Studies of the Nucleon Spin

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for the HERMES collaboration

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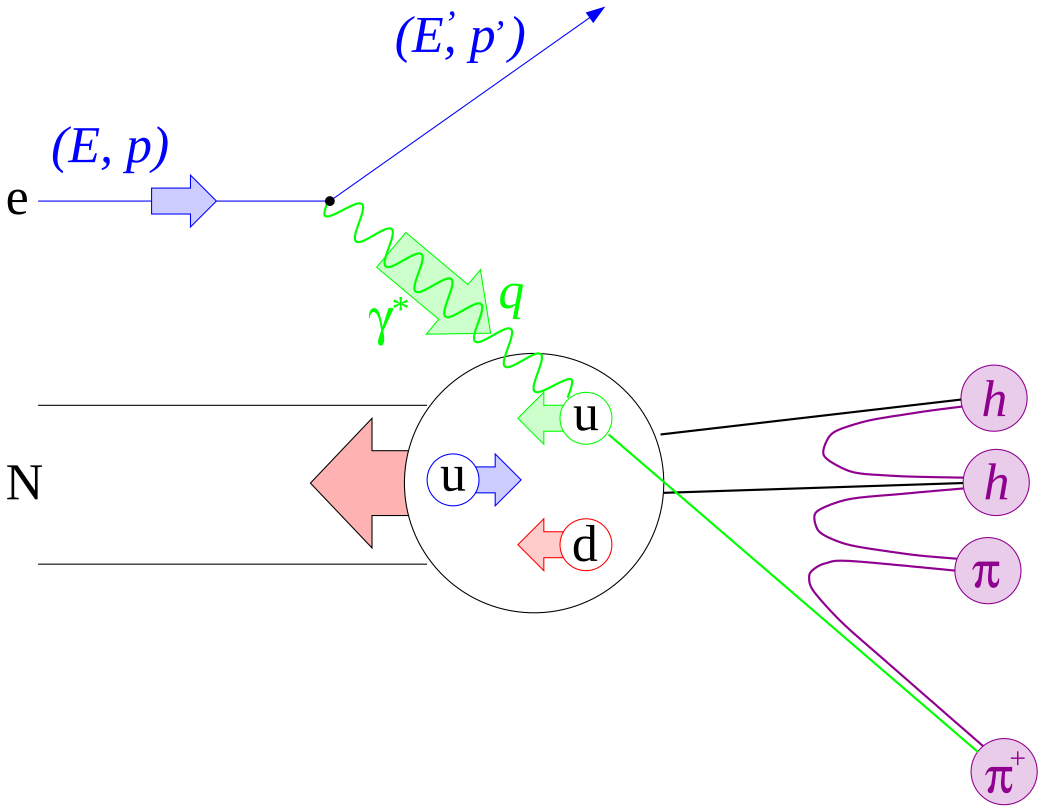
- Introduction: The Nucleon Spin
- Inclusive Measurements
- Semi-Inclusive Measurements
- Exclusive Measurements
- Conclusion and Outlook

Polarised Deep Inelastic Scattering

$$\frac{1}{2} = \frac{1}{2}\,\Delta\Sigma + \Delta G + (L_q + L_g)$$



- Inclusive DIS: $e + N \rightarrow e' + X$

  $$\Delta\Sigma = (\Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} + \Delta s + \Delta\bar{s})$$

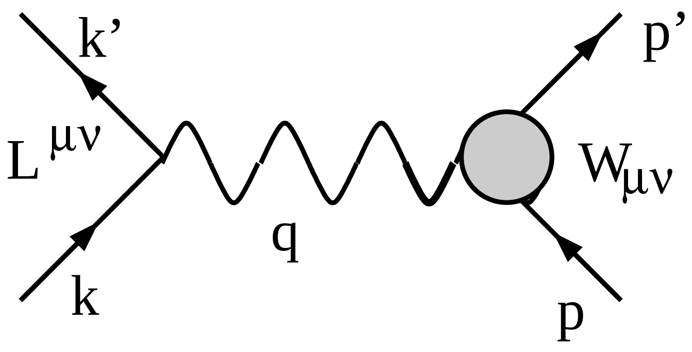
- Semi-inclusive DIS: $e + N \rightarrow e' + h + X$

  $$\Delta u,\ \Delta\bar{u},\ \Delta d,\ \Delta\bar{d},\ \Delta s,\ \Delta\bar{s}$$

- Exclusive, e.g. DVCS: $e + N \rightarrow e' + N' + \gamma$

  $(L_q + L_g)$ **???**

The DIS Cross Section



$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}\Omega\,\mathrm{d}E'} = \frac{\alpha^2}{M\,Q^4}\,\frac{E'}{E}\,L_{\mu\nu}W^{\mu\nu}$$

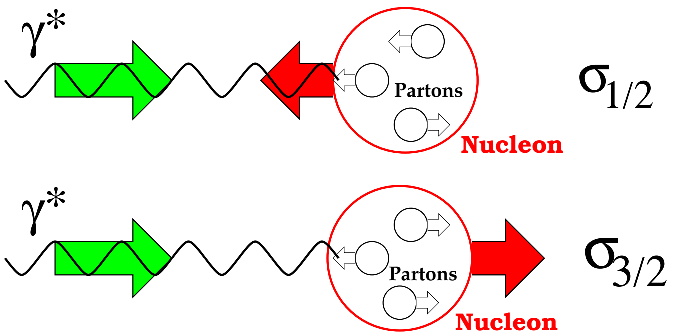
$$\begin{aligned} L_{\mu\nu} =& 2\left[k_\mu k'_\nu + k_\nu k'_\mu - \left(k\cdot k' - m_e^2\right) g_{\mu\nu} \right. \\ & \left. + \, i\, m_e\, \epsilon_{\mu\nu\alpha\beta}\, s^\alpha \left(k - k'\right)^\beta \right] \end{aligned}$$

$$\begin{aligned} W^{\mu\nu} =& - g^{\mu\nu}\, F_1(x,Q^2) \\ & + \frac{p^\mu p^\nu}{\nu}\, F_2(x,Q^2) \\ & + \frac{i}{\nu}\, \epsilon^{\mu\nu\lambda\sigma}\, q_\lambda S_\sigma\, g_1(x,Q^2) \\ & + \frac{i}{\nu^2}\, \epsilon^{\mu\nu\lambda\sigma}\, q_\lambda \left(p\cdot q\, S_\sigma - S\cdot q\, p_\sigma\right)\, g_2(x,Q^2) \end{aligned}$$

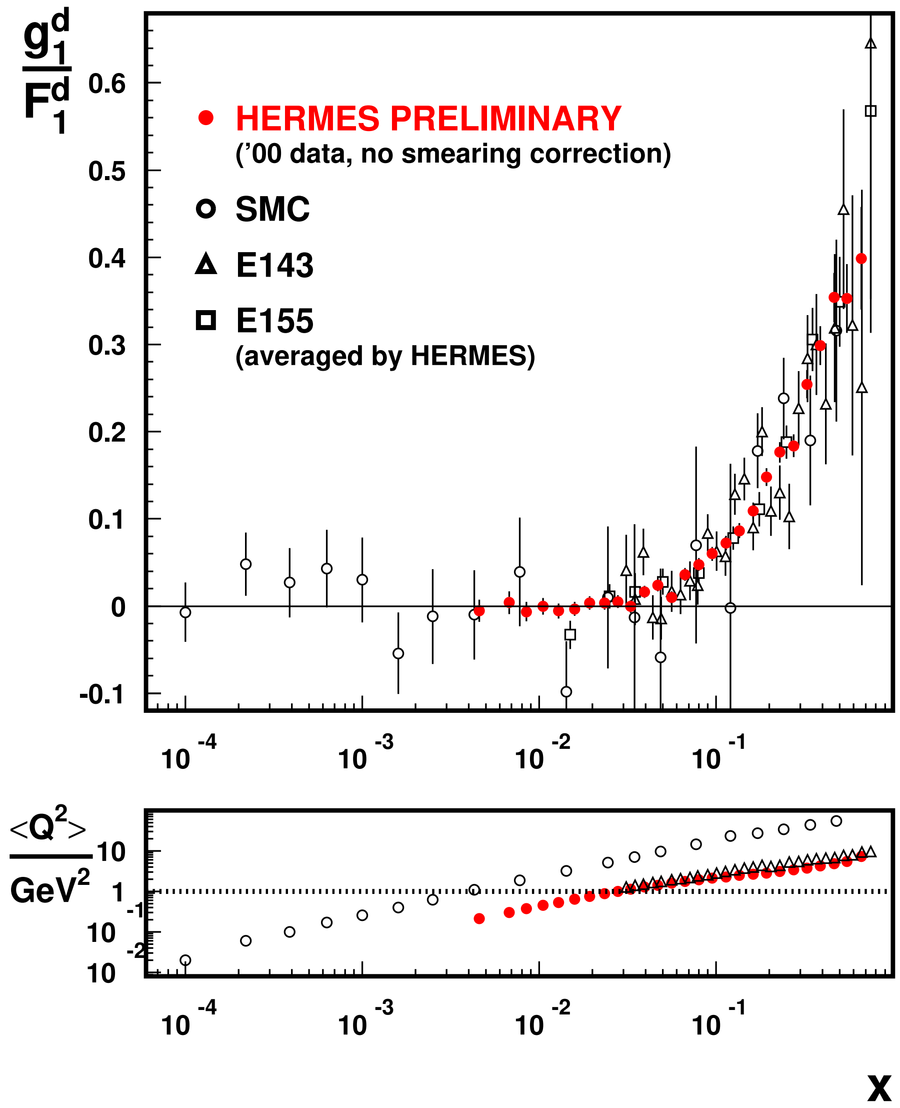
F_1, F_2... Unpolarised Structure Functions

g_1, g_2... Polarised Structure Functions

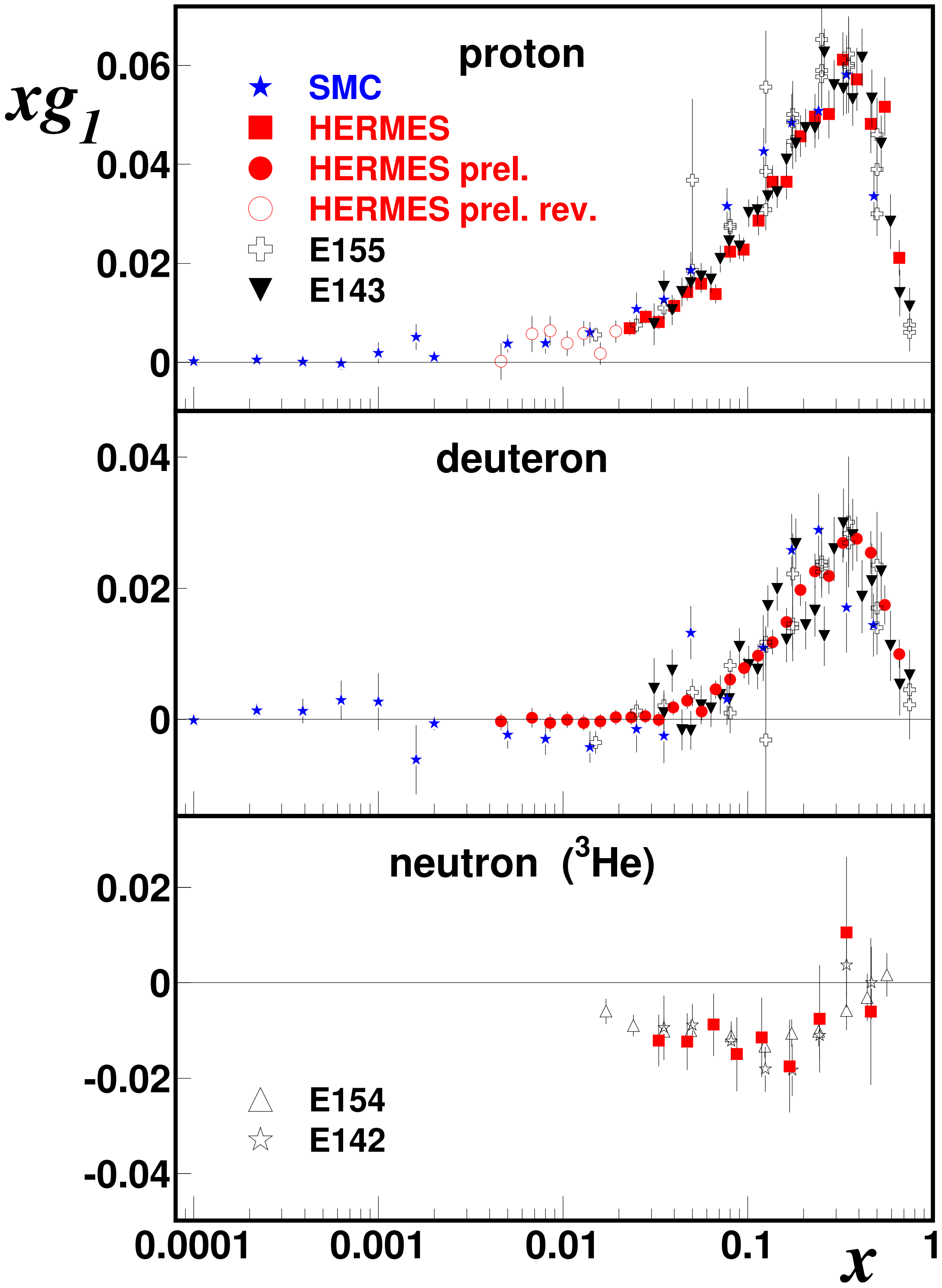
The Deuteron Double Spin Asymmetry A_1^d



$$A_1(x) = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}(x)$$
$$\approx \frac{g_1}{F_1}(x)$$



World Data on Spin Structure Functions



Semi-Inclusive DIS

Inclusive case:

$$A_1(x) = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \approx \frac{g_1}{F_1}(x) = \frac{\frac{1}{2}\sum_f e_f^2\, \Delta q_f(x)}{\frac{1}{2}\sum_f e_f^2\, q_f(x)}$$

Semi-inclusive case:

$$A_1^h(x) = \frac{\sigma_{1/2}^h - \sigma_{3/2}^h}{\sigma_{1/2}^h + \sigma_{3/2}^h}$$

$$= \sum_f \underbrace{\frac{e_f^2\, q_f(x) \int \mathrm{d}z\, D_f^h(z)}{\sum_{f'} e_{f'}^2\, q_{f'}(x)\, \int \mathrm{d}z\, D_{q_{f'}}^h(z)}}_{\equiv \mathcal{P}_f^h(x)} \frac{\Delta q_f(x)}{q_f(x)}$$

$\mathcal{P}_f^h(x)$... Purity, the prob. that a hadron h originates from an event with struck quark f

$\leadsto$ Carry out least squares fit:

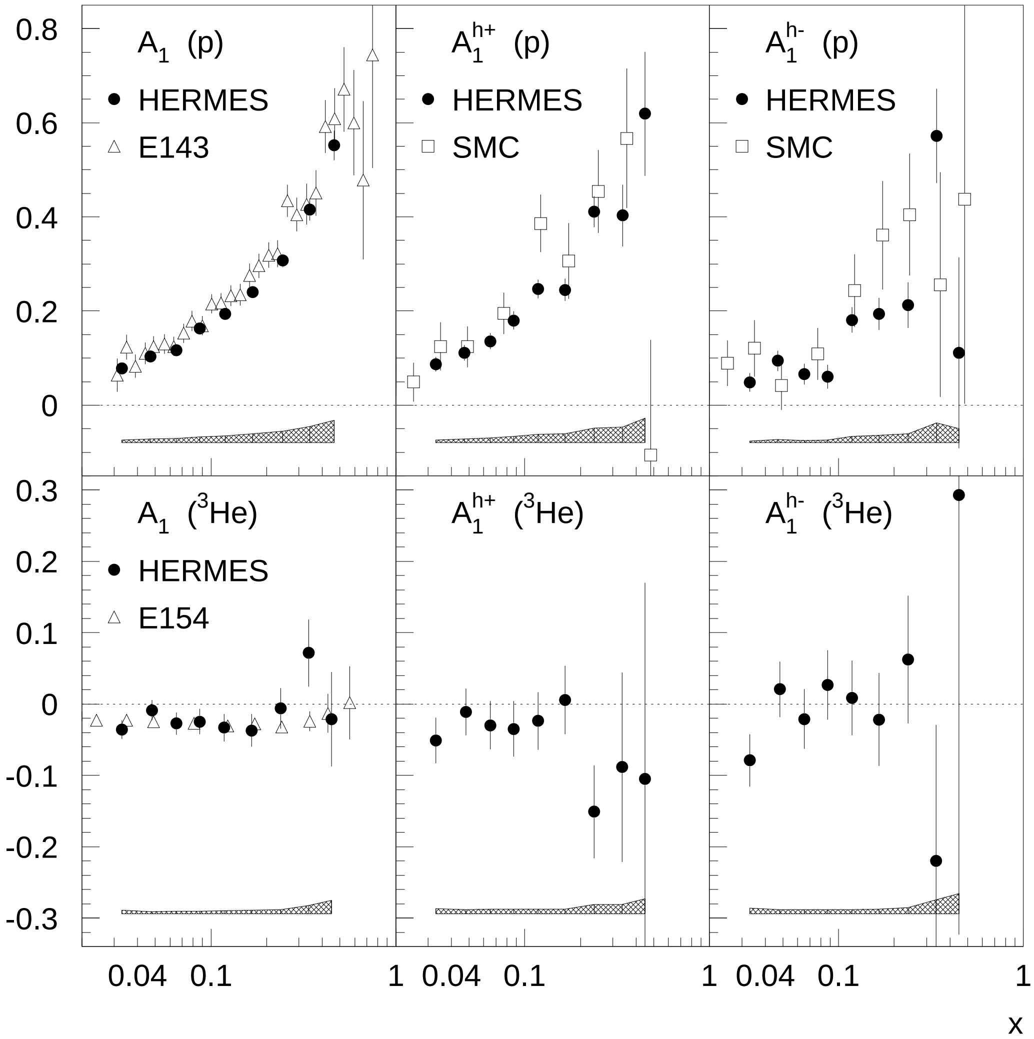
$$\vec{A}_{\mathrm{meas}} = \mathcal{P} \cdot \vec{Q}$$

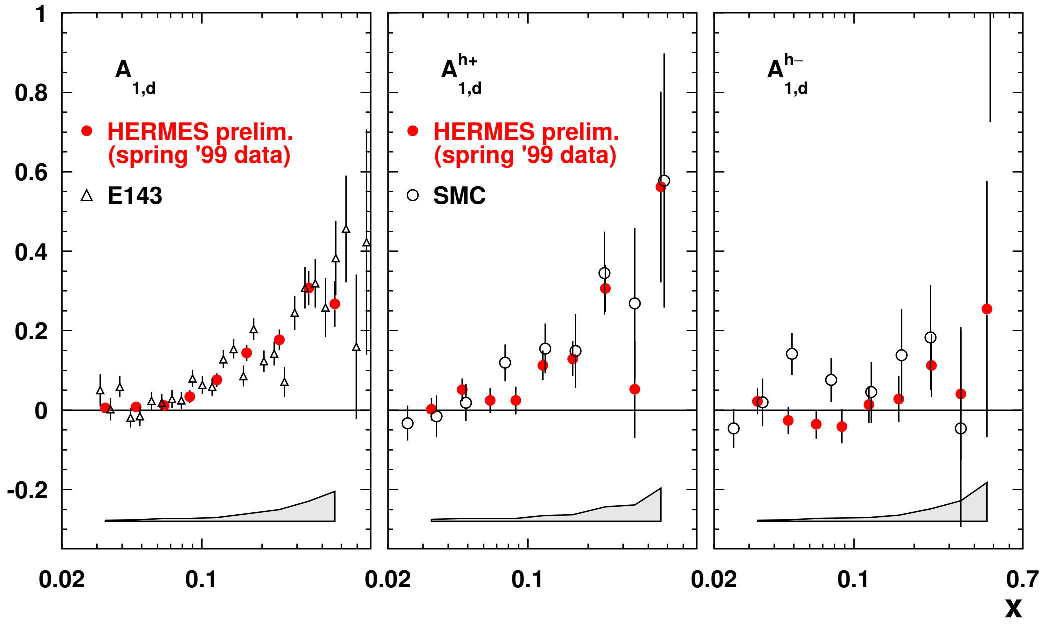
measured

Monte Carlo

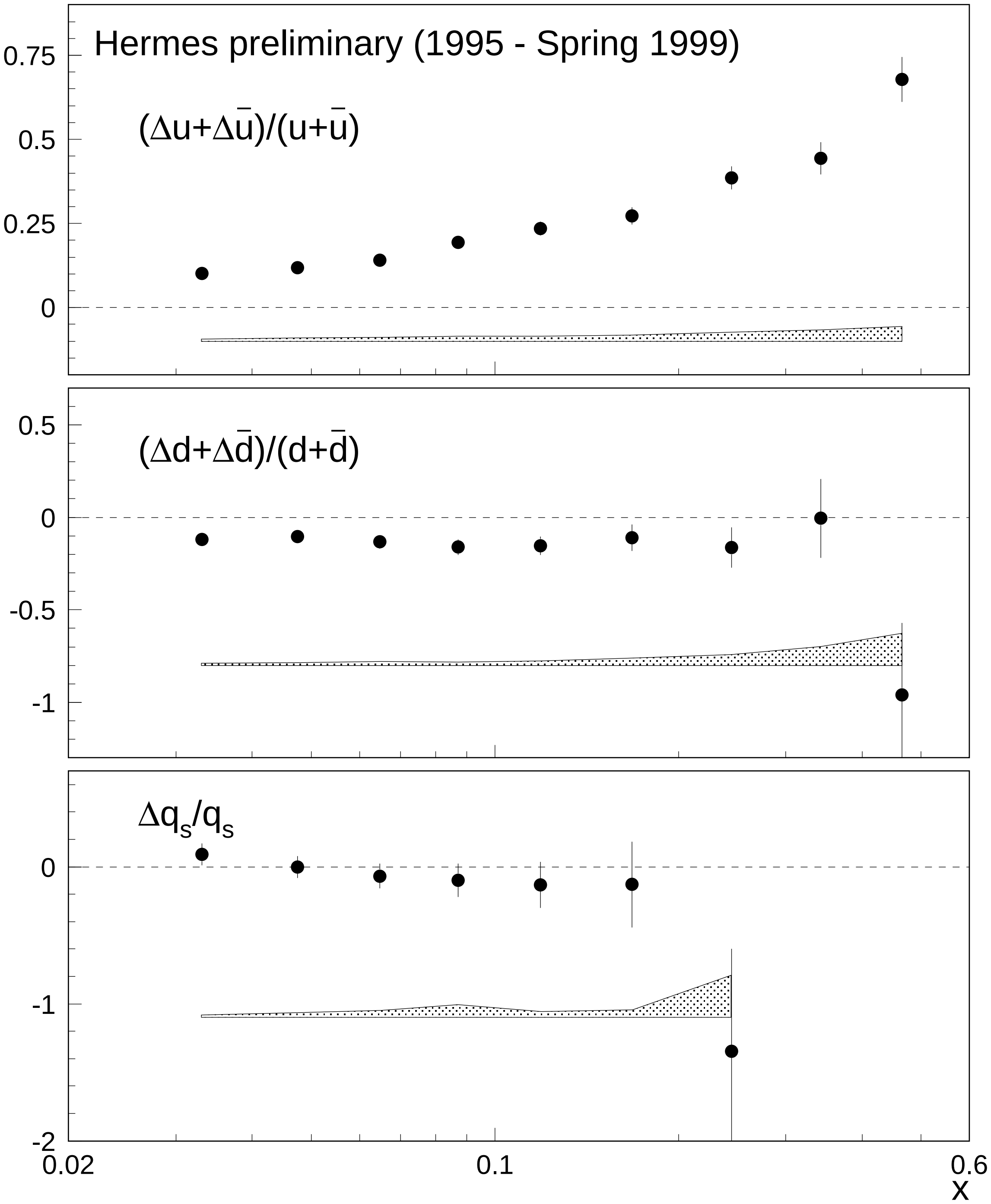
unknown

Semi-Inclusive Asymmetries

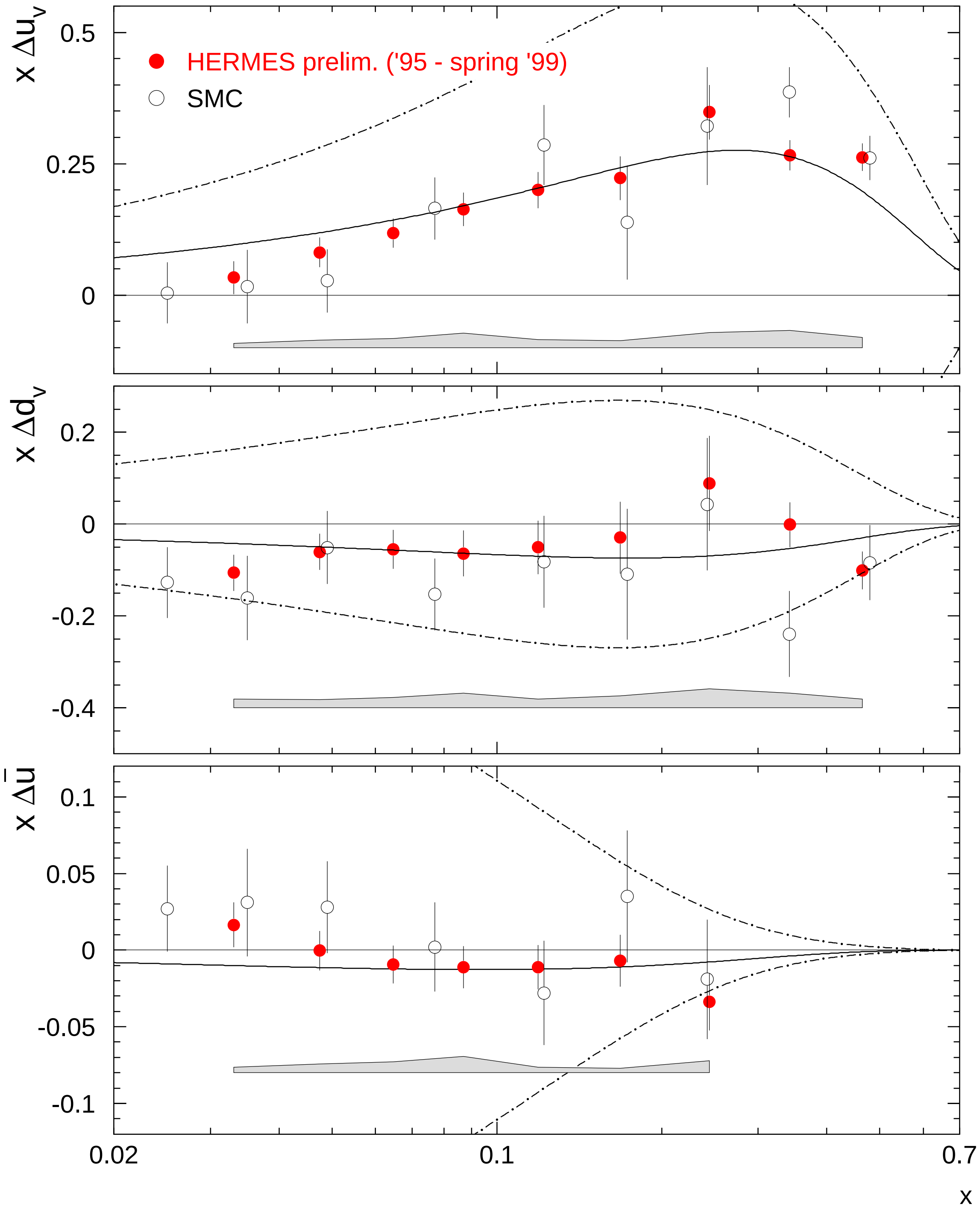




Quark Polarisations



Polarised Quark Densities

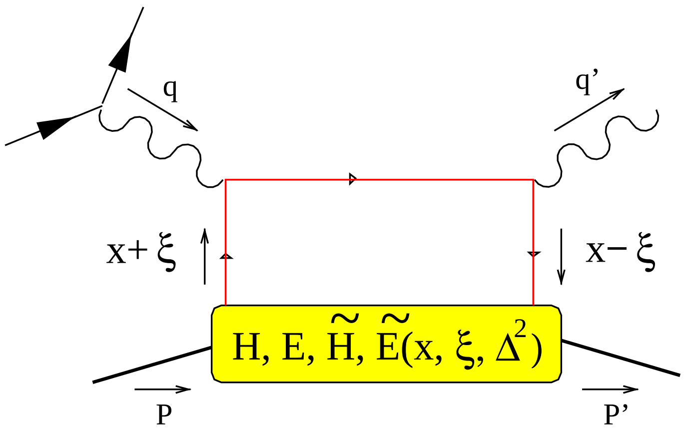


Dashed line: Positivity limit;

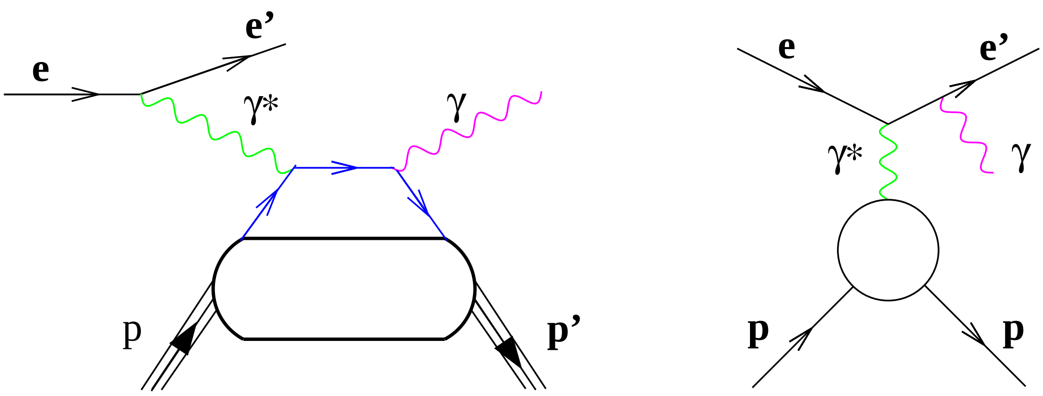
Solid line: GRSV

Deeply Virtual Compton Scattering

Generalised Parton Distributions: $H, E, \tilde{H}, \tilde{E}$



Exclusive lepto-production of photons:



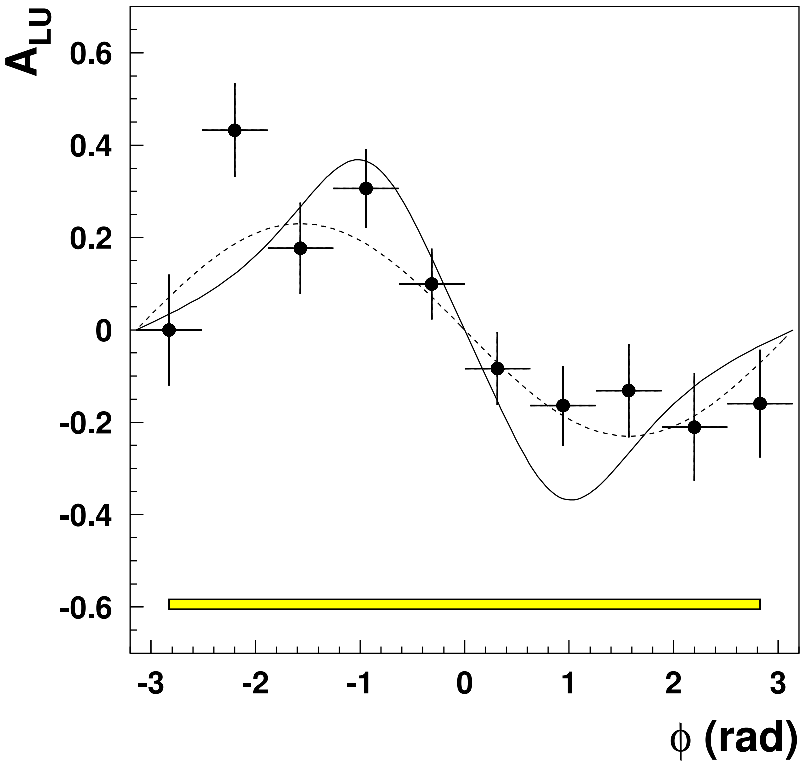
The interference is beam HELICITY dependent,

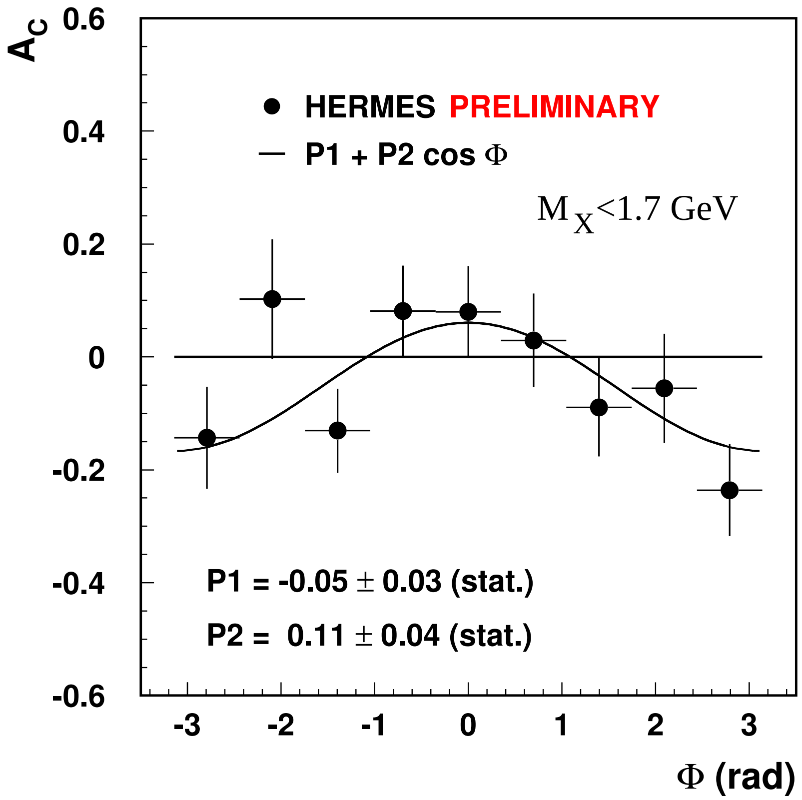
$$(\tau^*_{\mathrm{BH}}\tau_{\mathrm{DVCS}} + \tau_{\mathrm{BH}}\tau^*_{\mathrm{DVCS}}) \;\propto\; -e_l\, P_l\, \sin\phi\, \mathrm{Im}(\tilde{M}^{1,1})$$

and beam CHARGE dependent:

$$(\tau^*_{\mathrm{BH}}\tau_{\mathrm{DVCS}} + \tau_{\mathrm{BH}}\tau^*_{\mathrm{DVCS}}) \;\propto\; \pm\cos\phi\, \mathrm{Re}(\tilde{M}^{1,1})$$

Beam Spin and Beam Charge Asymmetries

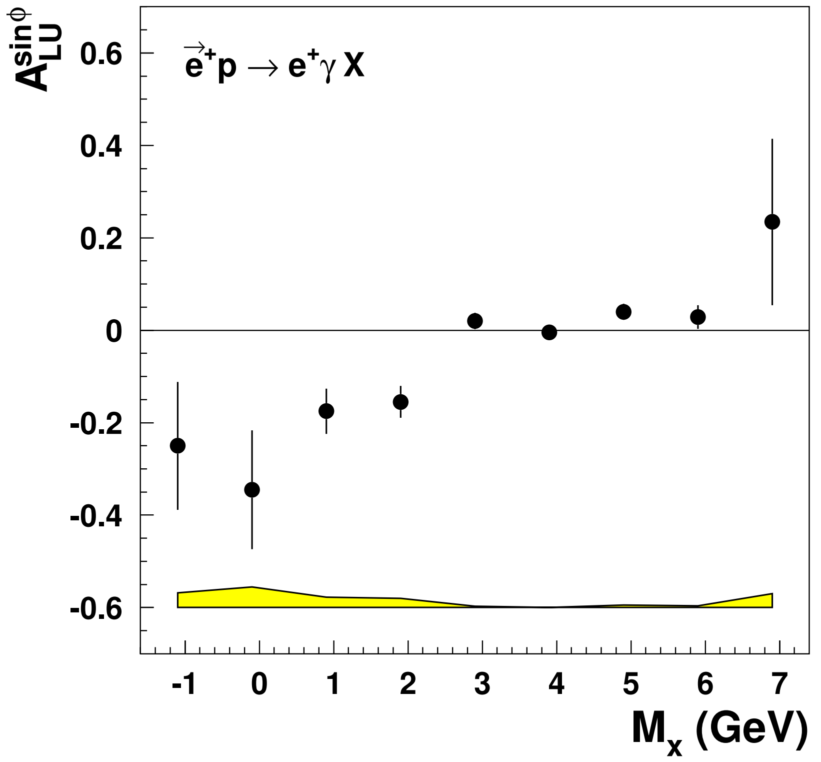


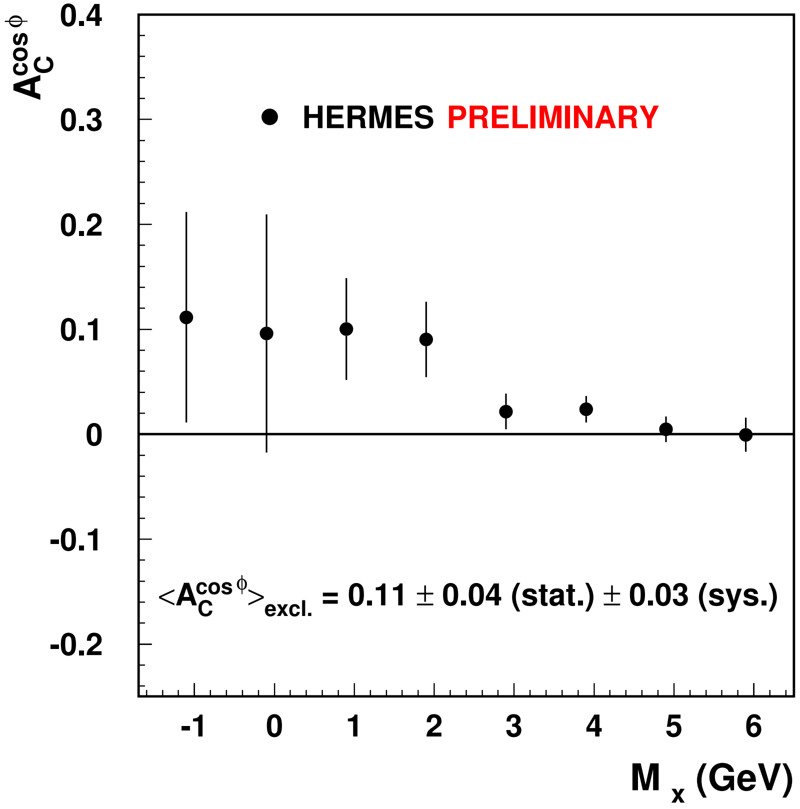


$$A_{LU}(\phi) = \frac{1}{\langle|P_l|\rangle} \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$

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

Beam Helicity and Beam Charge Moments





$$A_{LU}^{\sin\phi} = \frac{2}{N} \sum_{i=1}^{N} \frac{\sin\phi_i}{(P_l)_i}$$

$$A_C^{\cos\phi} = \sum_{i=1}^{N^{e^+}} \frac{\cos\phi_i}{N^{e^+}} - \sum_{i=1}^{N^{e^-}} \frac{\cos\phi_i}{N^{e^-}}$$

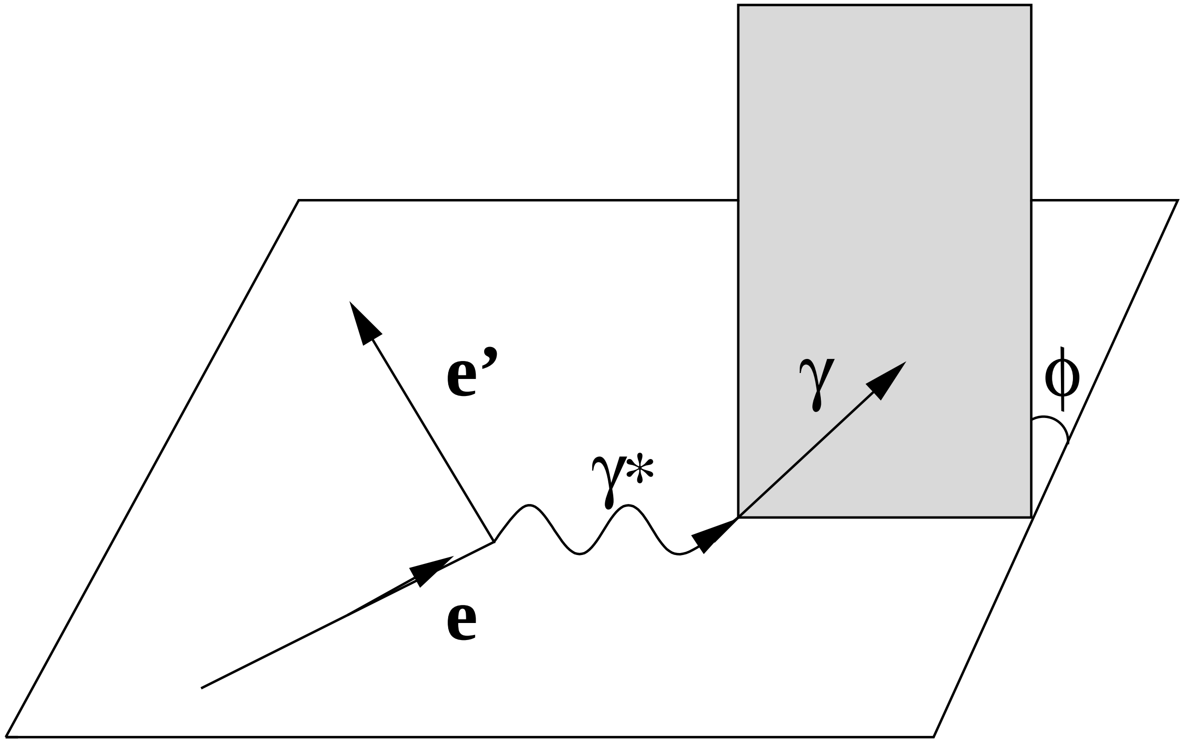
Conclusion and Outlook

- HERMES has measured inclusive and semi-inclusive asymmetries on p, d, and n
- Polarisations of up and down quarks determined with good precision:

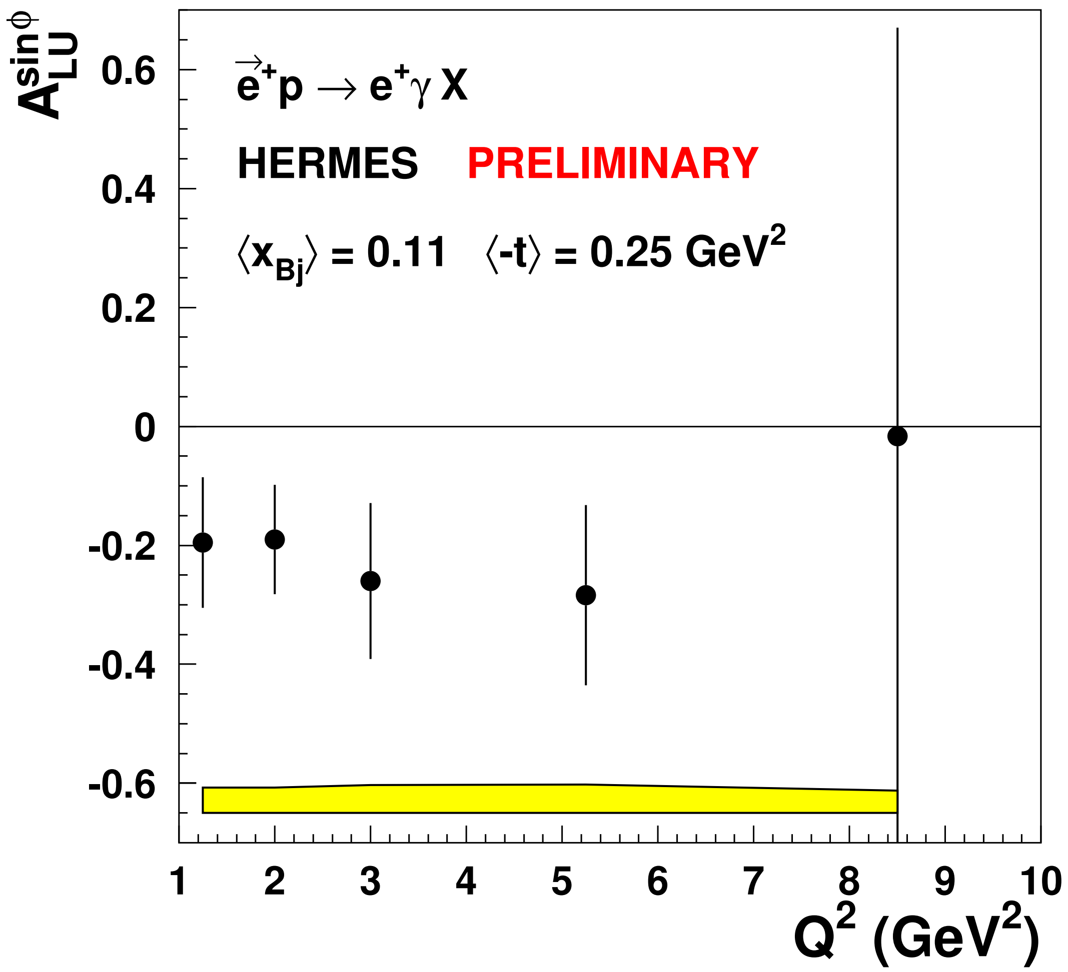
$$\Delta u > 0 \qquad \Delta d < 0; \qquad \Delta\bar{q} \approx 0$$

- Measurements of DVCS were carried out
- The inclusion of the full deuterium data-set will allow for a separation of the polarised sea quark distributions
- More exciting results coming soon

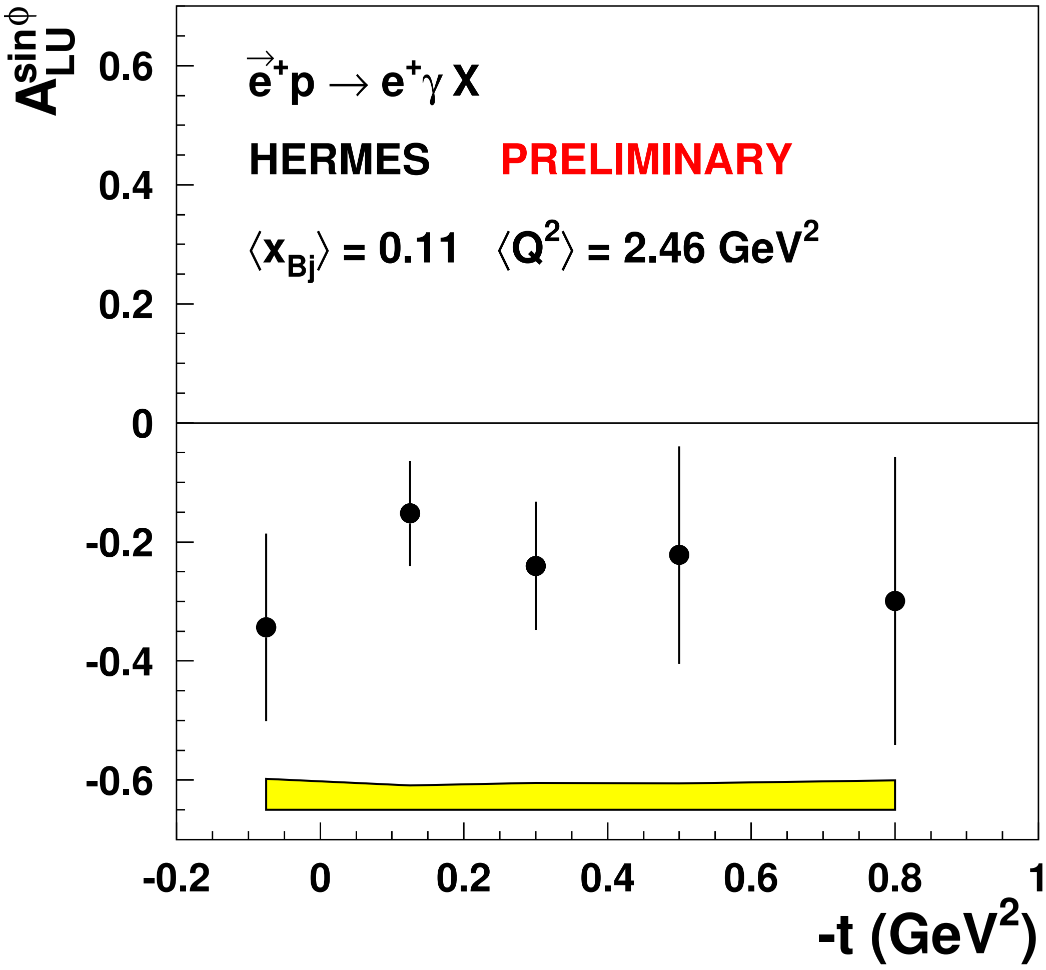
DVCS – The Azimuthal Angle ϕ



Beam Spin Asymmetry vs. Q^2



Beam Spin Asymmetry vs. t



Beam Spin Asymmetry vs. x_{bj}