MEASUREMENTS of DVCS at HERMES

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on behalf of the
HERMES Collaboration

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- Beam-spin asymmetry results on H, D, Ne and Kr targets
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- Lepton Charge Asymmetry results on H target
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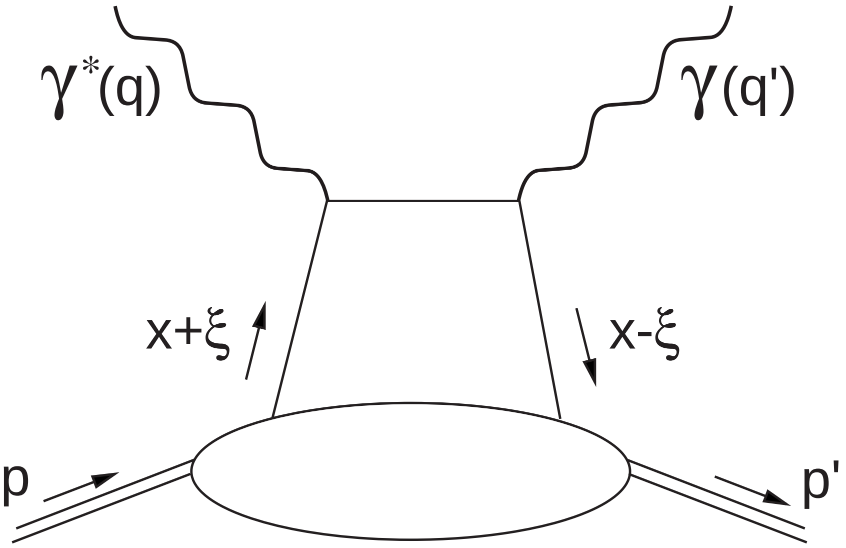
DVCS Handbag Diagram



- **In hard regime DVCS process factorizes**
- **In the off-forward domain described by new functions:** H, $\widetilde{H}$, E, $\widetilde{E}$

GPD's - General Formalism

- The functions H, $\widetilde{H}$, E, $\widetilde{E}$ depend upon three variables: **x, ξ, t.**

- Where the light-cone momentum fraction is defined by k^+ = xP^+, ξ = -Δ^+/2P^+ (Δ = P' - P) and -t = Δ^2.

- In the Bjorken limit 2$\xi \rightarrow x_{Bj}$/(1-x_{Bj}/2).

- E, $\widetilde{E}$ are new functions **vanishing at t$\rightarrow 0$ limit** of DIS

- In the limit of $\xi \rightarrow 0$ and t$\rightarrow 0$ H and $\widetilde{H}$ reduce to the ordinary parton distributions:

$$H(x, 0, 0) = q(x)$$
$$\widetilde{H}(x, 0, 0) = \Delta q(x)$$

GPD's - General Formalism

Integration over x gives the following sum rules:

$$\int_{-1}^{1} dx H(x, \xi, t) = F_1(t)$$

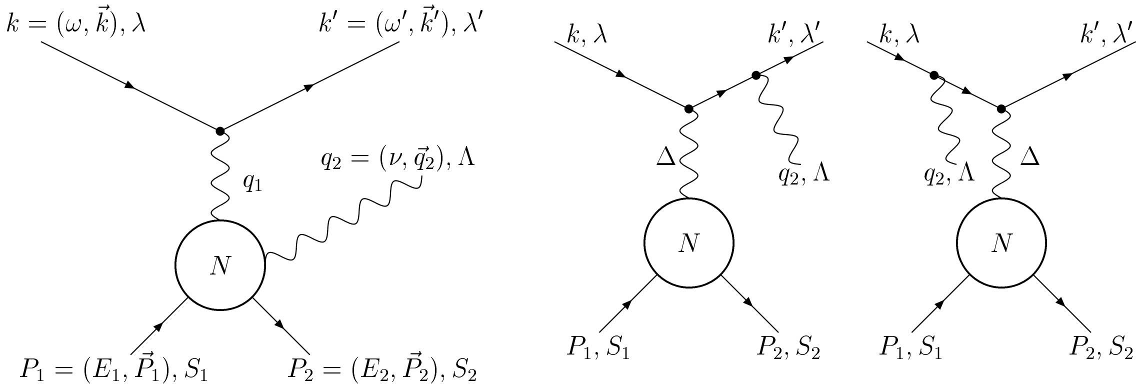
$$\int_{-1}^{1} \mathbf{dxE(x, \xi, t) = F_2(t)}$$

$$\int_{-1}^{1} \mathbf{dx\widetilde{H}(x, \xi, t) = G_A(t)}$$

$$\int_{-1}^{1} \mathbf{dx\widetilde{E}(x, \xi, t) = G_P(t),}$$

where F_1 and F_2 are the Dirac and Pauli form factors and G_A and G_P are the axial-vector and pseudo-scalar form factors.

DVCS and Bethe-Heitler



(a) (b)

Two different subprocesses have the same initial and final states

Therefore DVCS and BH subprocesses interfere!

Cross Sections and Amplitudes

Cross section for electro-production of real photons formally looks like:

$$d\sigma \sim |\tau_{BH} + \tau_{DVCS}|^2 = |\tau_{BH}|^2 + |\tau_{DVCS}|^2 + I$$

I **is the interference term**

$$I = \tau^*_{BH}\tau_{DVCS} + \tau^*_{DVCS}\tau_{BH}$$

Leading beam-spin dependent part looks as

$$I \sim e_l h_l sin\,(\phi) \cdot ImA$$

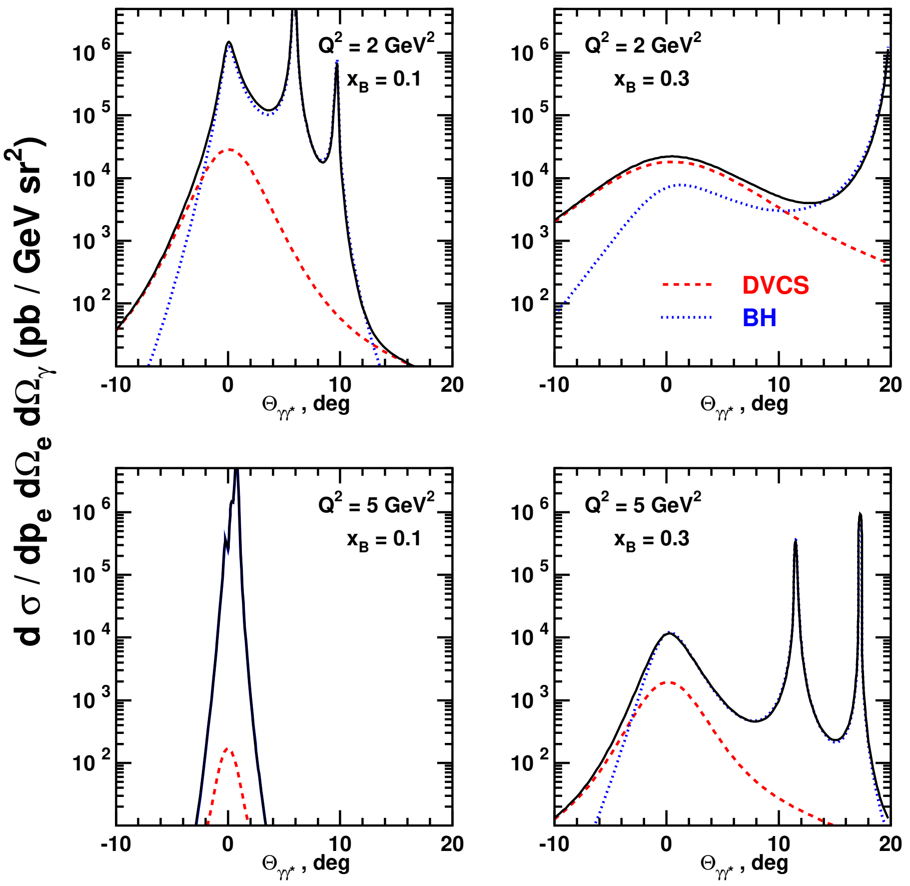
Leading beam-charge dependent part looks as

$$I \sim e_l cos\,(\phi) \cdot ReA$$

where e_l,h_l **are lepton charge and helicity**

DVCS and BH Cross Sections

In-plane differential cross-sections for the DVCS and BH at E = 27.5 GeV beam energy:



The cross-section of DVCS is smaller than that of BH in the whole kinematical region

Unpolarized Target

Following A.V. Belitsky, D. Müller, L. Niedermeier and A. Schäfer (hep-ph/0004059)

1. Polarized beam :

$$d\sigma \equiv d\sigma^{\uparrow} - d\sigma^{\downarrow} \sim \sin(\phi) \times \mathrm{Im}\left\{ F_1\mathcal{H}_1 + \frac{x}{2-x}(F_1+F_2)\widetilde{\mathcal{H}}_1 - \frac{\Delta^2}{4M^2}F_2\mathcal{E}_1 \right\}$$

2. Charge asymmetry in unpolarized experiment:

$$d\sigma \equiv d^{+}\sigma^{\mathrm{unp}} - d^{-}\sigma^{\mathrm{unp}} \sim \cos(\phi) \times \mathrm{Re}\left\{ F_1\mathcal{H}_1 + \frac{x}{2-x}(F_1+F_2)\widetilde{\mathcal{H}}_1 - \frac{\Delta^2}{4M^2}F_2\mathcal{E}_1 \right\}$$

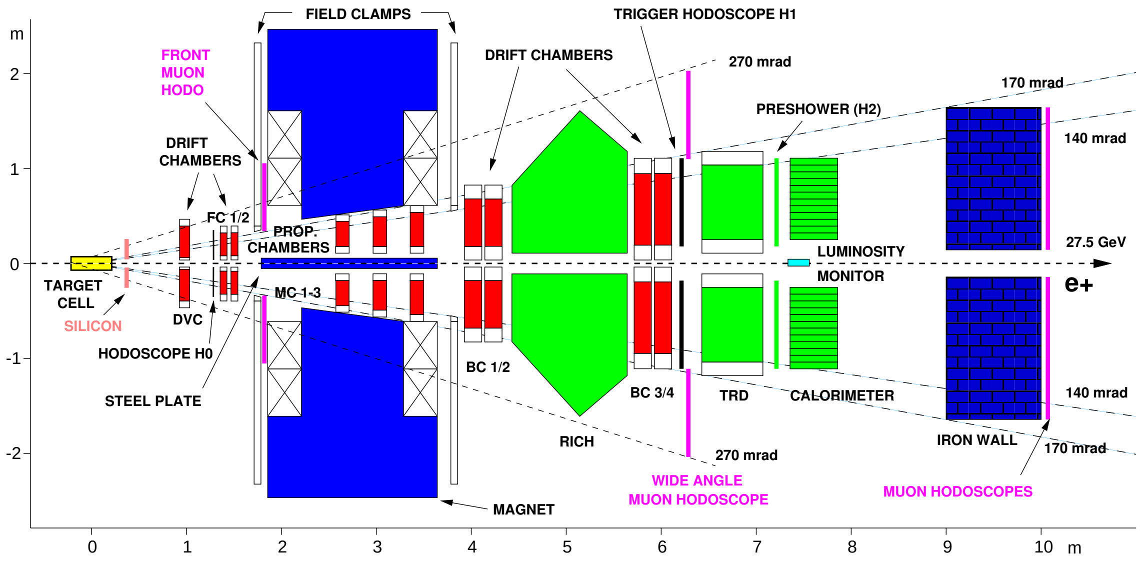
Unpolarized Beam

3. Longitudinally polarized target:

$$d\sigma \equiv d\sigma_{\uparrow} - d\sigma_{\downarrow} \sim \sin(\phi) \times \mathrm{Im}\left\{ F_1 \widetilde{\mathcal{H}}_1 \right.$$

$$\left. + \frac{x}{2-x}(F_1 + F_2)\mathcal{H}_1 + \frac{x}{2-x}\left(\frac{x}{2}F_1 + \frac{\Delta^2}{4M^2}F_2\right)\widetilde{\mathcal{E}}_1 \right\}$$

The HERMES Spectrometer

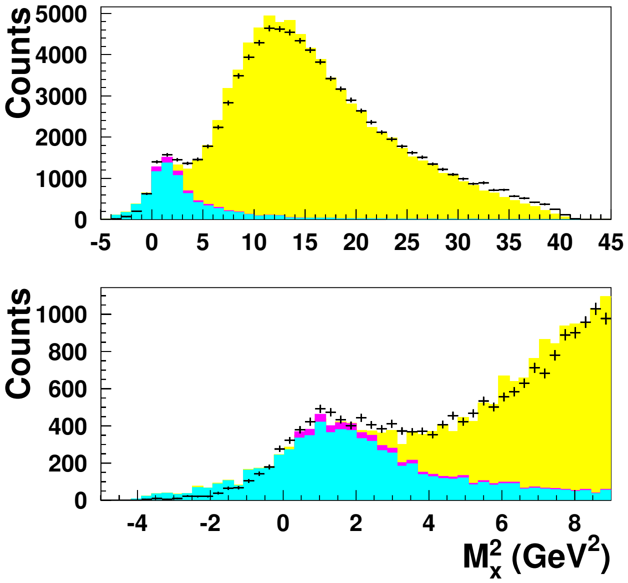


- **Polarized positrons of energy 27.5 GeV in the HERA storage ring with $P_B \sim 0.5$**
- **Forward spectrometer (0.04 $< \theta <$0.22) rad.**
- **Particle ID: RICH (Threshold Cherenkov), TRD, Preshower, Lead Glass Calorimeter**
- **Track reconstruction: $\delta P/P = 0.7 \div 1.3(2.6)\%$, $\delta\theta \leq$0.6 mrad.**

Event Selection

- **H, D(polarized and unpolarized), Ne and Kr targets**
- **Only one track -scattered positron e^+ in spectrometer**
- **Only one cluster in calorimeter without associated track**
- $W^2 > 4\ \mathrm{GeV}^2$**,** $Q^2 > 1\ \mathrm{GeV}^2$**,** $\nu < 24$ **GeV**
- **Opening Angle** $\Theta_{\gamma^*\gamma} < 0.070\ rad.$

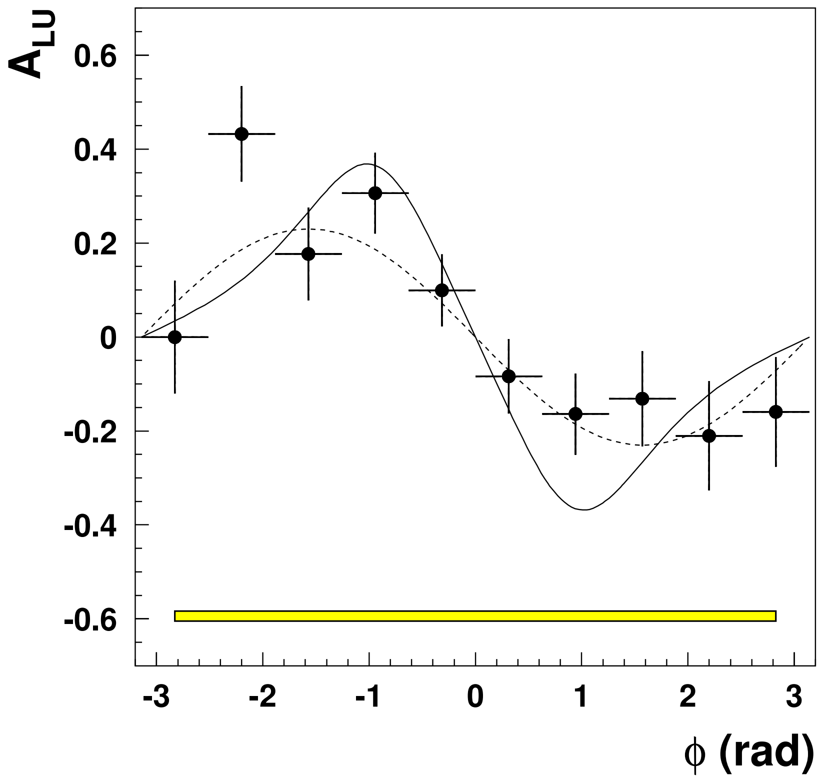
Electroproduction of Photons



$M_x^2 = (q - P_\gamma + P_p)^2$

- Cross points are data
- Blue color shows contribution from BH for N-N transition
- Pink color shows contribution from BH for N-Δ transition
- Yellow histogram shows contribution from decay of neutral mesons

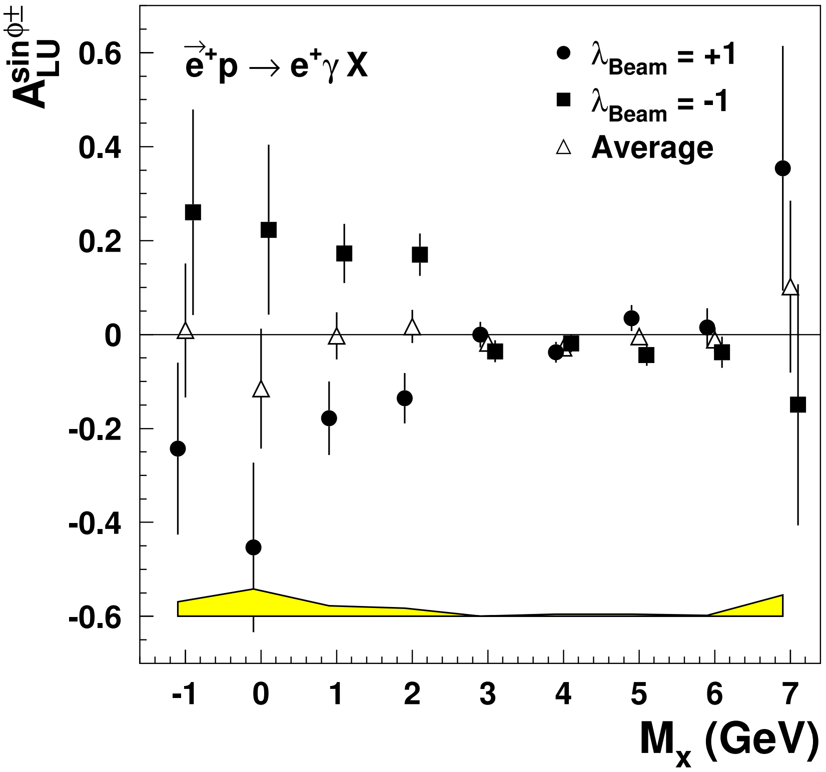
Single Spin Azimuthal Asymmetry



$$A_{LU}(\phi) = \frac{1}{\langle|P_l|\rangle} \cdot \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi))}$$

$N^{+(-)}$ – luminosity-normalized yields of events $-1.5 < M_x < 1.7$ GeV: 4015 events
$A_{LU}(\phi)$ = - 0.23 $\pm$0.04(stat.)$\pm$0.03(syst.)
Solid curve is the result of GPD calculation including twist-3 effects (N.Kivel, M.Polyakov, M.Vanderhaeghen, hep-ph/0012136)

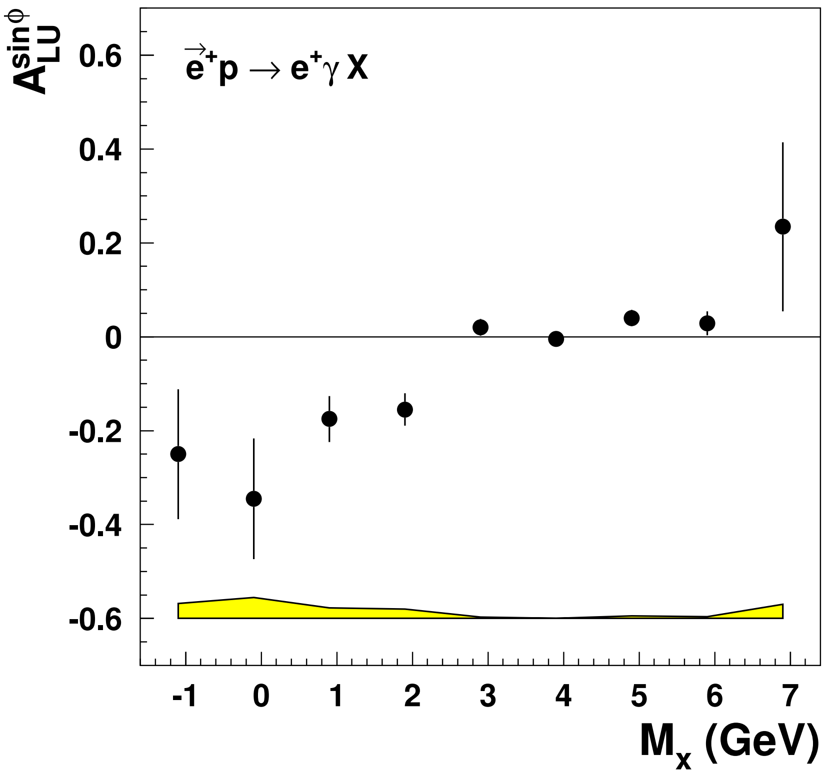
Sin-ϕ Moments versus M_x



The sin(ϕ) moment is defined as:

$$\frac{2 < sin\phi >_{LU}}{< |P_B| >} = \frac{2 \int_0^{2\pi} d\phi \, (d\sigma/d\phi) \, sin(\phi)}{< |P_b| > \int_0^{2\pi} d\phi \, (d\sigma/d\phi)}$$

Combined Sinϕ Moments versus M_x

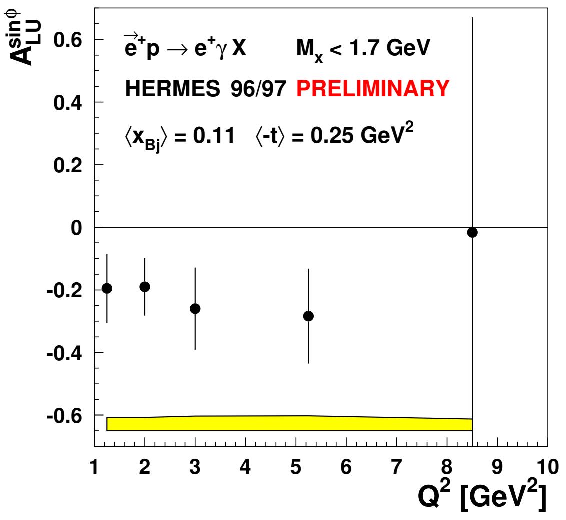


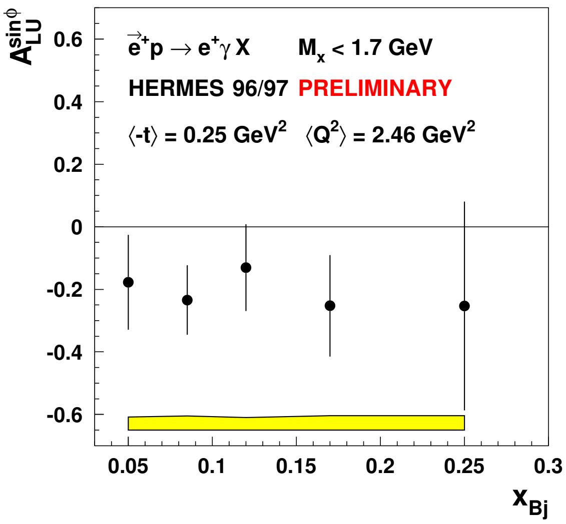
For combined lepton-helicity states:

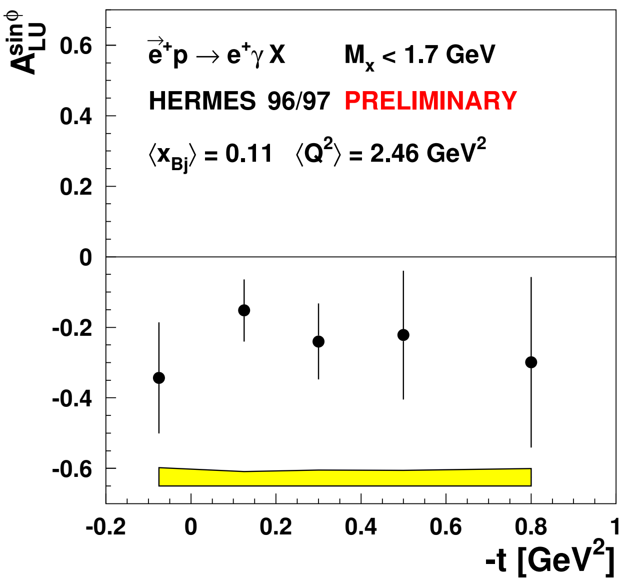
$$A_{LU}^{sin\phi} = \frac{2\int_0^{2\pi} d\phi\ (d\sigma^+/d\phi - d\sigma^-/d\phi)\ sin(\phi)}{<|P_b|> \int_0^{2\pi} d\phi\ (d\sigma^+/d\phi + d\sigma^-/d\phi)}$$

where $^{+,-}$ superscripts are for parallel and anti-parallel helicities of incoming lepton beam

Sin-ϕ Moments versus Q^2, x and -t

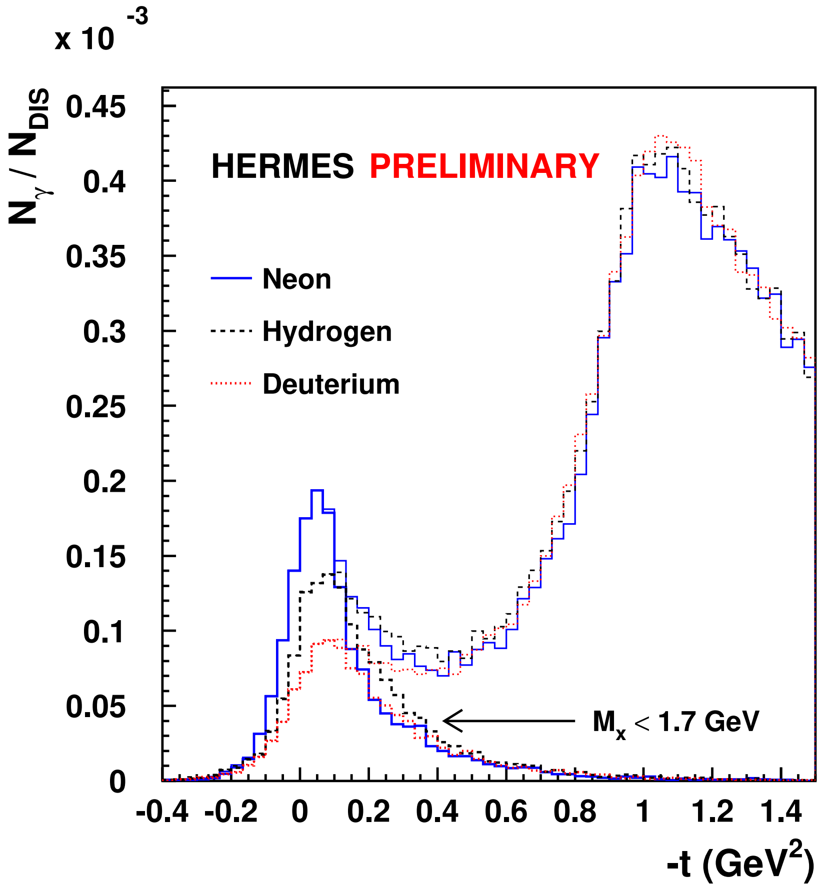






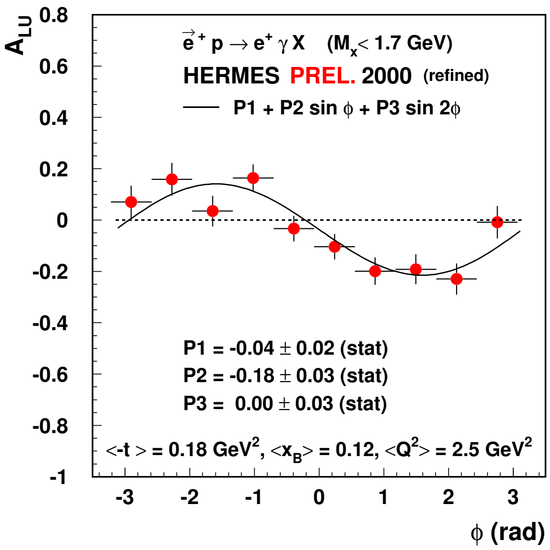
Q^2, x and t dependences of A$_{LU}$ are weak within HERMES kinematical range

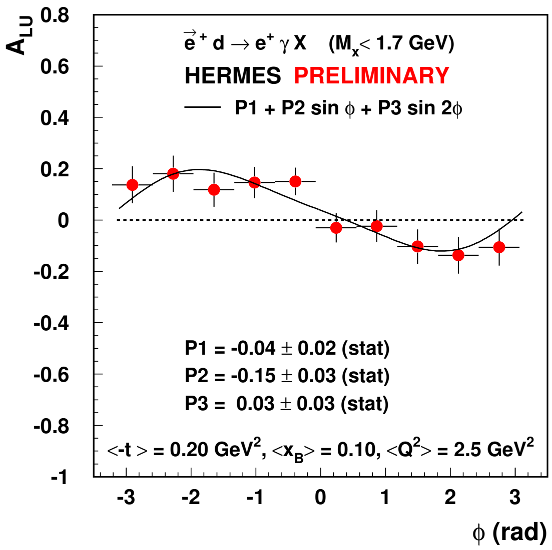
Normalized Yield for H, D, Ne Targets

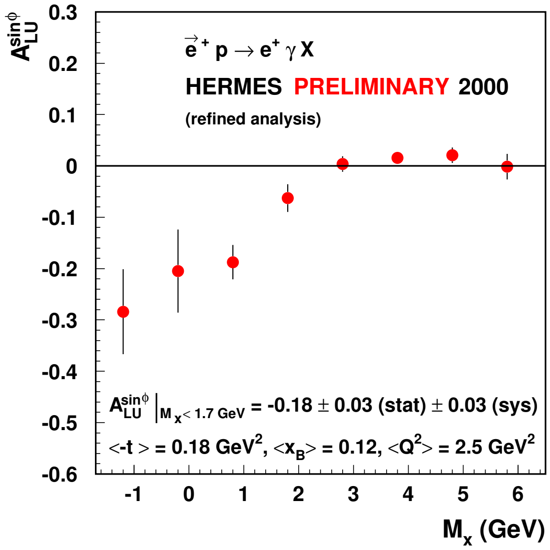


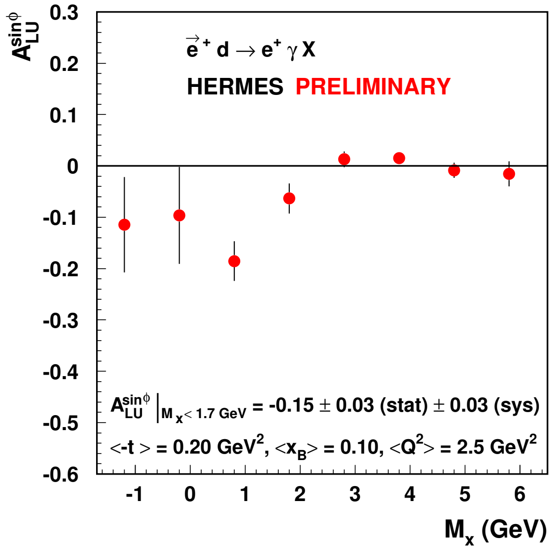
Prominent peak on Ne is due to coherent BH process

BSA for H and D Targets

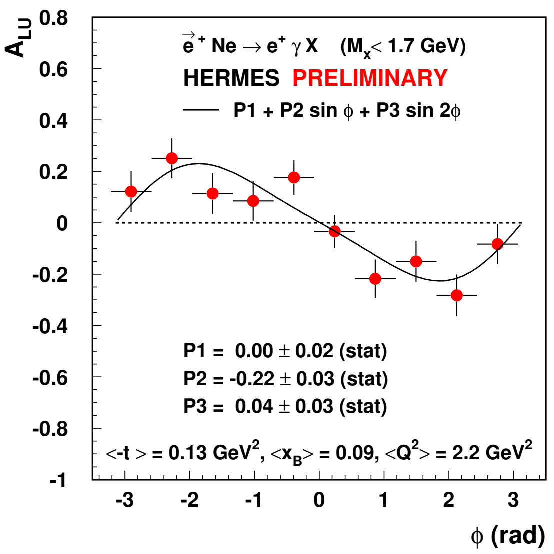


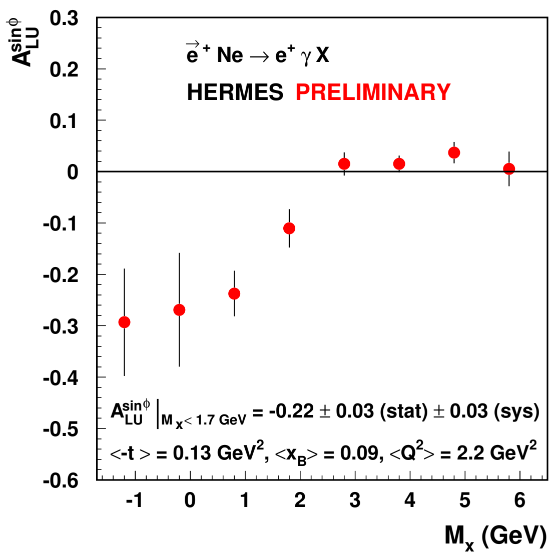


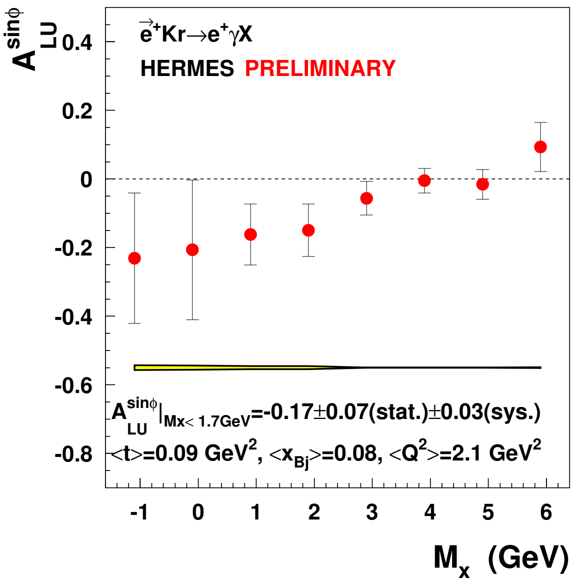




BSA for Ne and Kr Targets

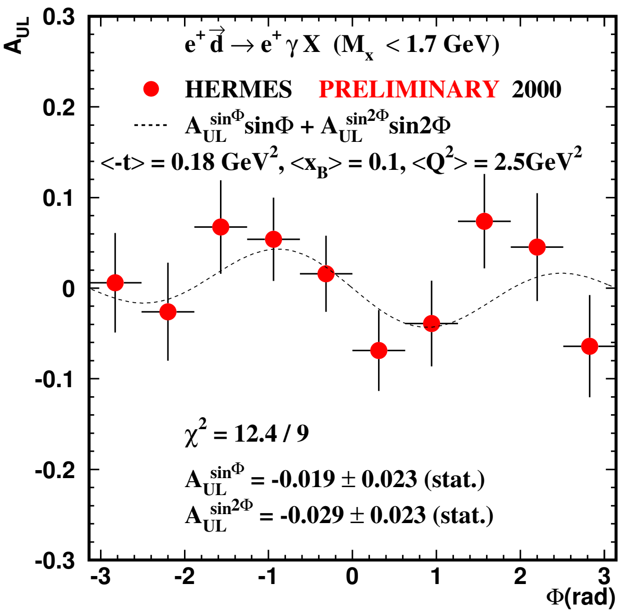


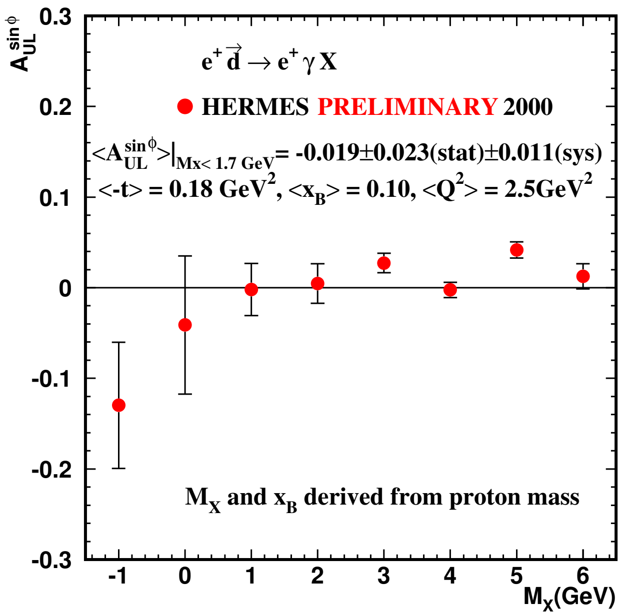




BSA on Ne and H are similar

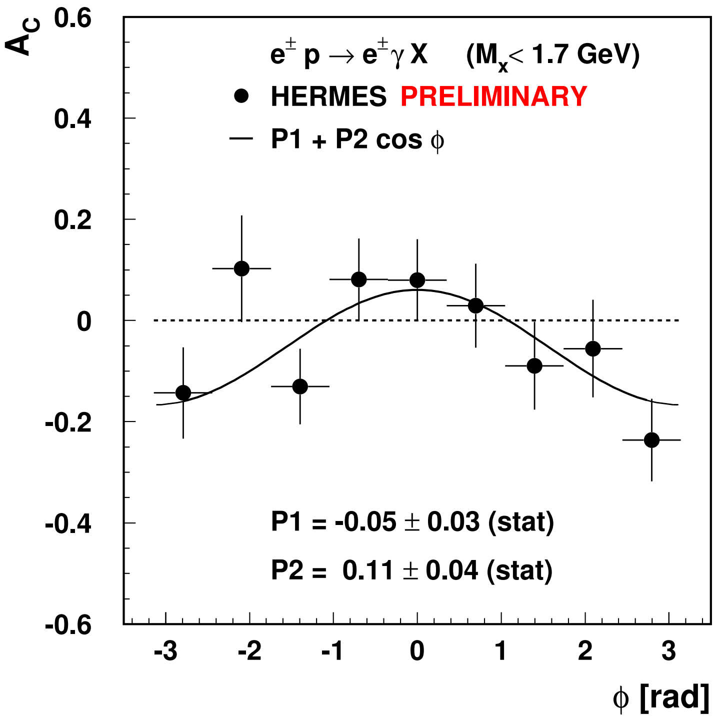
Target-Spin Asymmetry on Deuteron





A_{UL} is small as expected $\sim \tilde{H}$

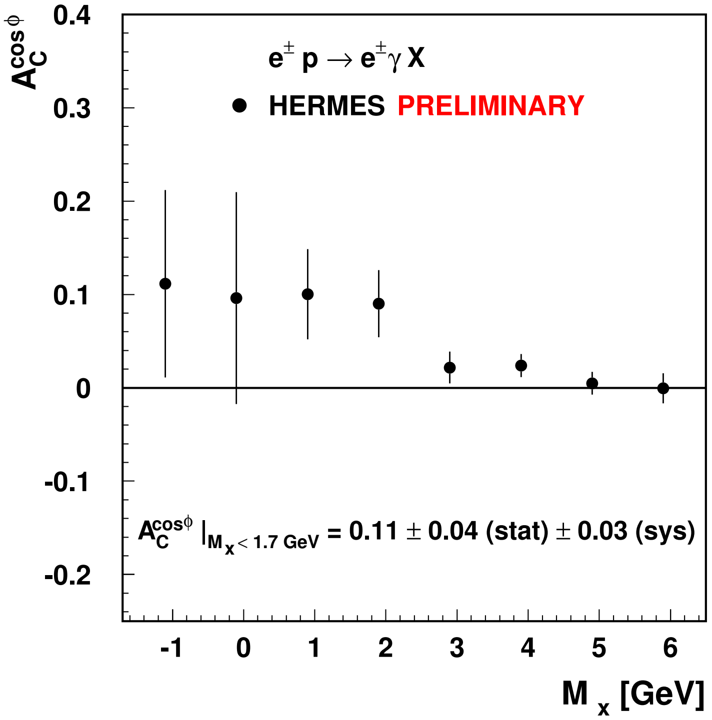
Beam Charge Asymmetry (BCA)



$$A_c(\phi) = \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi))}$$

where $^{+,-}$ superscripts are for positron/electron beam respectively

cosϕ-Moment of BCA



$$A_{LU}^{cos\phi} = \frac{2\int_0^{2\pi} d\phi\ (d\sigma^+/d\phi - d\sigma^-/d\phi)\ cos(\phi)}{\int_0^{2\pi} d\phi\ (d\sigma^+/d\phi + d\sigma^-/d\phi)}$$

where $^{+,-}$ superscripts are for positron/electron beam respectively

OUTLOOK

- **Presented experimental results are based on data collected during 96+97 and 98-00 running periods**

- **Single Beam-Spin Asymmetry is measured for H, D, Ne and Kr targets**

- **Target-Spin Asymmetry is measured on a deuteron (TSA on hydrogen is in progress)**

- **Beam Charge Asymmetry is measured for hydrogen (BCA on deuteron is in progress)**

- **In the long range plan with recoil detector HERMES will improve in statistics and in precision significantly**

- **Hermes experiment is planning to get a first results on different GPD's using HERA polarized beams of e^+/e^- by the end of 2006**