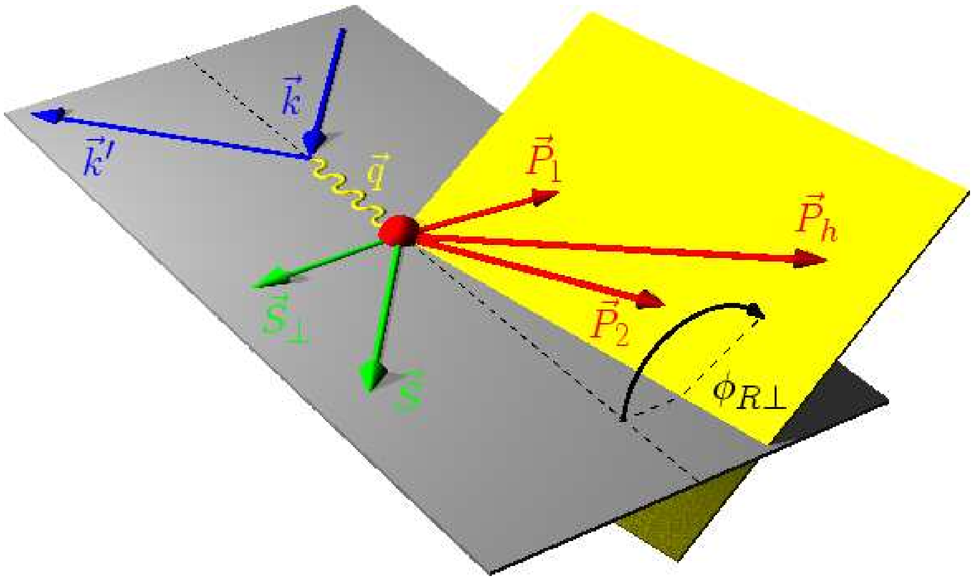
Advantages:

- cross section asymmetry directly proportional to $h_1 H_1^{\sphericalangle}$ (No weighting needed)
- No Collins/Sivers ‘problem’
- Completely independent from 1π analysis

Disadvantages:

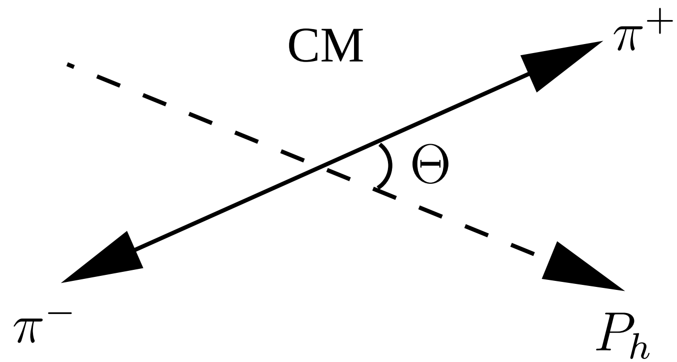
- less statistics
- $H_1^{\sphericalangle}$ unknown (but can be measured at Belle & Babar)

Single Spin Asymmetry

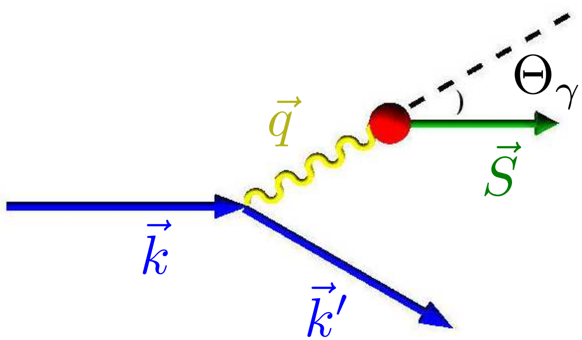


longitudinally polarized deuterium target

$$\vec{P}_h \equiv \vec{P}_1 + \vec{P}_2$$



$$A_{UL} \sim \sin\phi_{R\perp} \sin\Theta \left[|\vec{S}_{\parallel}| h_L H_1^{\sphericalangle} - |\vec{S}_{\perp}| h_1 H_1^{\sphericalangle} \right]$$

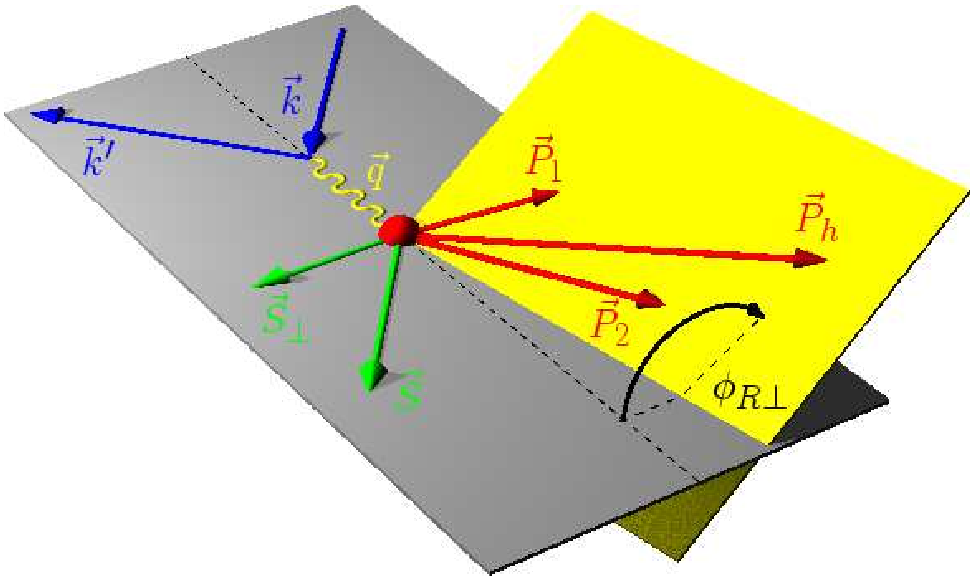


$$|\vec{S}_\perp| = \sin\Theta_\gamma |\vec{S}_\parallel| \implies \langle \sin\Theta_\gamma \rangle \simeq 0.05$$

If $H_1^{\sphericalangle} \neq 0$: 2 hadron fragmentation can acces h_1!

h_1

Single Spin Asymmetry



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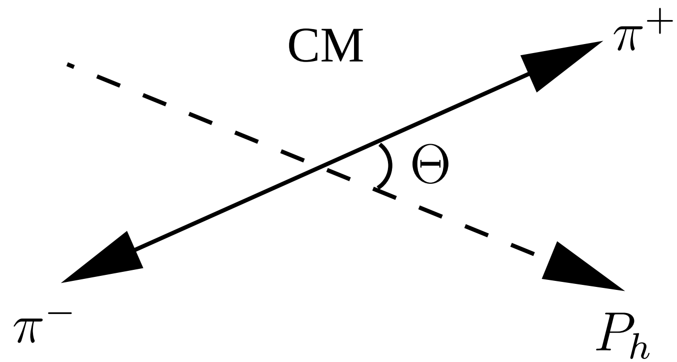


What is measured:

$$A_{UL}(\phi_{R\perp}) = \frac{1}{|P_T|} \frac{N^{\leftarrow}(\phi_{R\perp})/N^{\leftarrow}_{\mathrm{DIS}} - N^{\rightarrow}(\phi_{R\perp})/N^{\rightarrow}_{\mathrm{DIS}}}{N^{\leftarrow}(\phi_{R\perp})/N^{\leftarrow}_{\mathrm{DIS}} + N^{\rightarrow}(\phi_{R\perp})/N^{\rightarrow}_{\mathrm{DIS}}}$$

h_1

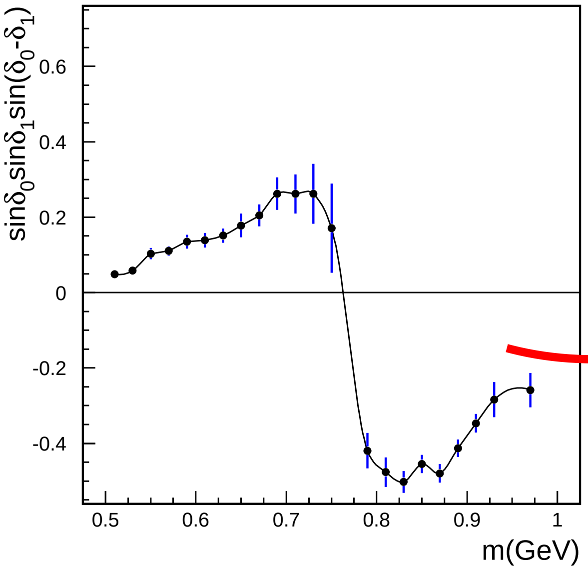
Interference FF

$$A_{UL} \sim \sin\phi_{R\perp} \sin\Theta \left[|\vec{S}_{\parallel}| h_L H_1^{\sphericalangle} - |\vec{S}_{\perp}| h_1 H_1^{\sphericalangle} \right]$$

Expansion of $H_1^{\sphericalangle}$ in Legendre moments:

$$H_1^{\sphericalangle}(z, \cos\Theta, M_{\pi\pi}^2) = H_1^{\sphericalangle,sp}(z, M_{\pi\pi}^2) + \cos\Theta H_1^{\sphericalangle,pp}(z, M_{\pi\pi}^2)$$

about $H_1^{\sphericalangle,sp}$:



Jaffe et al. [**hep-ph/9709322**]:

$$H_1^{\sphericalangle,sp}(z, M_{\pi\pi}^2) = \underline{\sin\delta_0 \sin\delta_1 \sin(\delta_0 - \delta_1)} H_1^{\sphericalangle,sp'}(z)$$

δ_0 (δ_1) $\rightarrow$ S(P)-wave phase shifts

$$= \mathcal{P}(M_{\pi\pi}^2) H_1^{\sphericalangle,sp'}(z)$$

$\Longrightarrow A_{UL}^{\sin\phi_{R\perp}}$ might depend stongly on $M_{\pi\pi}$

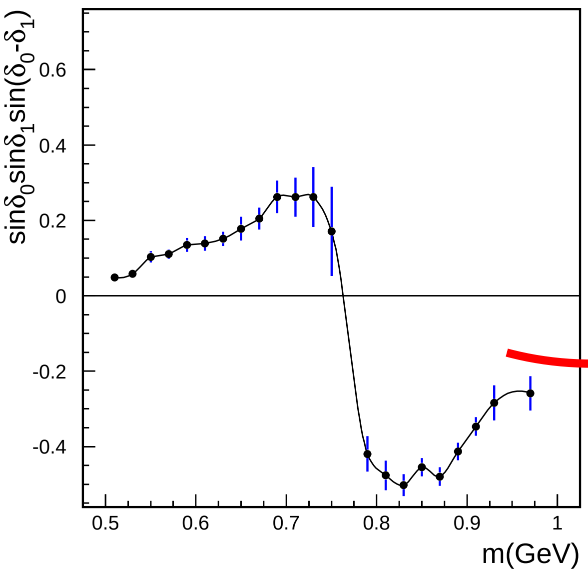
h_1

Interference FF

$$A_{UL} \sim \sin\phi_{R\perp} \left(|\vec{S}_{\parallel}| h_L - |\vec{S}_{\perp}| h_1 \right) \left[\sin\Theta H_1^{\sphericalangle,sp} + \sin 2\Theta H_1^{\sphericalangle,pp} \right]$$

drops out since $\Theta \in [0, \pi]$

about $H_1^{\sphericalangle,sp}$:



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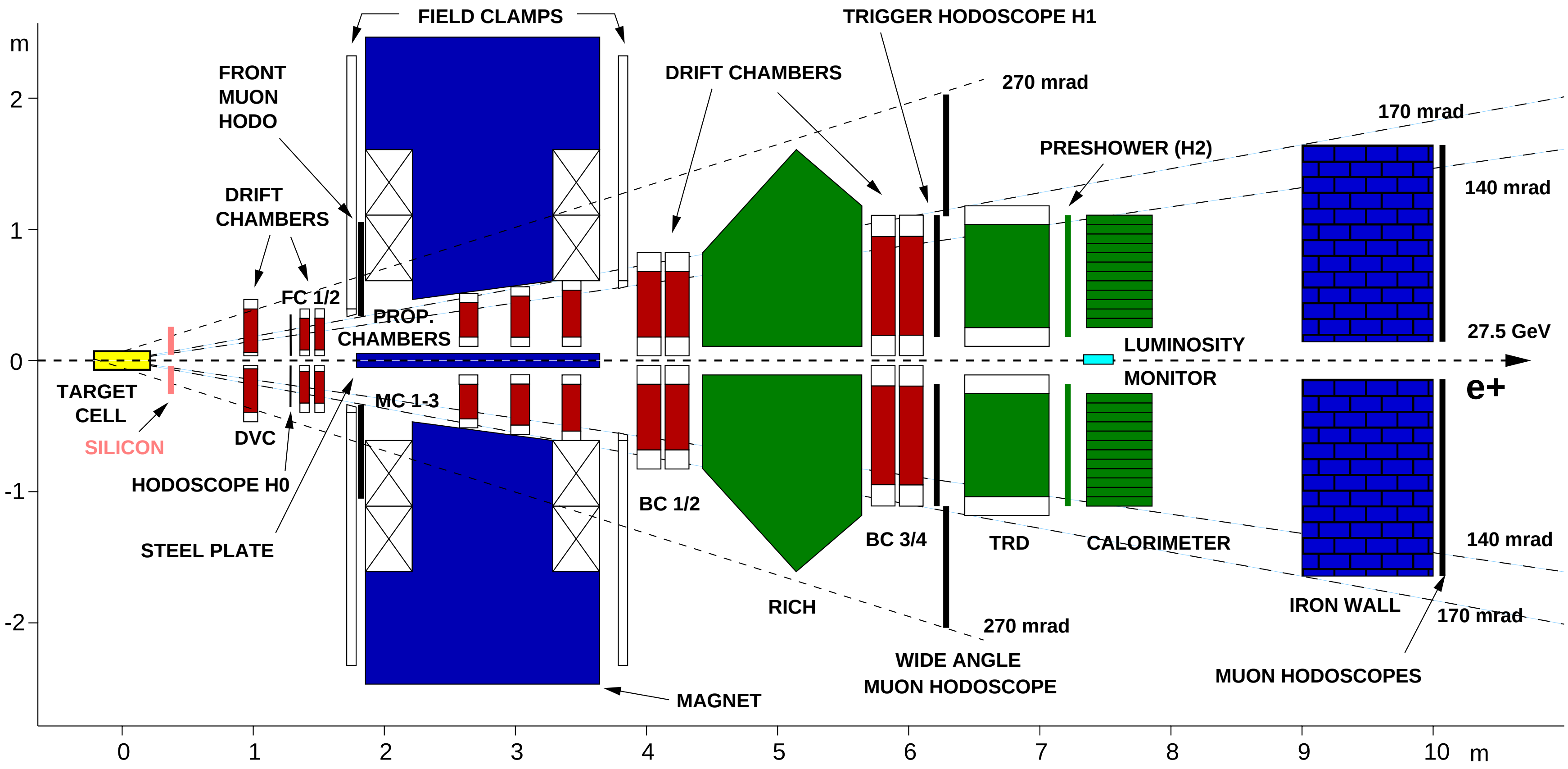
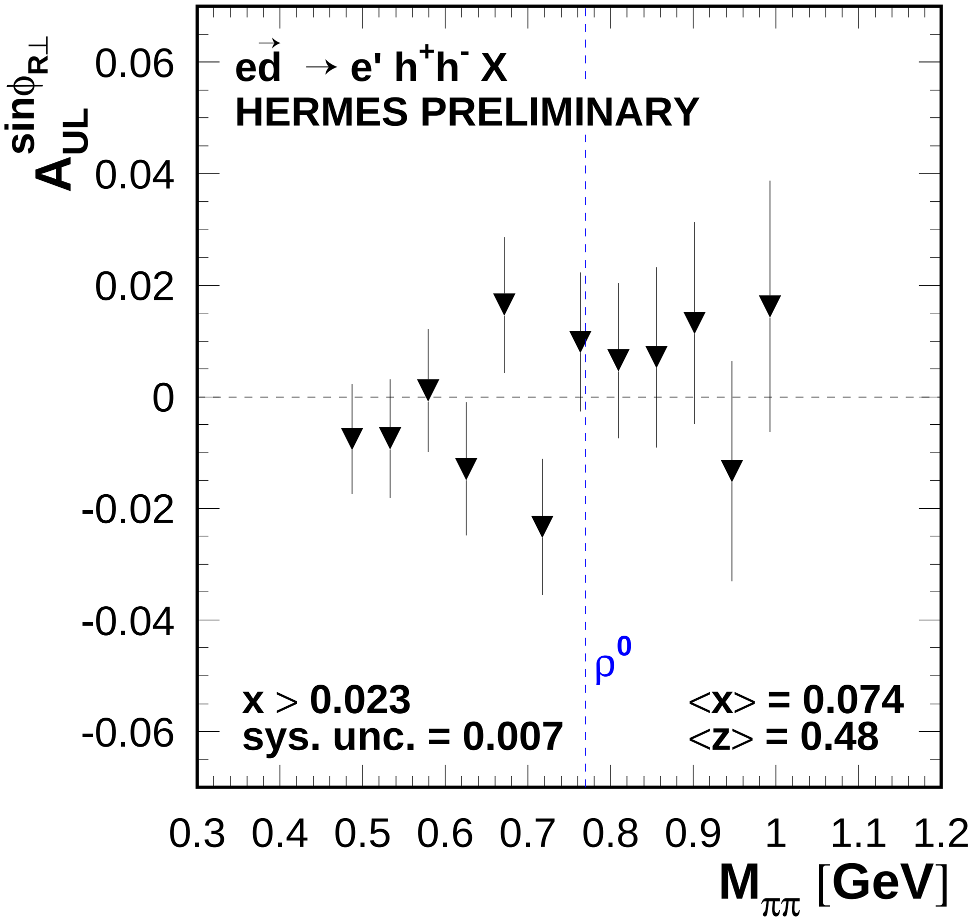
The HERMES Experiment



- Forward acceptance spectrometer: 40 mrad $\leq \Theta \leq 220$ mrad
- Tracking: 57 tracking planes: $\delta P/P = (0.7 - 1.3)\%$, $\delta\Theta \leq 0.6$ mrad

Results

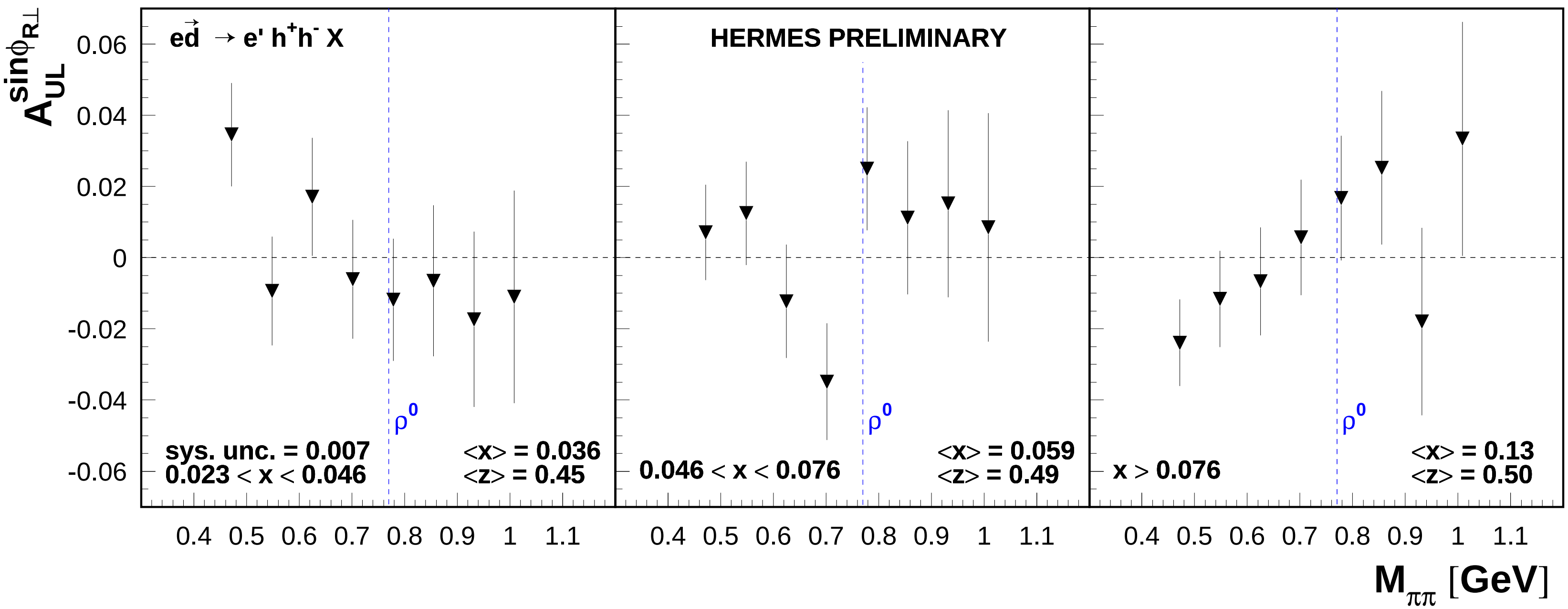


- first measurement ever of $A_{UL}^{\sin\phi_{R\perp}}$
- small asymmetries

x-dependence

Attempt to study x and z-dependence:

$$A_{UL}^{\sin\phi_{R\perp}} \propto h_1(x) H_1^{\sphericalangle,sp}(z, M_{\pi\pi}) + (\ldots)$$



- no strong x-dependence observed

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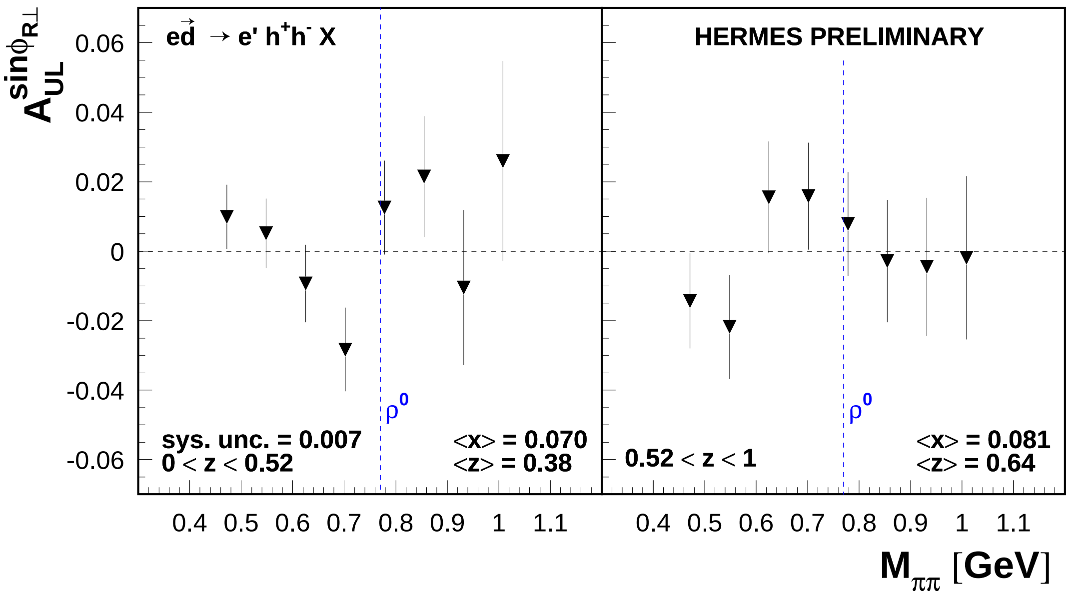
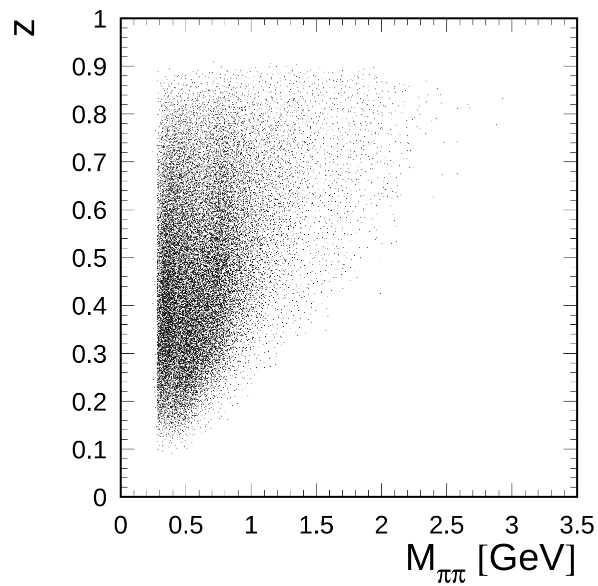
z-dependence



$$z \equiv \frac{E_{\pi\pi}}{\nu}$$

- no strong z-dependence observed
- no more than two bins possible



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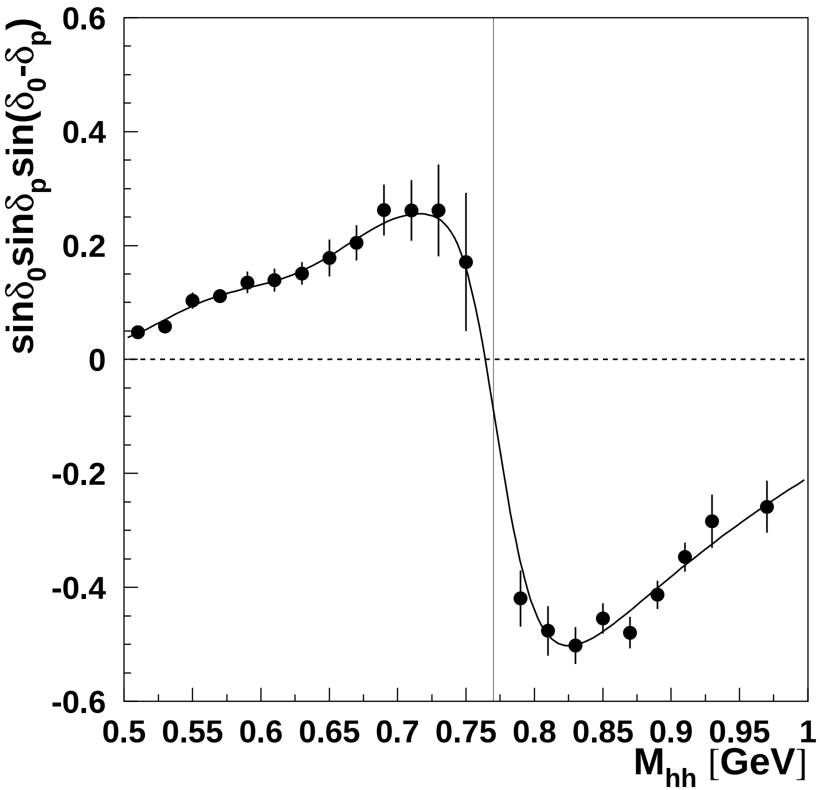
comparison to model prediction



Model by Jaffe et al.:

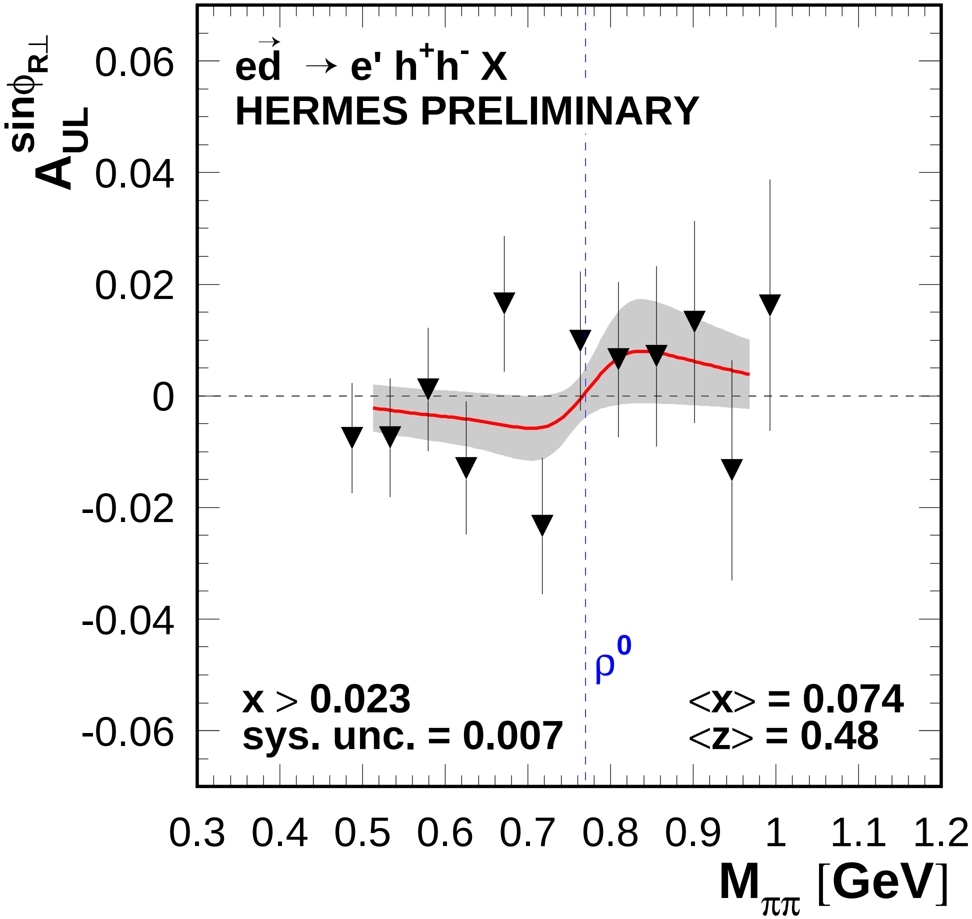
- predicts mass dependence
- NO statements on size/sign of the asymmetry

Fit data with:

$$g(M_{\pi\pi}^2) \simeq c_1 \mathcal{P}(M_{\pi\pi}^2) + c_2$$

by extracting c_1 & c_2 a qualitative comparison can be made to the model prediction

comparison to model prediction

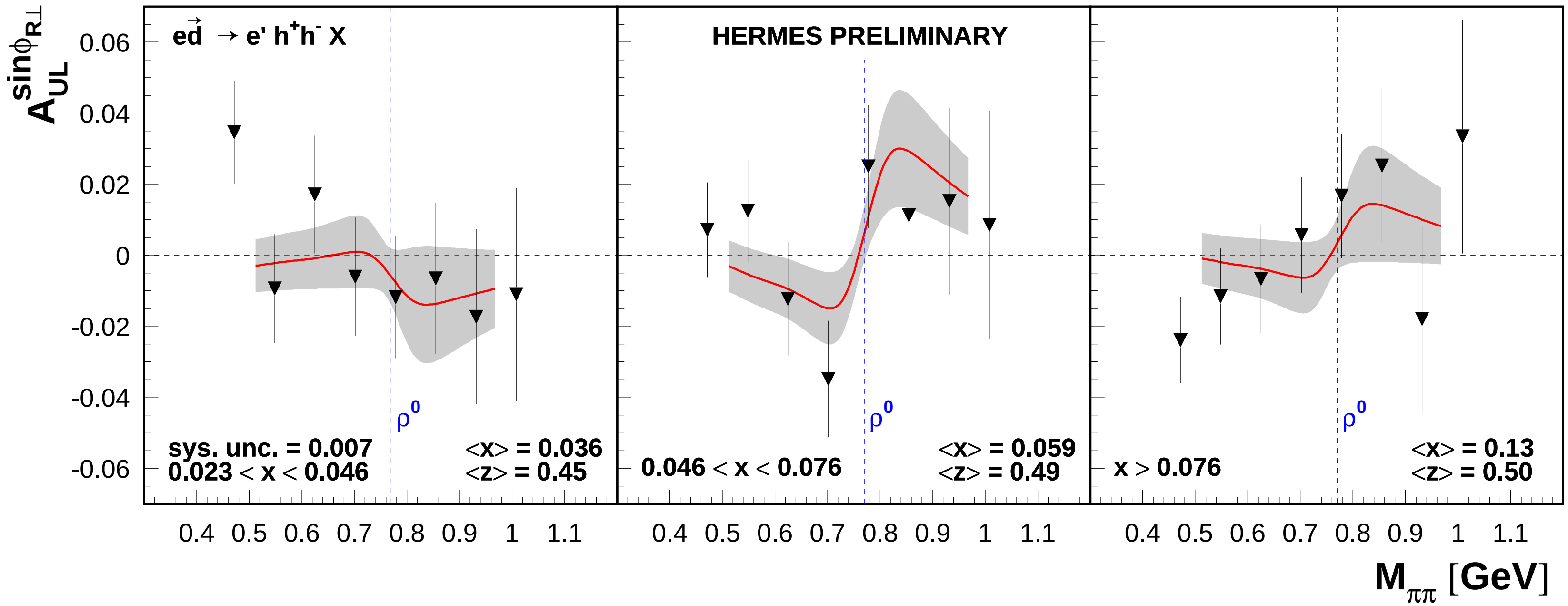


$$
\begin{aligned}
c_1 &= \quad 0.040 \pm 0.036 \\
c_2 &= -0.001 \pm 0.004
\end{aligned}
$$

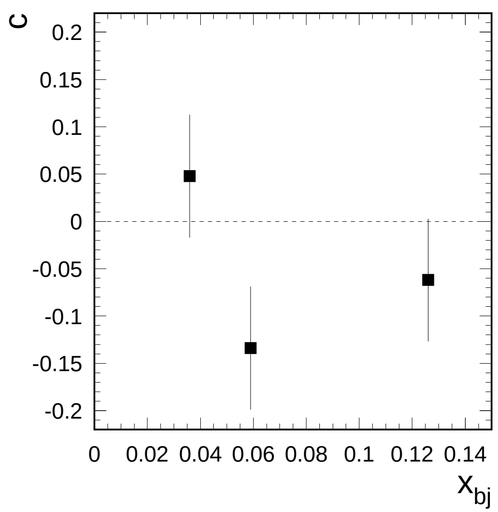
- hint of a sign change at the ρ^0 mass

$$g(M_{\pi\pi}^2) \simeq c_1 \mathcal{P}(M_{\pi\pi}^2) + c_2$$

x-dependence



- higher x: hint of sign change at ρ^0 according to Jaffe's model
- $c_1(x) \propto h_1(x)$?



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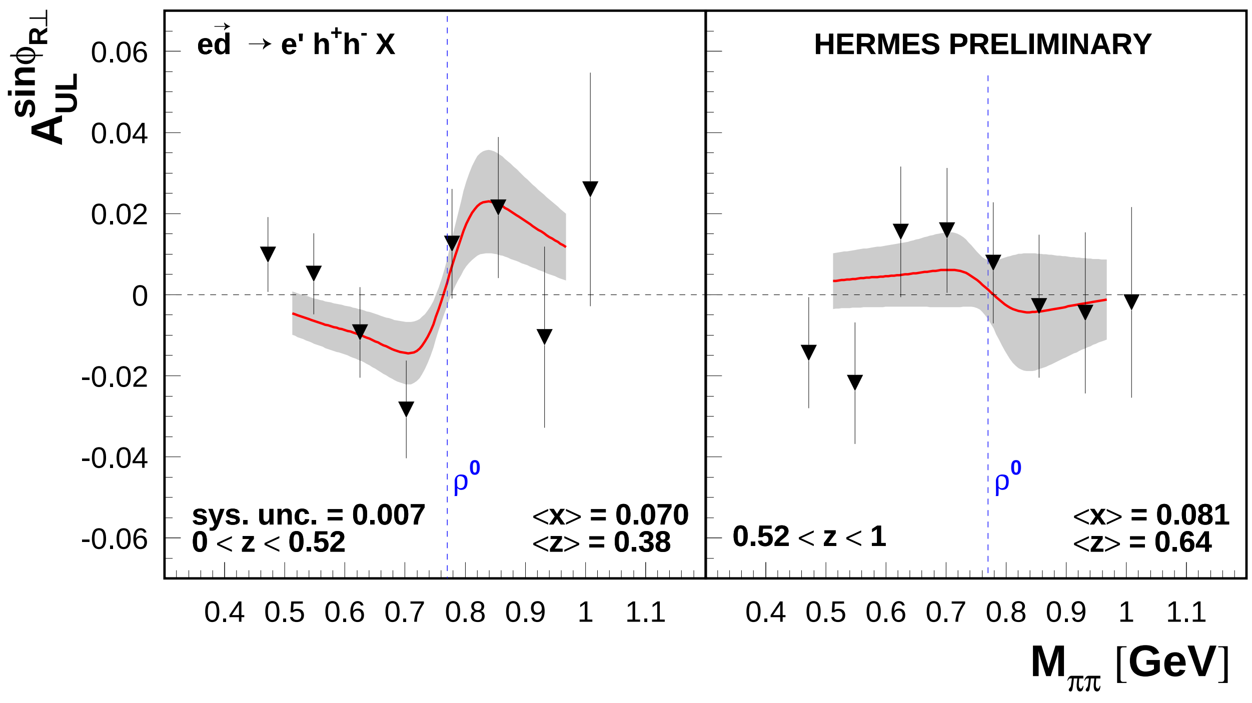
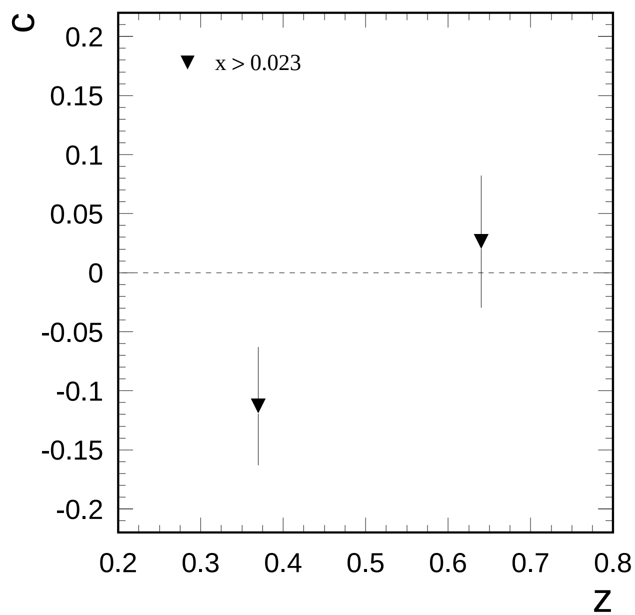
z-dependence





- sign change at ρ^0 according to Jaffe's model for low z
- $c_1(z) \propto H_1^{\sphericalangle,sp}(z, M_{\pi\pi})$?

h1

Conclusions & Outlook

Conclusions:

- Presented fi rst measurement of $A_{UL}^{\sin\phi_{R\perp}}$
- Asymmetries of order $\sim 2\%$, but also consistent with zero
- $M_{\pi\pi}$-dependence consistent with model by Jaffe et al.
- Comparison with model prediction hints at x and z dependence
  $\Longrightarrow$ sensitive to $h_1(x)H_1^{\sphericalangle,sp}(z, M_{\pi\pi})$?

Outlook:

- extract $A_{UL}^{\sin\phi_{R\perp}\,\sin 2\Theta}$ $\Longrightarrow$ relates to $h_1 H_1^{\sphericalangle,pp}$

Outlook to $A_{UT}^{\sin\phi_{R\perp}}$:

- comparable error bars:
- much larger transverse target polarization $\rightarrow$ $\sim$1/0.045 $= 22$ times bigger!

h_1