Beam-Spin Azimuthal Asymmetries in Pion Electroproduction at HERMES

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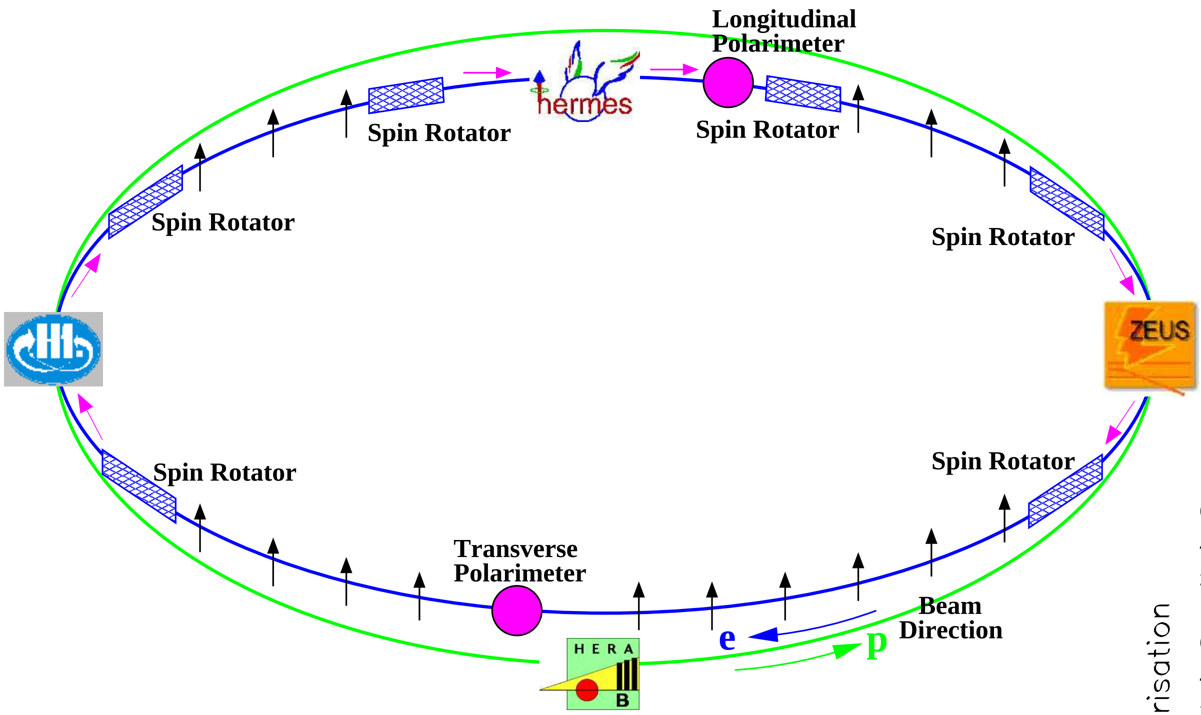
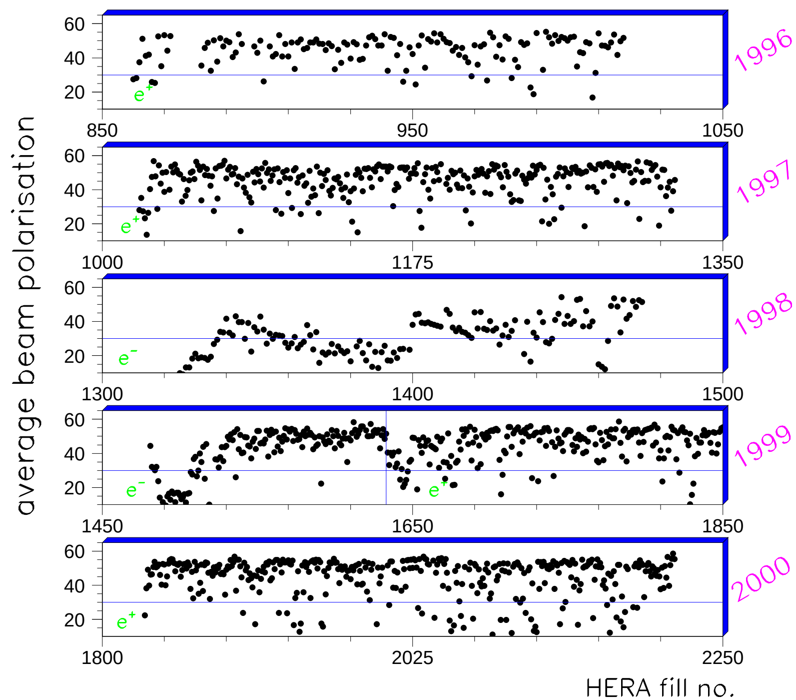
Eduard Avetisyan

eduard.avetisyan@desy.de

(Yerevan Physics Institute / INFN Frascati)

HERA setup:



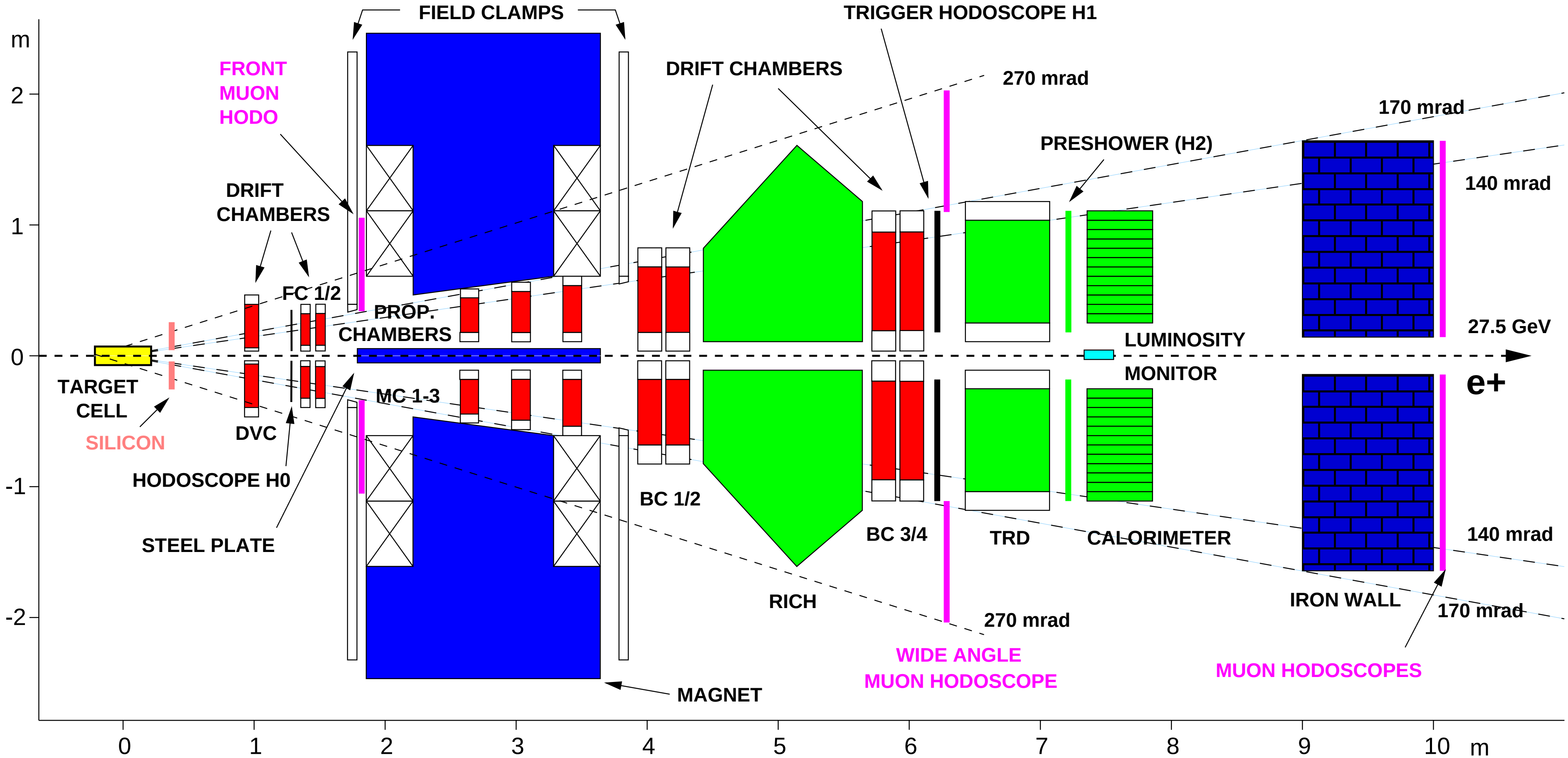


HERA-e beam self-polarized due to emission of synchrotron radiation

$\Rightarrow$ **Sokolov-Ternov effect**

$< \mathbf{P_{beam}} > \simeq \mathbf{55\%}$

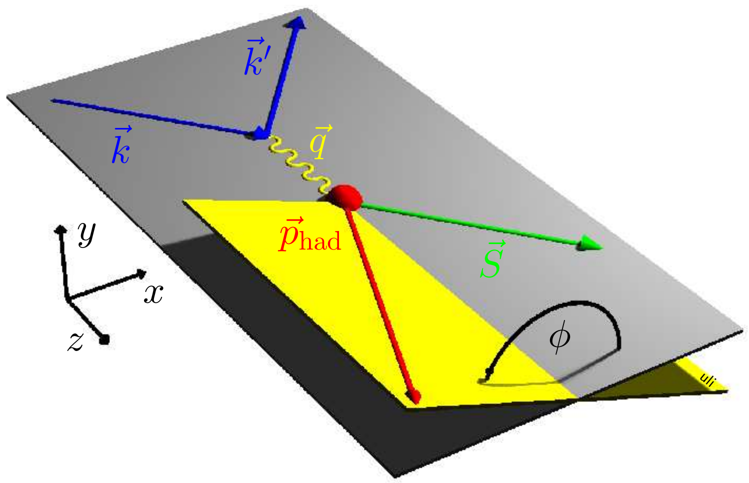
HERMES Spectrometer:



$$\mathrm{e} + \mathrm{p} \rightarrow \mathrm{e}'\mathrm{X} \quad \Longleftrightarrow \quad \mathrm{e} + \mathrm{p} \rightarrow \mathrm{e}'\mathrm{hX}$$

Semi Inclusive DIS:

$\vec{e}p \rightarrow e'hX$



$$
\begin{aligned}
Q^2 &= 4EE'\sin^2(\tfrac{\theta}{2}) \\
\nu &= E - E' \\
x &= \frac{Q^2}{2m\nu} \\
y &= \frac{\nu}{E} = \frac{p\cdot q}{p\cdot k} \\
z &= \frac{E_h}{\nu} \\
cos\phi &= \frac{[\vec{q}\times\vec{k}][\vec{q}\times\vec{P}_h]}{|\vec{q}\times\vec{k}||\vec{q}\times\vec{P}_h|}
\end{aligned}
$$

$$
\begin{aligned}
\sigma(\phi) &= A_0 + A_1\sin\phi + B_1\cos\phi + A_2\sin 2\phi + B_2\cos 2\phi \ldots \\
\frac{\mathrm{d}^3\sigma_{UU}}{\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z\,\mathrm{d}\phi} &= \frac{1}{2}\left(\frac{\mathrm{d}^3\sigma^+}{\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z\,\mathrm{d}\phi} + \frac{\mathrm{d}^3\sigma^-}{\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z\,\mathrm{d}\phi}\right) \\
\frac{2}{P}\,\frac{\mathrm{d}^3\sigma_{LU}}{\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z\,\mathrm{d}\phi} &= \frac{1}{P^+}\,\frac{\mathrm{d}^3\sigma^+}{\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z\,\mathrm{d}\phi} - \frac{1}{P^-}\,\frac{\mathrm{d}^3\sigma^-}{\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z\,\mathrm{d}\phi}
\end{aligned}
$$

DFs and FFs:

Factorization $\Rightarrow$ $\sigma^{eH\to ehX} = \sum f^{H\to q} \otimes \sigma^{eq\to eq} \otimes D^{q\to h}$

$\Downarrow$ **Distribution** — $\Downarrow$ **Fragmentation**

$$\sigma_{unpol} \equiv \sigma_{UU} \propto (1-y+y^2/2)\sum_{a,\bar{a}} e_a^2 x f_1^a(x) D_1^a(z)$$

KNOWN!

$$\sigma_{pol} = \{\sigma_{UL}, \sigma_{LL}, \sigma_{UT}, \sigma_{LU}, \sigma_{LT}\}$$

Beam Target polarization

$$\sigma_{UL} \propto S_L \sin\phi\,(2-y)\sqrt{1-y}\frac{M}{Q}\sum_{a,\bar{a}} e_a^2 x^2 h_L^a(x) H_1^{\perp a}(z)$$

$$\sigma_{UT} \propto S_T(1-y)\sin(\phi+\phi_s)\sum_{a,\bar{a}} e_a^2 x h_1^a(x) H_1^{\perp a}(z)$$

$$\sigma_{LU} \propto \lambda_e \sin\phi\, y\sqrt{1-y}\frac{M}{Q}\sum_{a,\bar{a}} e_a^2 x^2 \left[e^a(x) H_1^{\perp a}(z) + h_1^{\perp a}(x) E^a(z)\right]$$

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Asymmetries:

$$A_{LU} = \frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-} = \frac{d\sigma_{LU}}{d\sigma_{UU}}$$

$$A_{LU} \propto \frac{e(x)H_1^\perp(z) + h_1^\perp(x)E(z)}{f_1(x)D_1(z)}$$

	Distribution	Fragmentation
Twist-2	$h_1^\perp$	$H_1^\perp$
Twist-3	e	E

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NEWS FROM THEORY!

$$\sigma_{LU} \propto \lambda_e \sin\phi\, y\sqrt{1-y}\frac{M}{Q}\sum_{a,\bar{a}} e_a^2 x^2 \Big[xz e^a(x) H_1^{\perp a}(z) + h_1^{\perp a}(x) E^a(z) + $$

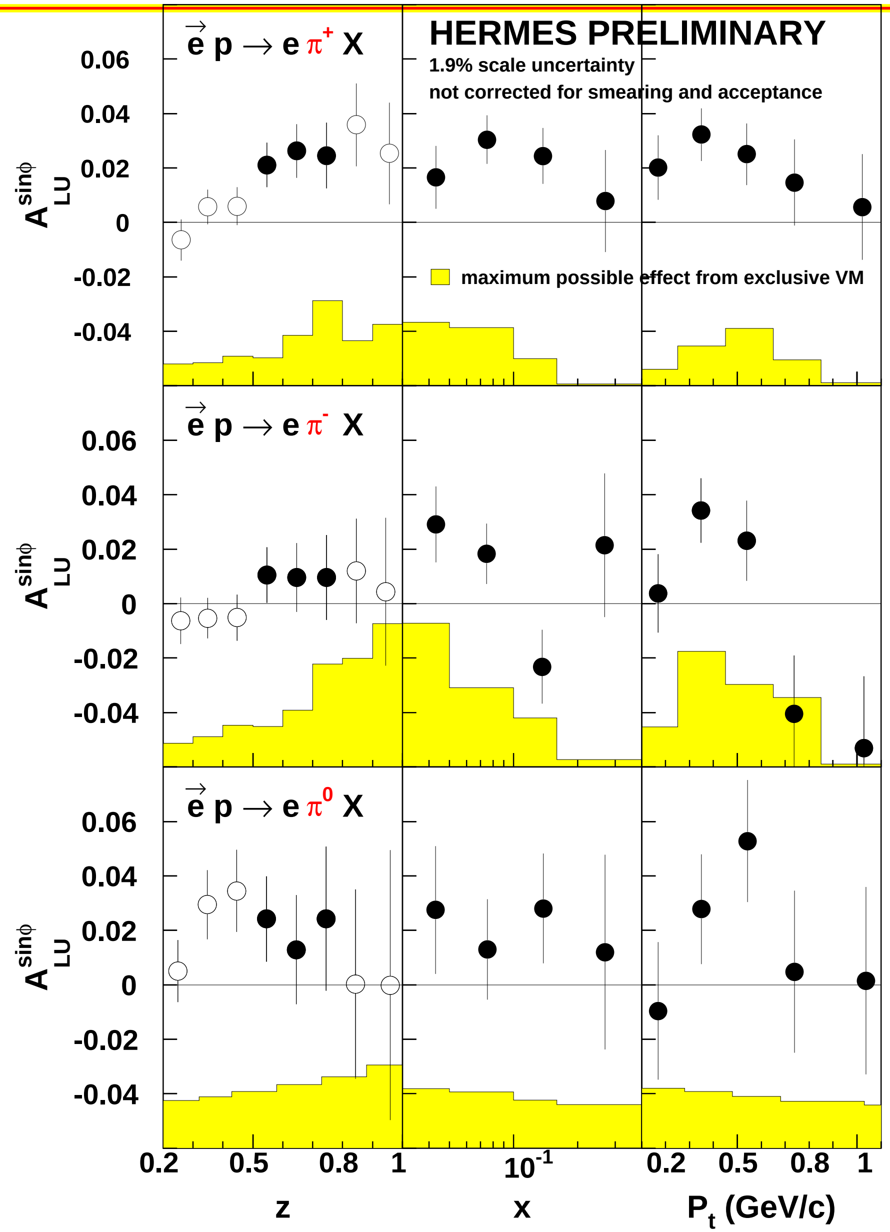
$$+ \frac{M_h}{M} f_1^a(x) G^{\perp a}(z) - xz\frac{M}{M_h} g^{\perp a}(x) D_1^a(z) -$$

$$- \frac{m}{M} z f_1^a(x) H_1^{\perp a}(z) - \frac{m}{M_h} z h_1^{\perp a}(x) D_1^a(z) \Big]$$

Beam SSA at HERMES

Asymmetry extraction:

$$A_{LU}^{\pm} = \frac{1}{P^{\pm} N^{\pm}} \sum_{i=1}^{N^{\pm}} \sin\phi$$



Beam SSA at HERMES

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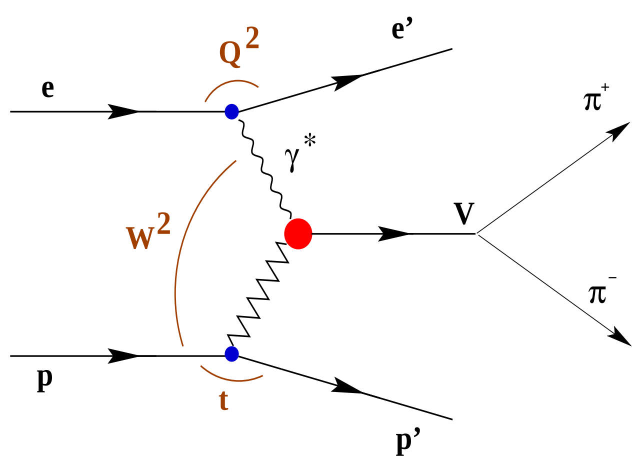
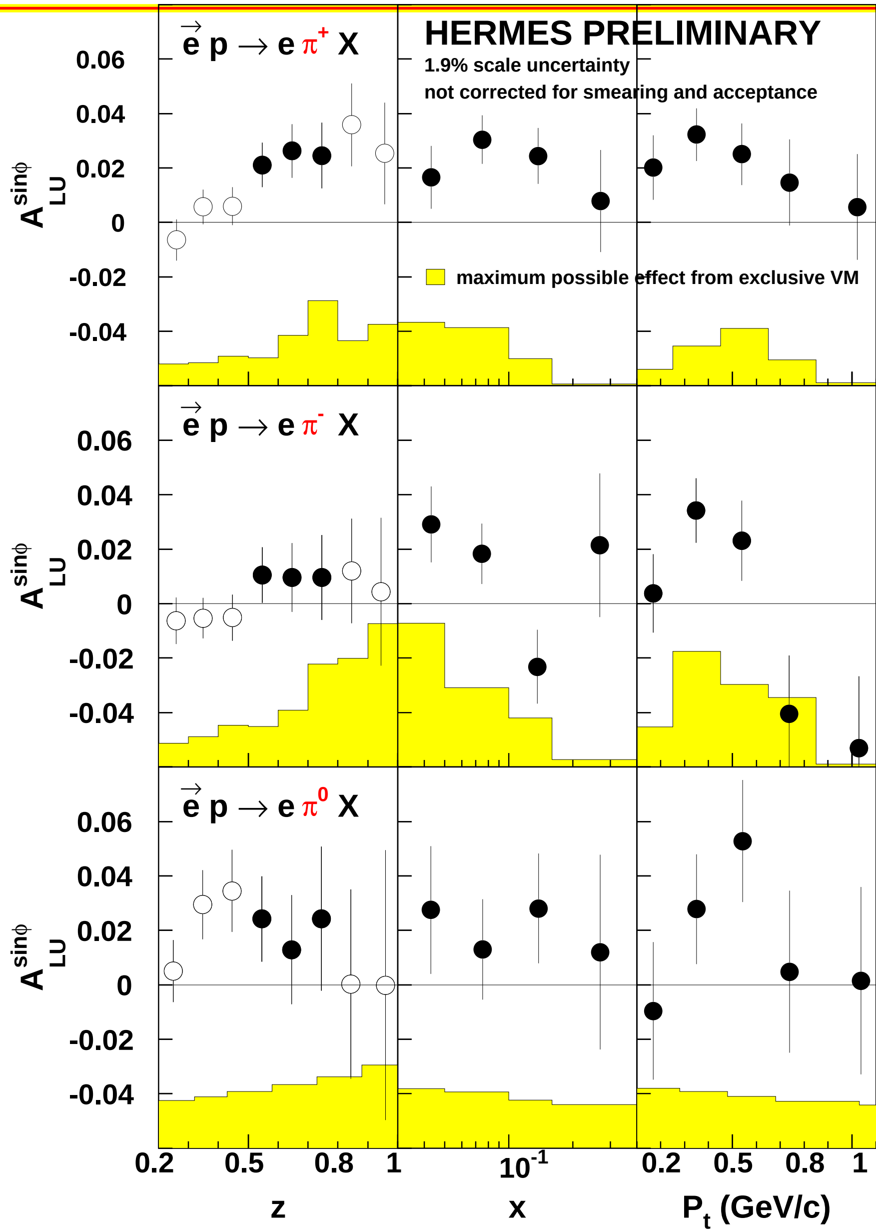
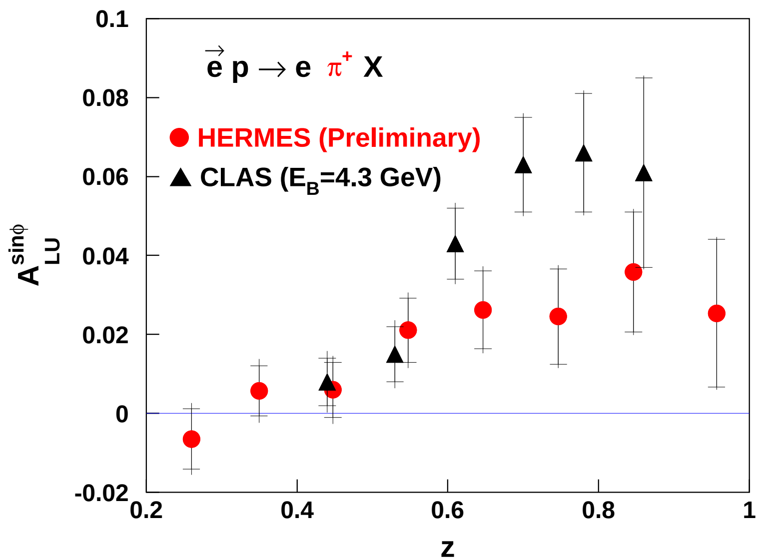
Systematic error from VM

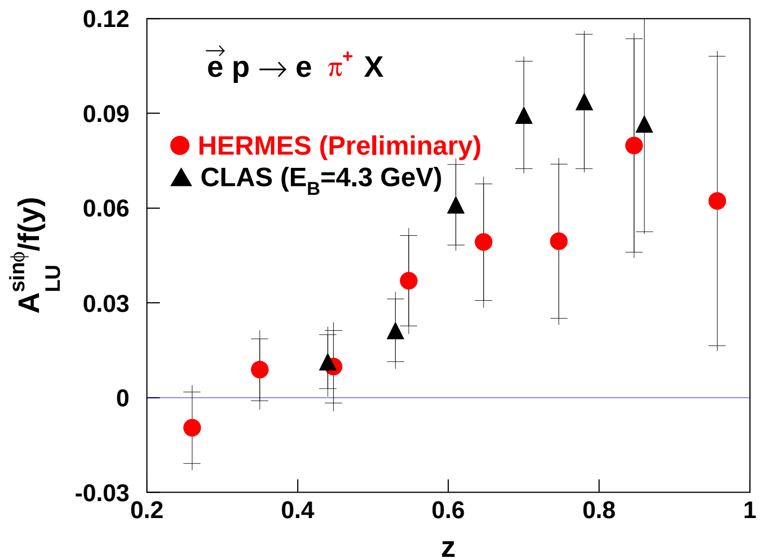


estimated from Monte-Carlo.



Comparison with CLAS:



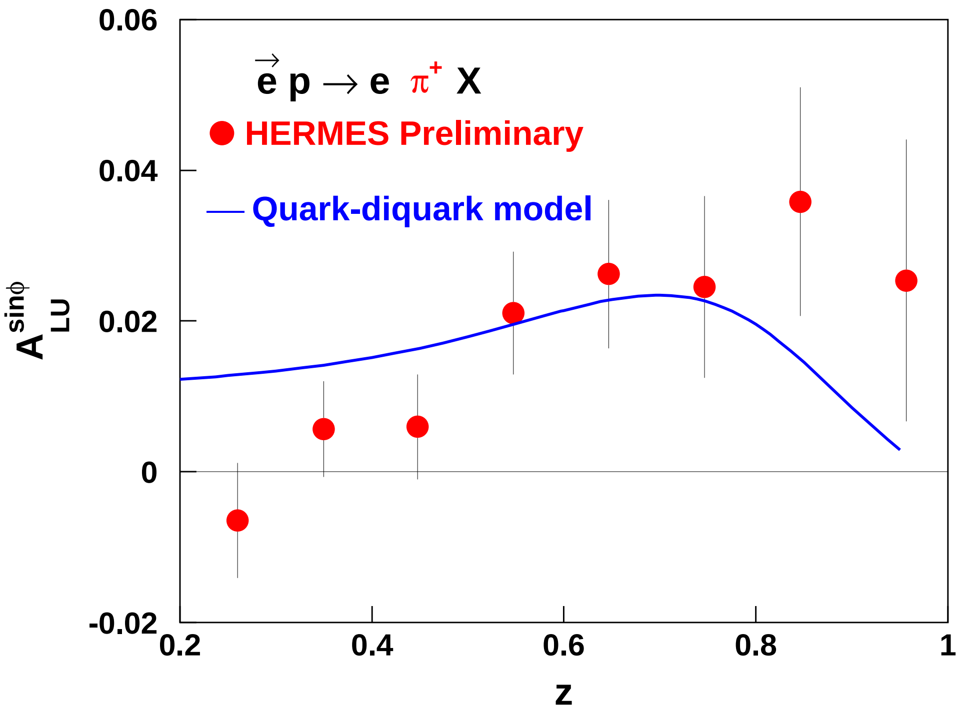


In leading order (neglecting σ_L/σ_T):

$$f(y) = \frac{\sqrt{2(1-y)}}{1-y+y^2/2}$$

Strong kinematic suppression factor in HERMES ($0.7 \rightarrow 0.35$ at higher z) roughly constant $(f(y) \simeq 0.7)$ in CLAS.

Comparison with Theory:



Average kinematics:

$< P_T >= 0.45 GeV$

$< Q^2 >= 2.4 GeV^2$

L.Gamberg, D.Hwang, K.Oganessyan, hep-ph/0311221, Phys. Lett. B584 (2004) 276.

Quark-diquark spectator model prediction for A_{LU} at HERMES kinematics.

Conclusion:

- First measurement of beam-spin asymmetry for all pions
- Independent source of information about $H_1^{\perp}$ Collins function
- Possibility to access a set of new DFs and FFs
- Agreement with CLAS measurement of BSA for π^+ (after kinematic range corrections)
- Agreement with theoretical model calculation