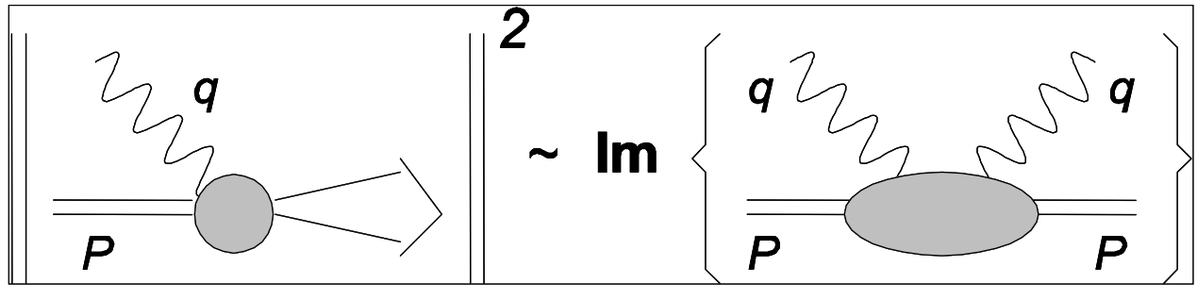
From Inclusive Scattering to Exclusive Reactions

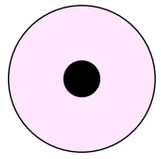
Recent Results from HERMES
QCD '05, Montpellier, France

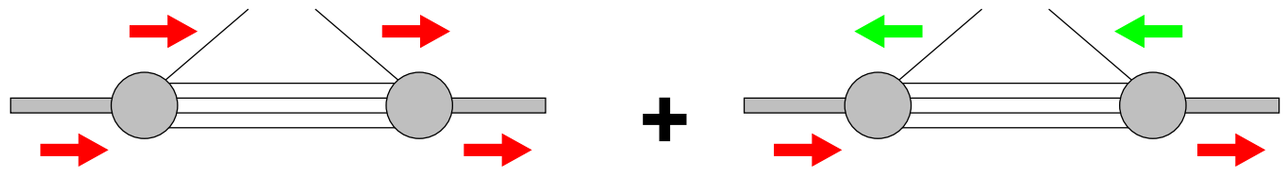
B. Seitz on behalf of the HERMES Collaboration

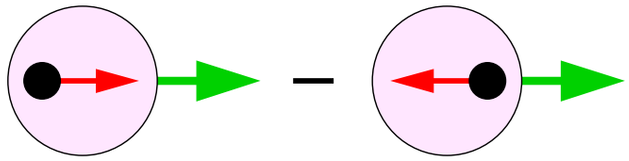
Leading Order Parton Distributions

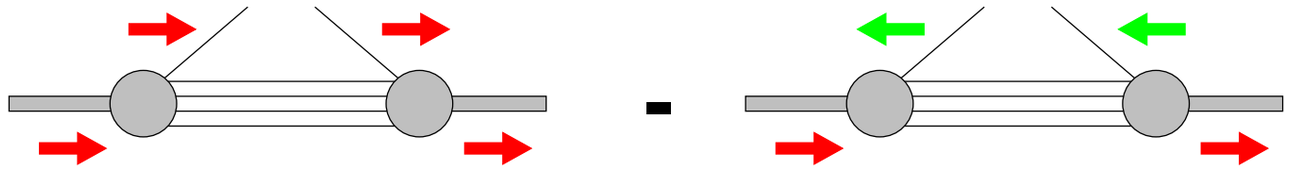
via optical theorem:

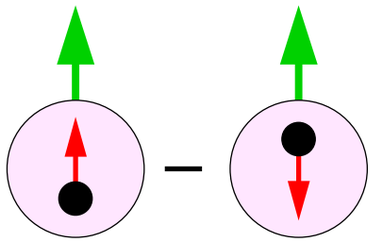


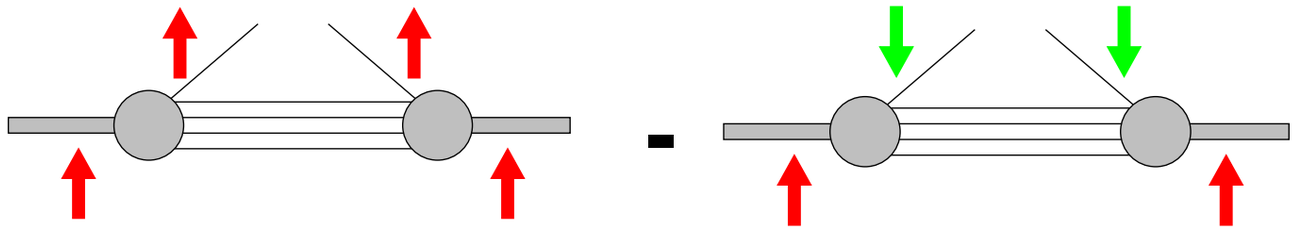
f_1= 

$f_1 \sim$ 

g_1= 

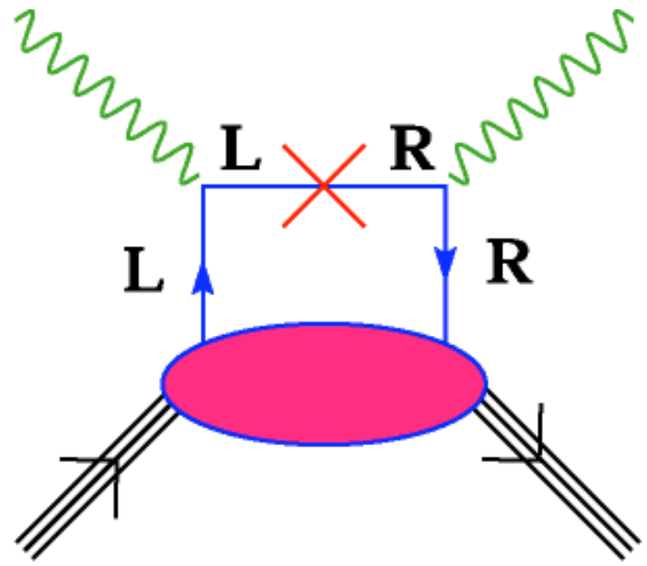
$g_1 \sim$ 

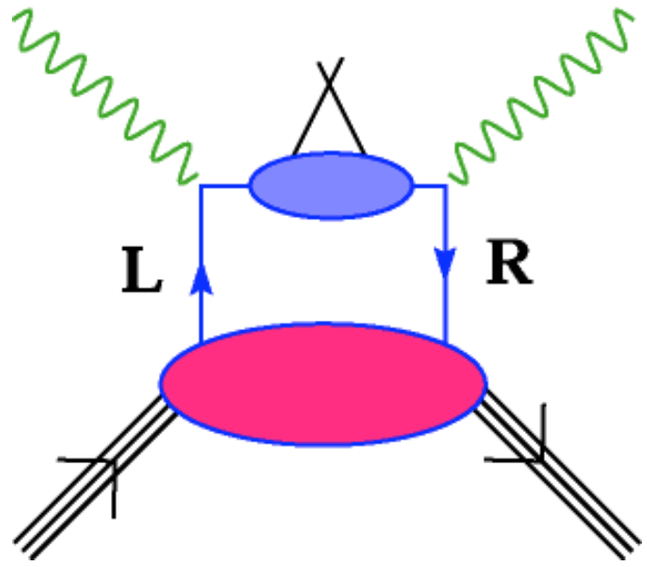
h_1= 

$h_1 \sim$ 

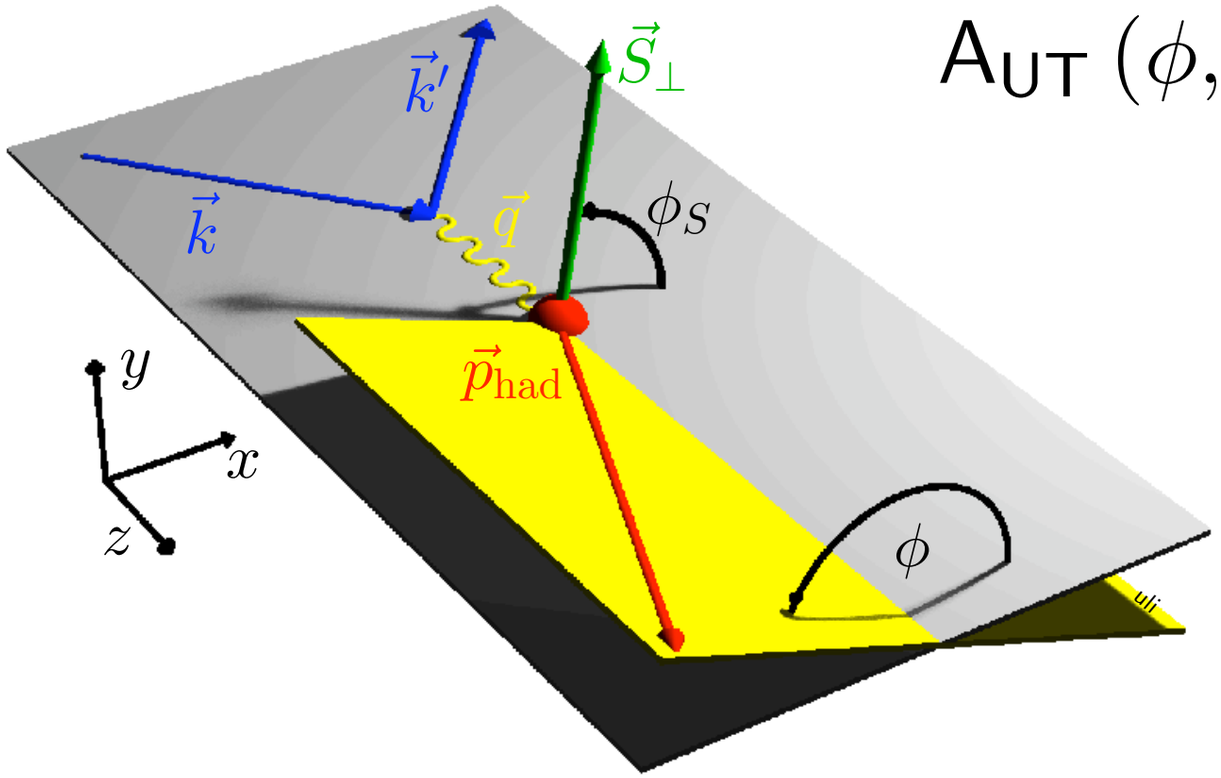
Measuring Transversity

- h_1 (a.k.a. δq) chiral odd
  - no access in inclusive scattering
  - need combination with another chiral odd object: $H_1^\perp$
    - correlates q-Polarisation with k_T in fragmentation $\Rightarrow P_h^\perp$
- alternative: T-odd distribution $f_{1T}^\perp$
  - allowed by FSI
  - requires orbital angular momentum





Transverse target asymmetries



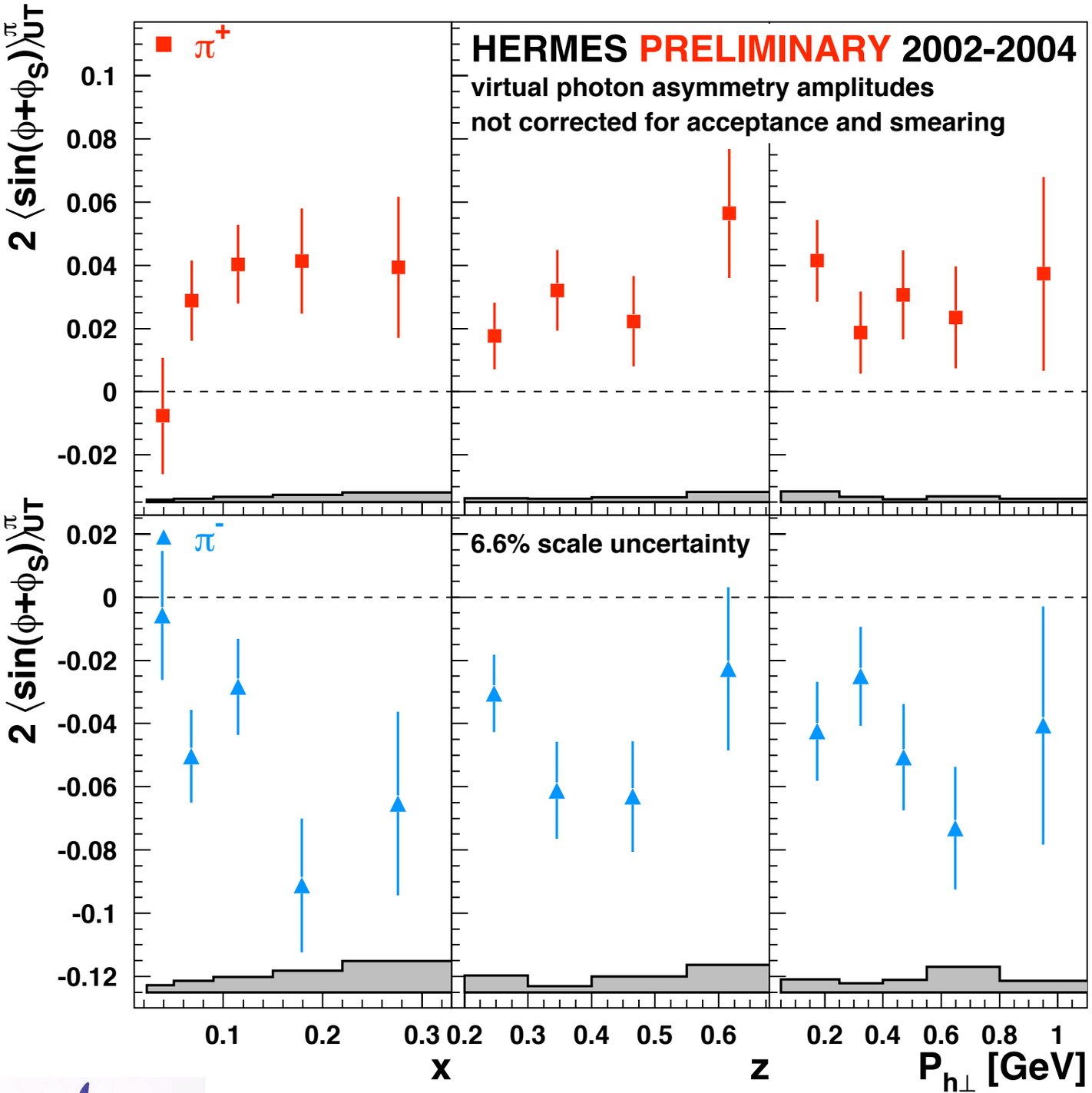
$$A_{UT}(\phi,\phi_S) = \frac{1}{S_\perp}\frac{N_h^\uparrow(\phi,\phi_S) - N_h^\downarrow(\phi,\phi_S)}{N_h^\uparrow(\phi,\phi_S) + N_h^\downarrow(\phi,\phi_S)}$$

$$\propto \sin(\phi+\phi_S)\frac{\sum_q e_q^2 \delta q(x) H_1^\perp(z)}{\sum_q e_q^2 q(x) D_1(z)}$$

$$+ \sin(\phi-\phi_S)\frac{\sum_q e_q^2 f_{1T}^\perp(x) D_1(z)}{\sum_q e_q^2 q(x) D_1(z)}$$

- measurement depends on ϕ and ϕ_s
- perform two-dimensional fit to extract amplitudes
- combined fit prevents acceptance effects

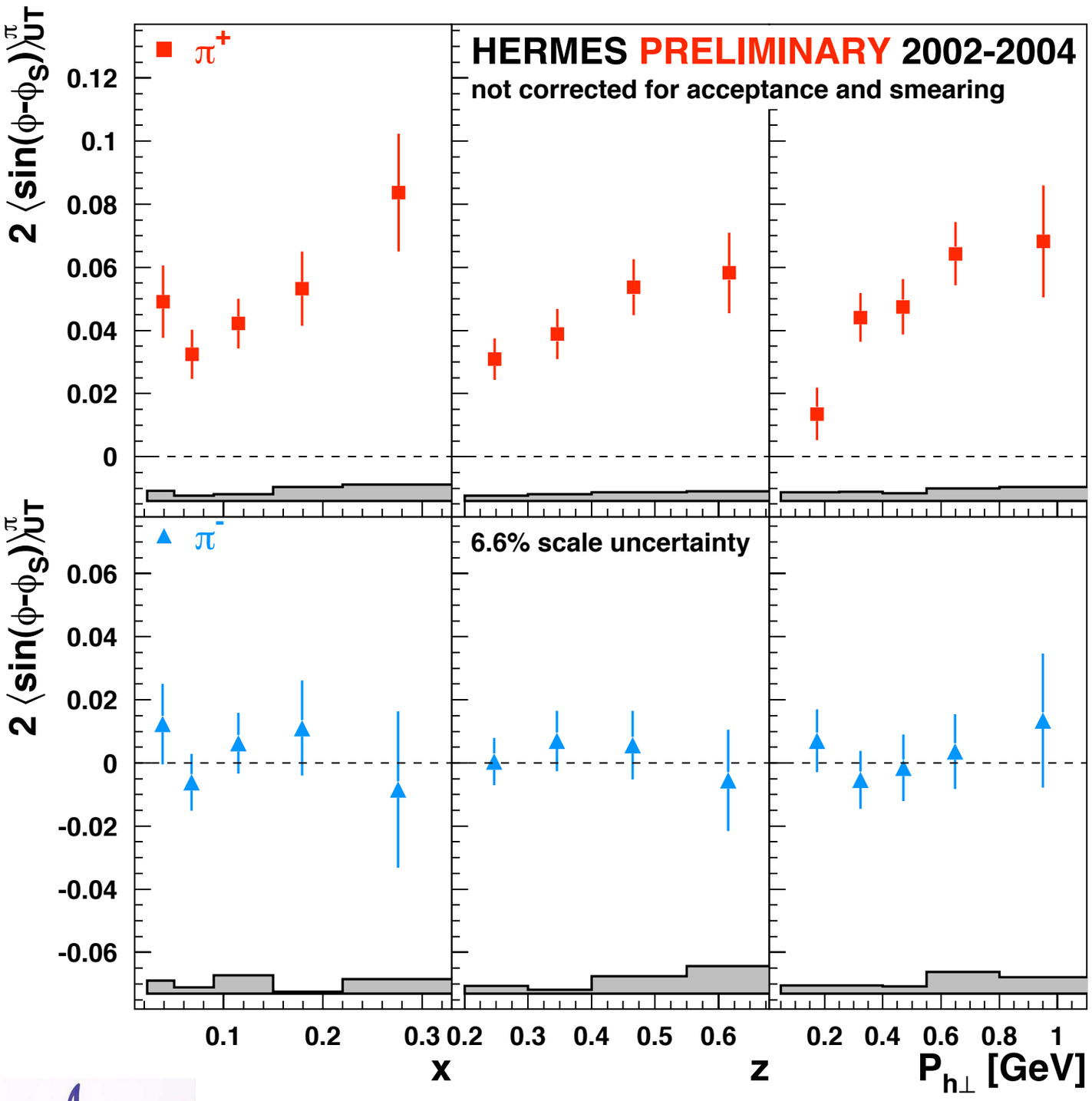
Extracted Collins Moments



- positive for π^+, negative for π^-
- expectation $\delta u > 0$, $\delta d < 0$
- unexpected large absolute value for π^-
- Interpretation:

$$H_d / H_f < 0$$

Extracted Sivers Moments

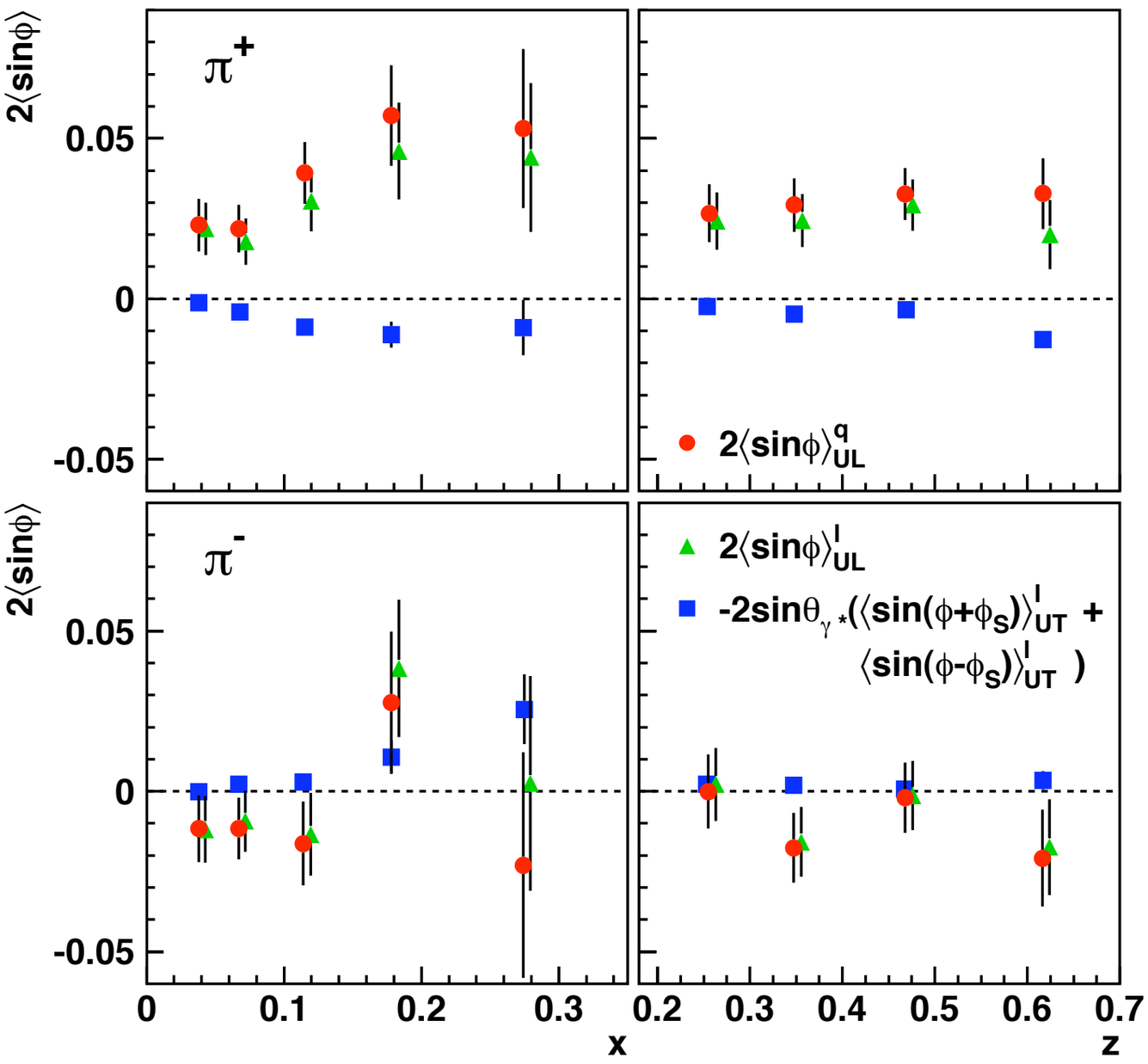


- significantly positive for π^+
- π^- asymmetry consistent with zero
- first hint of T-odd distribution function in DIS

$$A_S^{\pi^+} = 0.034 \pm 0.008$$

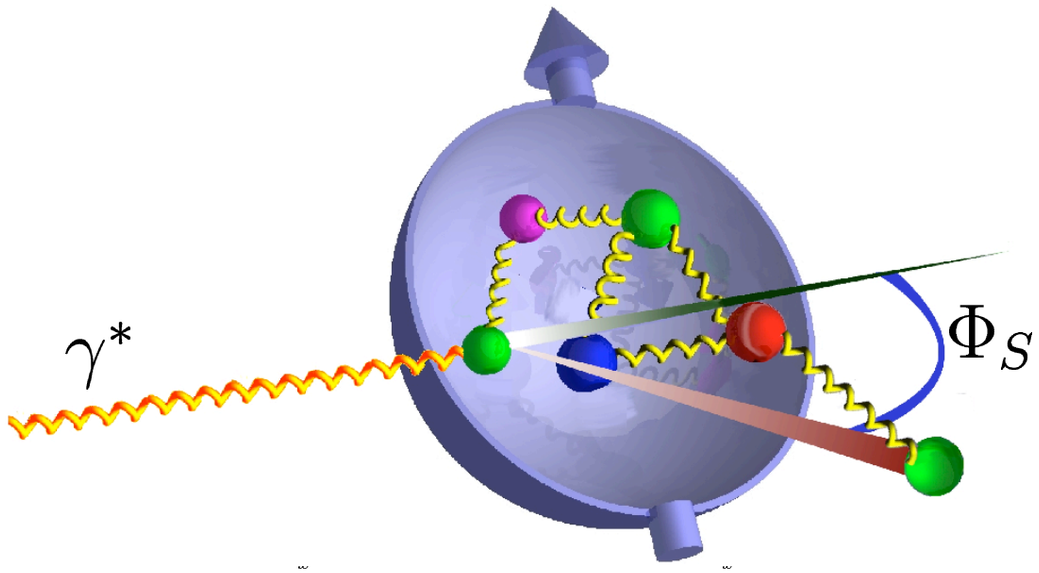
$$A_S^{\pi^-} = 0.004 \pm 0.010$$

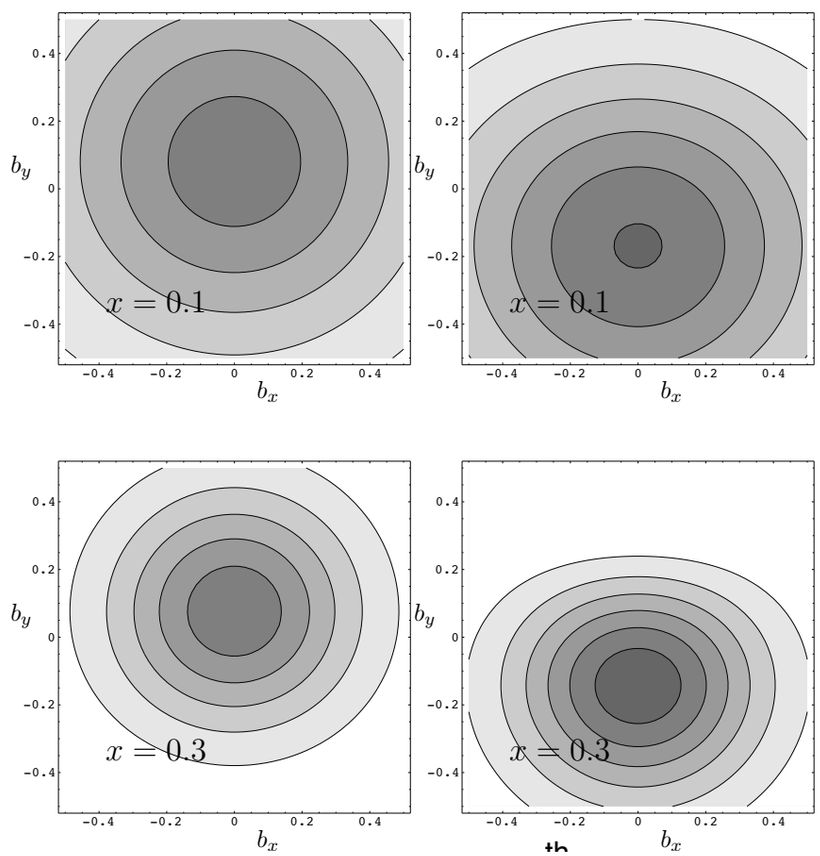
Subleading twist effects



- measurement on longitudinal polarised target contains transverse component wrt. γ^*
- asymmetry contains subleading twist contribution
- extraction possible with measurements on longitudinal and transverse target

A model for the Sivers effect

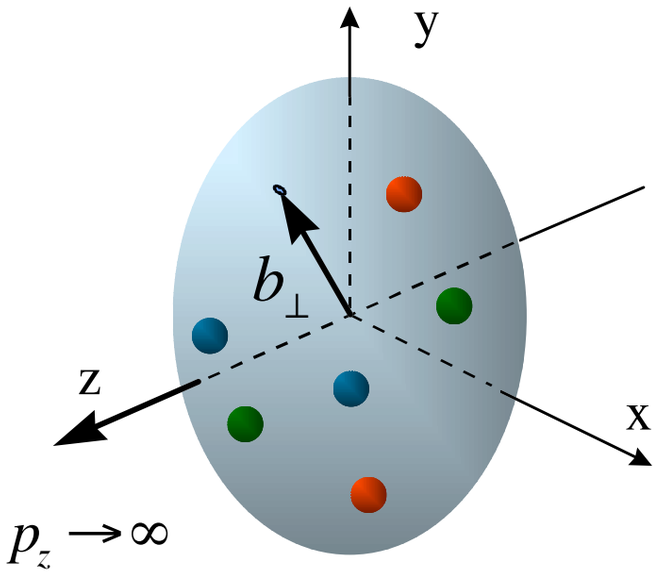


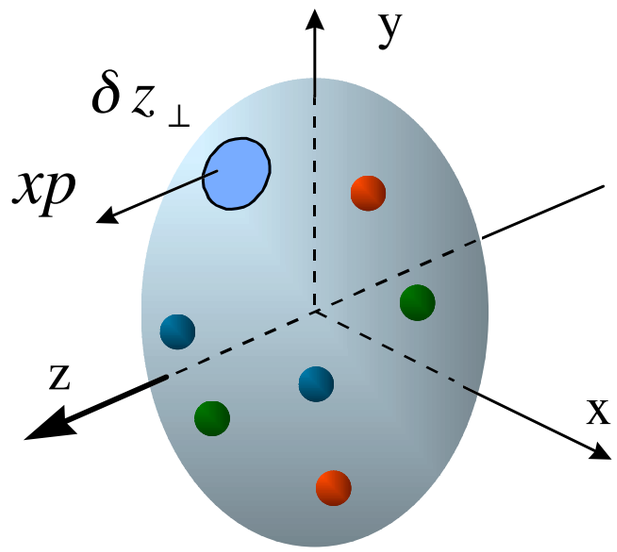


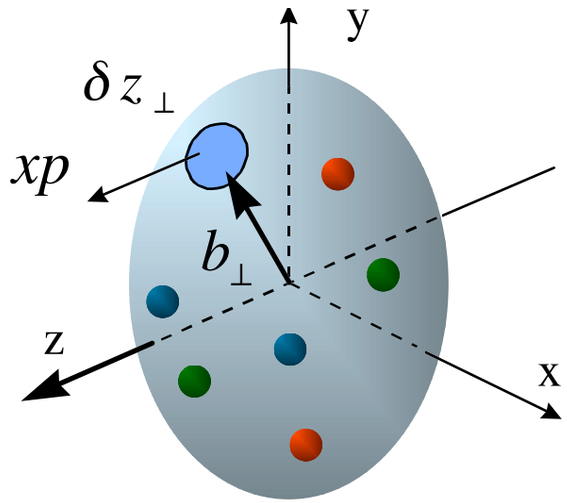
- rescattering of hit quark by gluon
- impact parameter formalism by M. Burkhardt (hep-ph/0309269)
- orbital angular momentum at finite impact parameter
- q(x) not flat

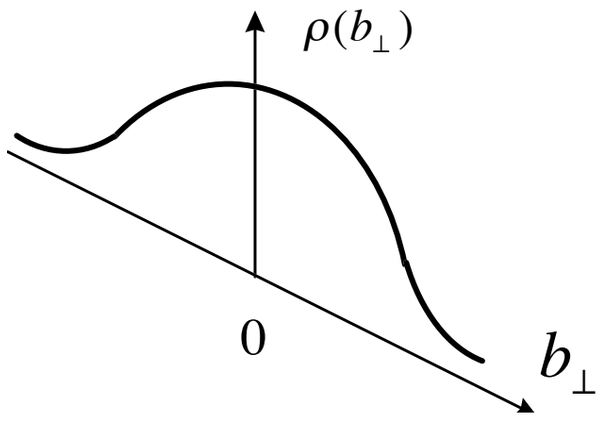
$$x_{obs} = x_{true} \pm \Delta x$$

(Generalised) Distribution Functions

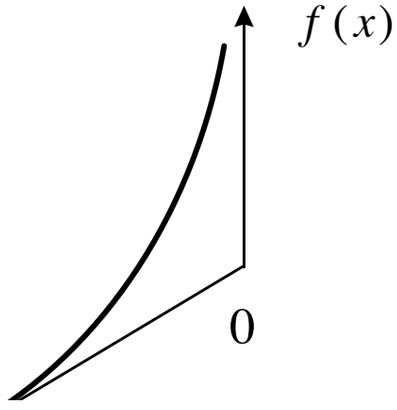




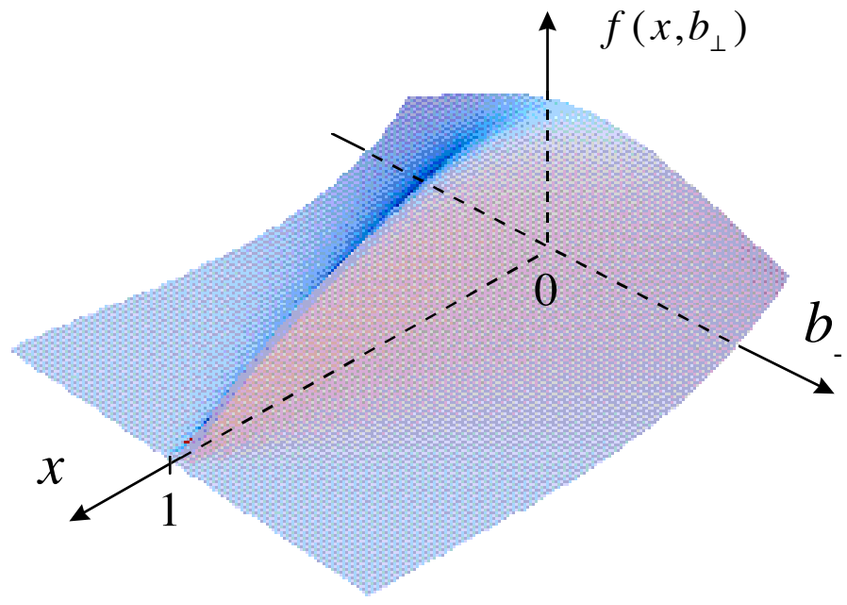




Formfactor

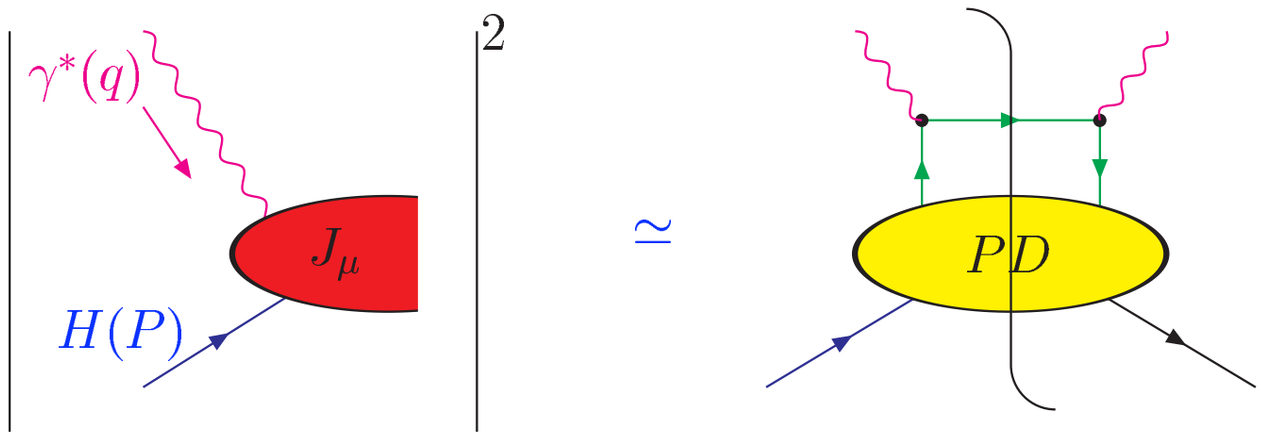


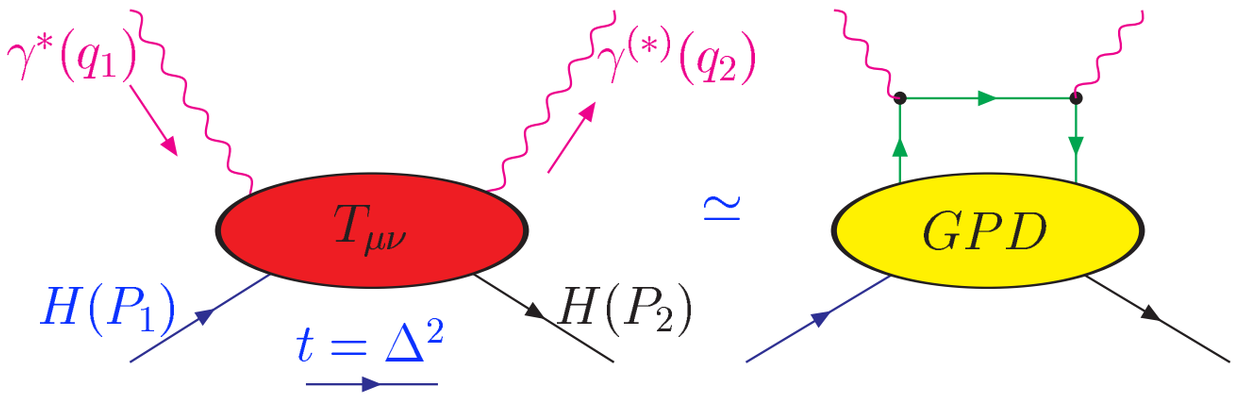
Parton density



Generalised Parton Distribution

From DIS to GPDs





leading twist : H, E, $\tilde{H}$, $\tilde{E}$

- DIS cross section from forward Compton amplitude via optical theorem
- Hadron described by PDF
- Off-forward Compton Amplitude by allowing momentum transfer
- new information on Hadron structure by Generalised Parton Distributions

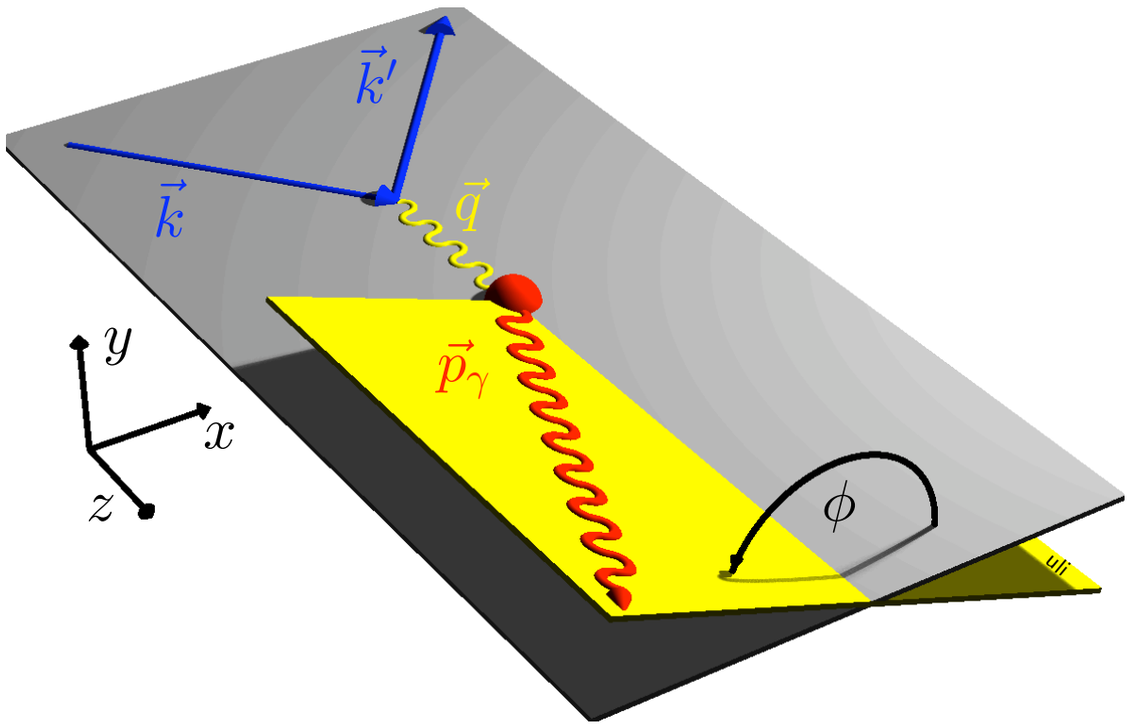
GPDs in Exclusive Reactions

Pseudoscalar Mesons	Deeply Virtual Compton Scattering	Vectormesons
$\tilde{H}^q, \tilde{E}^q$	$H^q, E^q, \tilde{H}^q, \tilde{E}^q$	H^q, E^q

$$J^q = \lim_{t \to 0} \frac{1}{2} \int_{-1}^{1} dx\, x \left[H^q(x.\xi, t) + E^q(x, \xi, t) \right]$$

Total angular momentum: Ji 's sum rule

Measuring DVCS Asymmetries



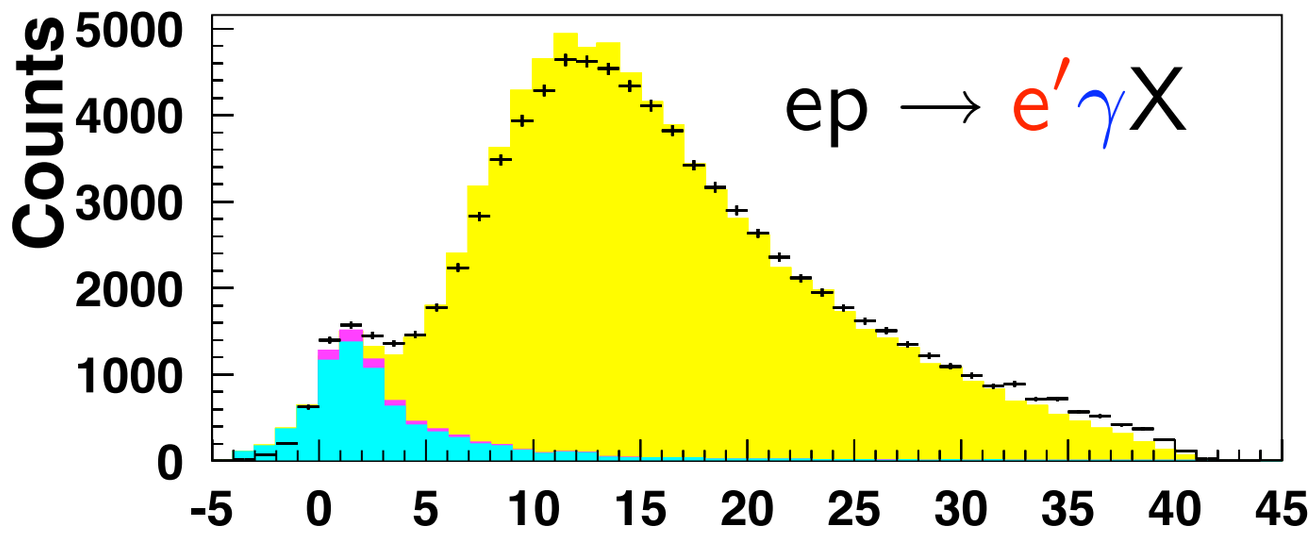
- DVCS BH interference gives direct access to amplitudes
- Beam Charge Asymmetry gives the real part
- Beam Spin Asymmetry gives the imaginary part

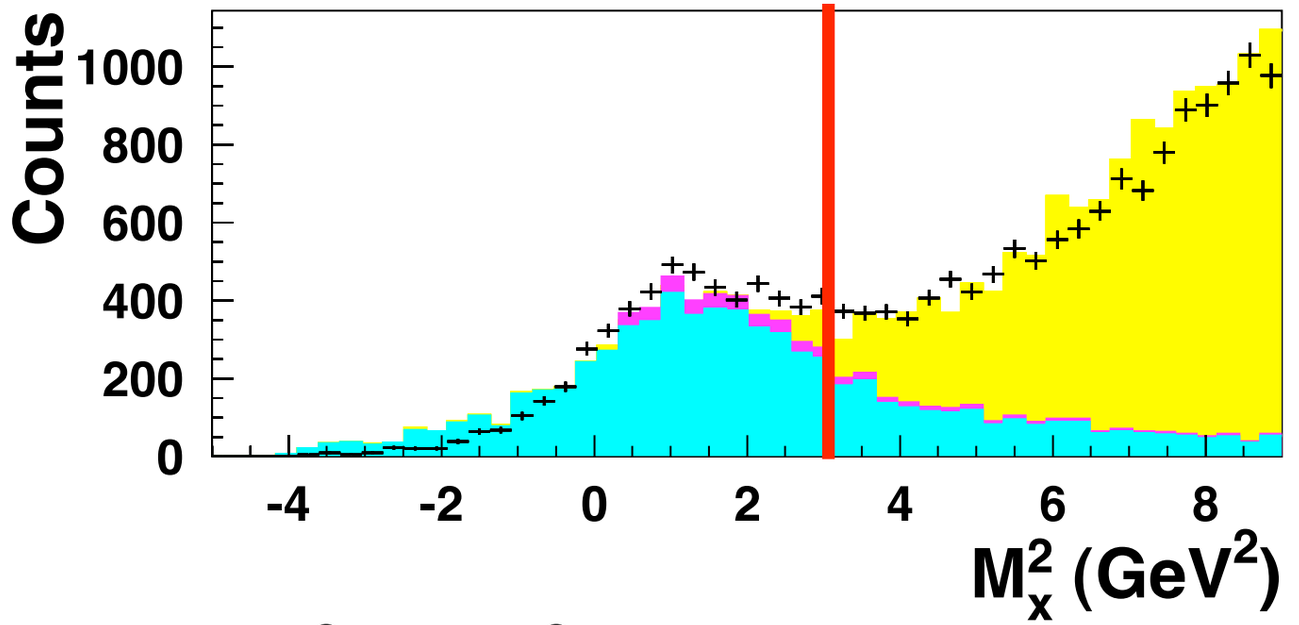
$$I = \pm \frac{4\sqrt{2}\, m\, e^6}{t\, Q\, x_B} \frac{1}{\sqrt{1-x_B}} \times \left[\cos\phi \frac{1}{\sqrt{\epsilon(\epsilon-1)}} \Re M^{1,1} - P_l \sin\phi \sqrt{\frac{1+\epsilon}{\epsilon}} \Im M^{1,1} \right]$$

HERMES measures the complete DVCS amplitude !

Current Analysis Strategy

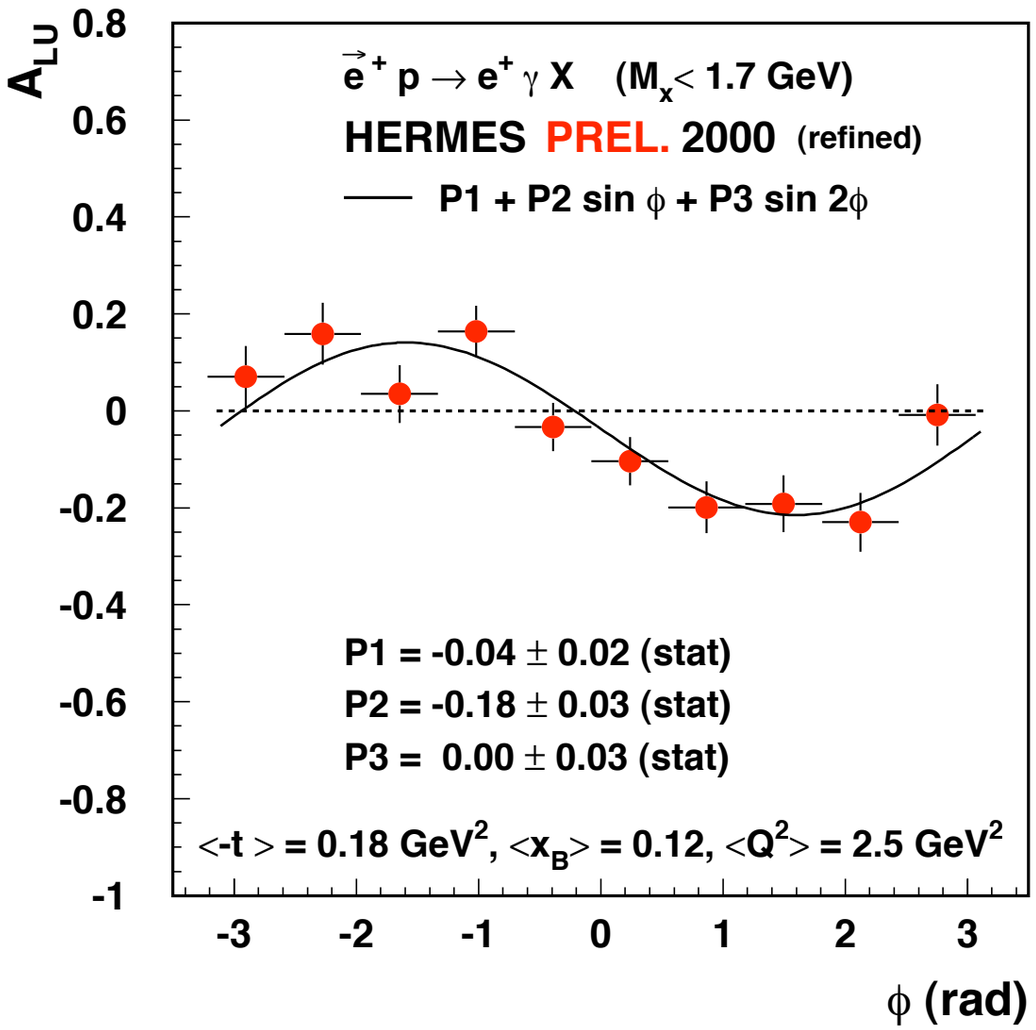
- Spectrometer detects photon and lepton
- missing particle: recoil proton
- identify reaction by missing mass cut
- measure asymmetries with respect to azimuthal angle ϕ

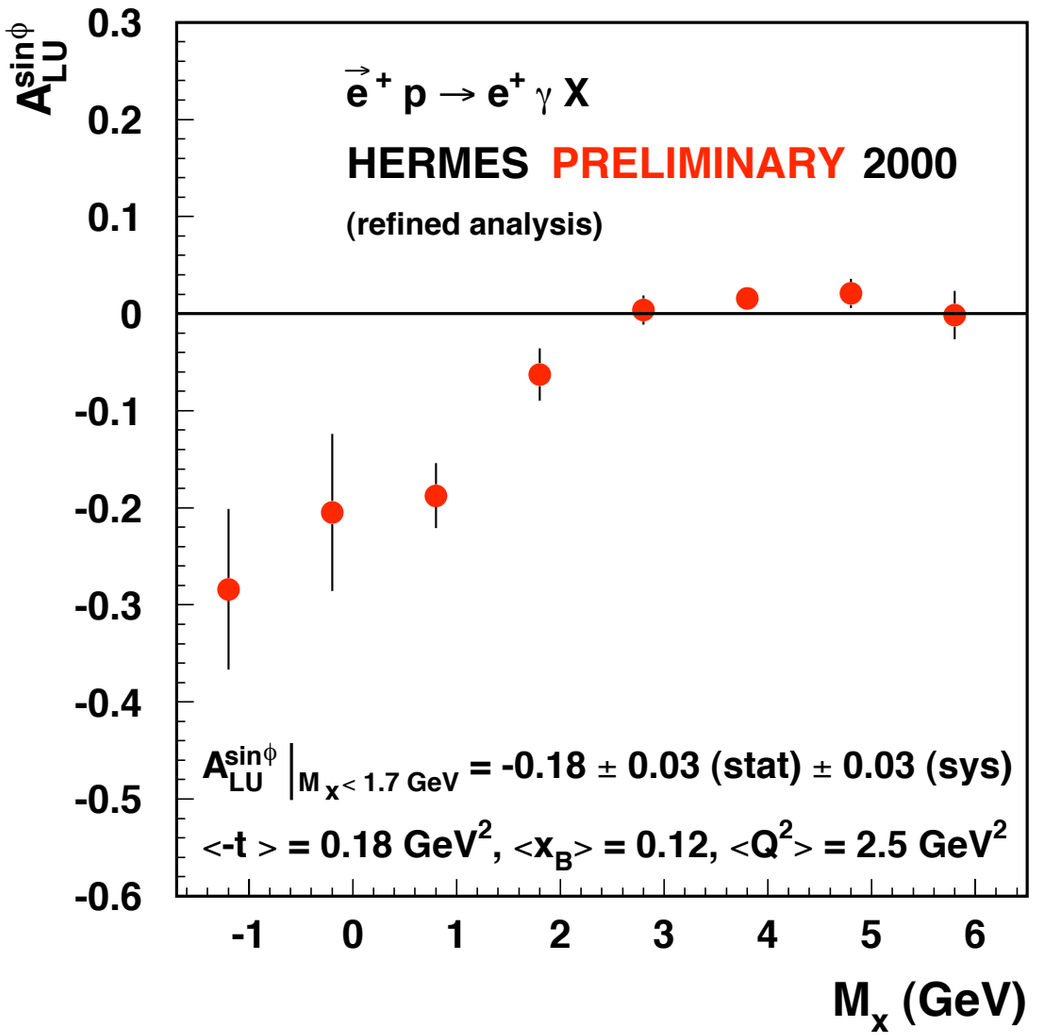




$$M_x^2 = m_p^2 + 2m_p(\nu - E_\gamma)$$

Getting the imaginary part:
Beam Spin Asymmetry





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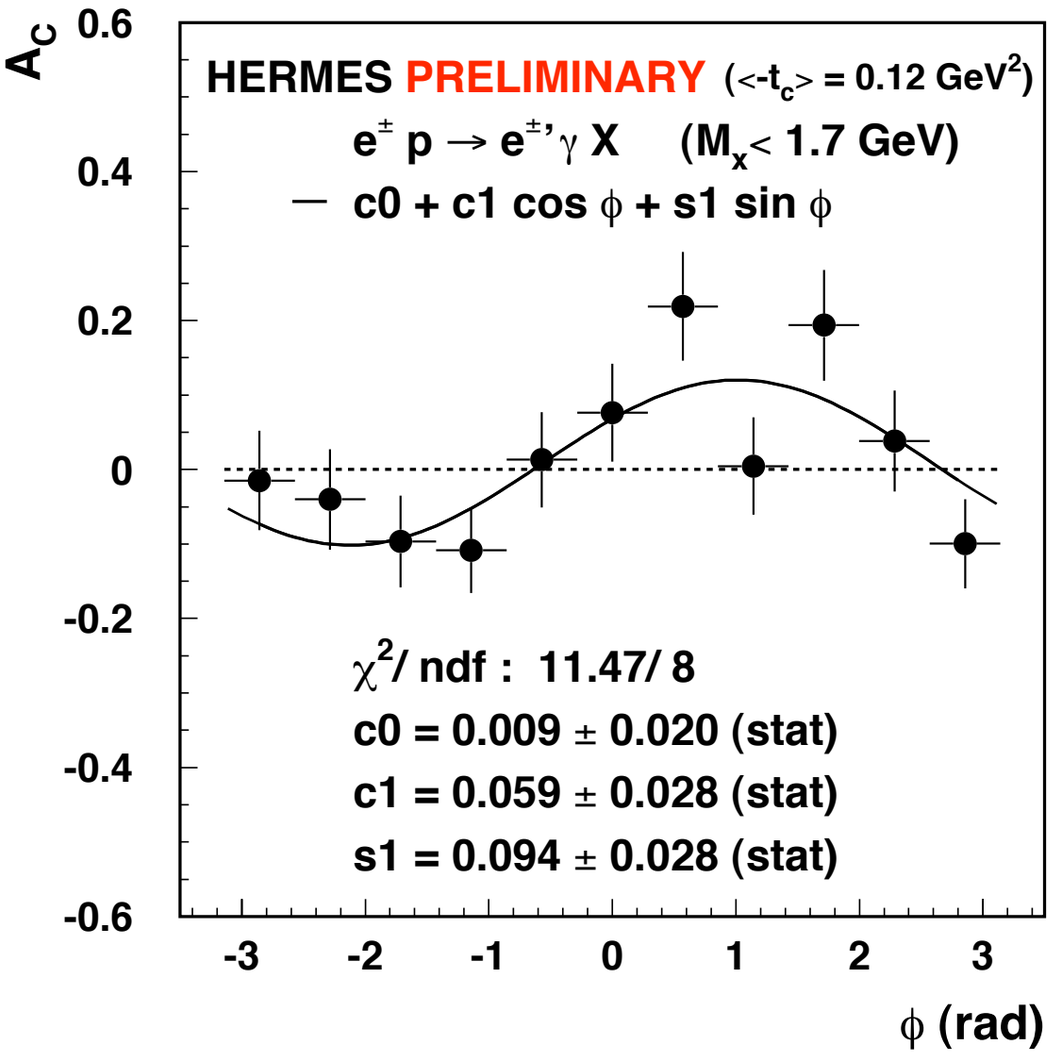
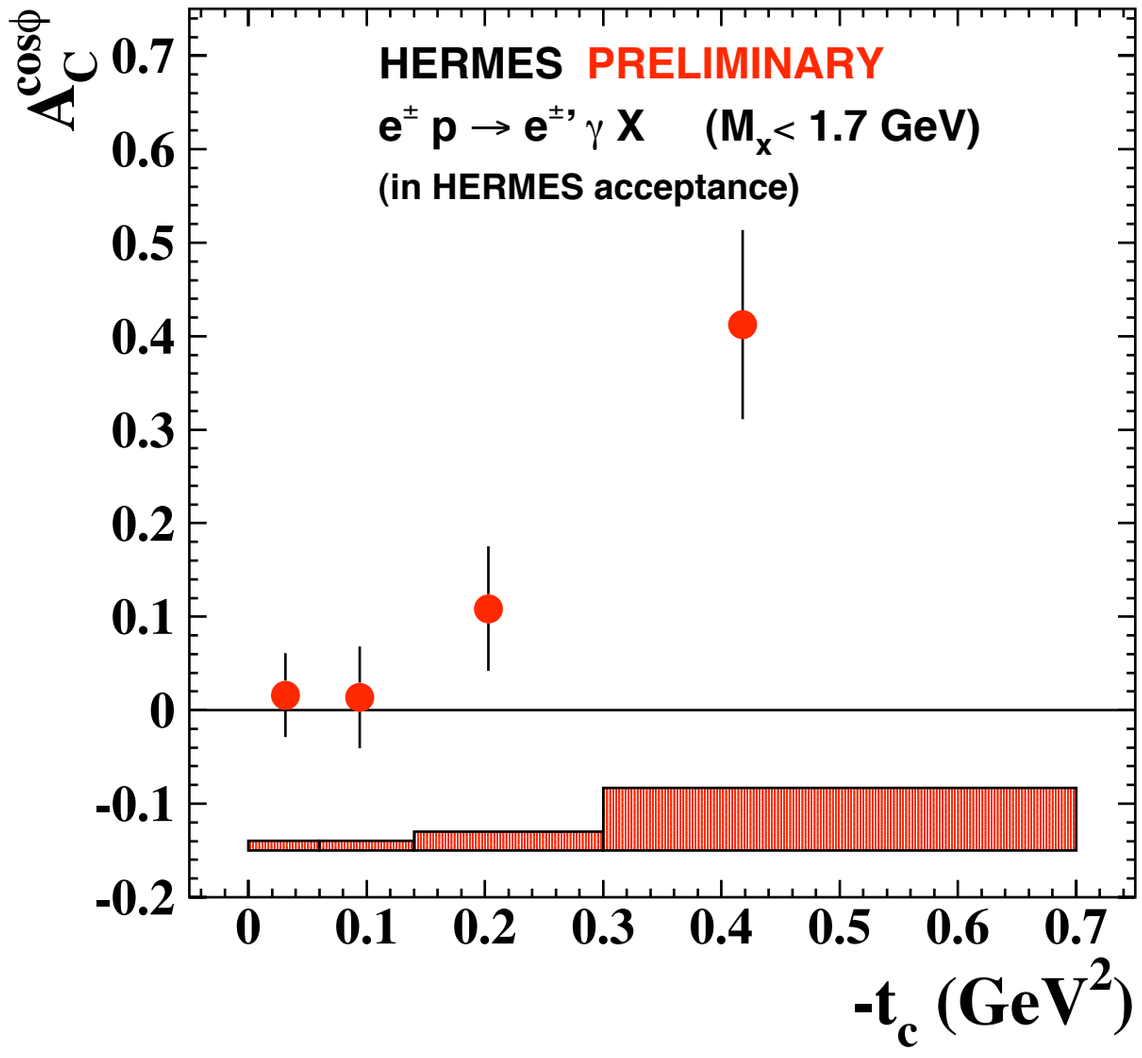
Getting the real part: Beam Charge Asymmetry





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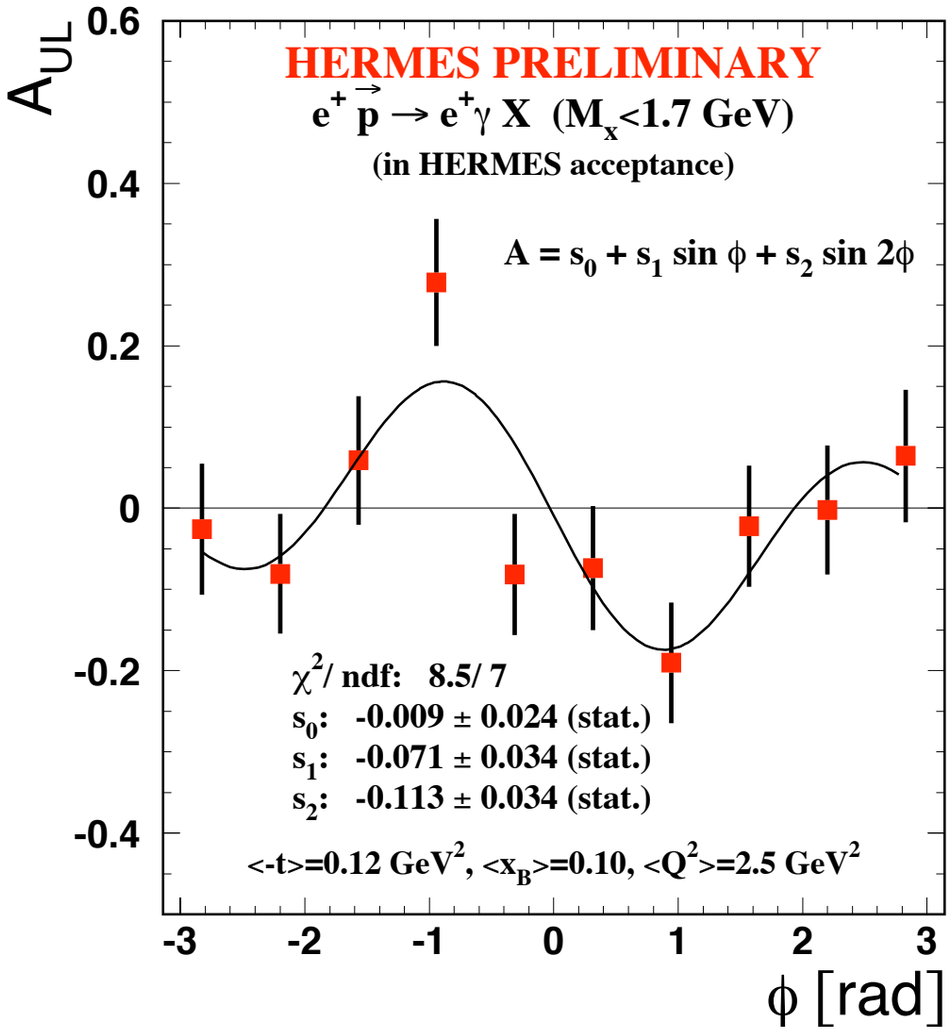
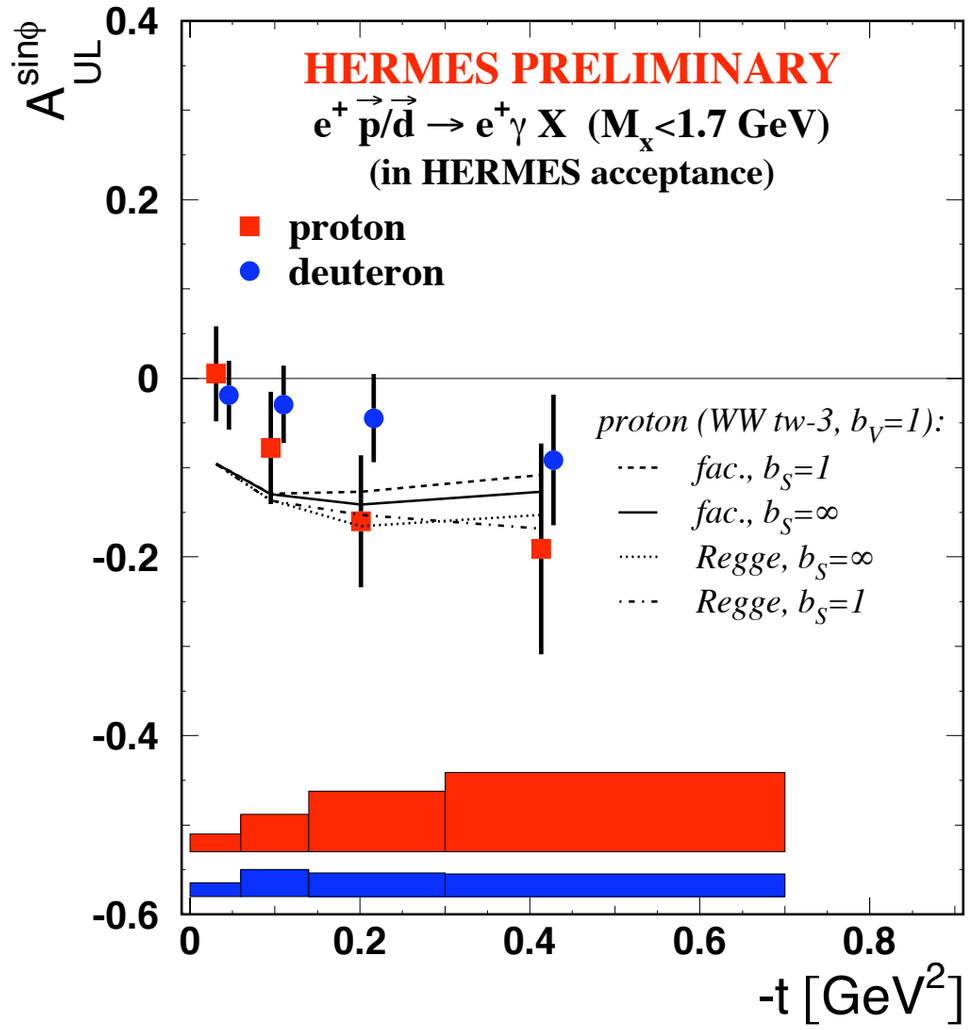
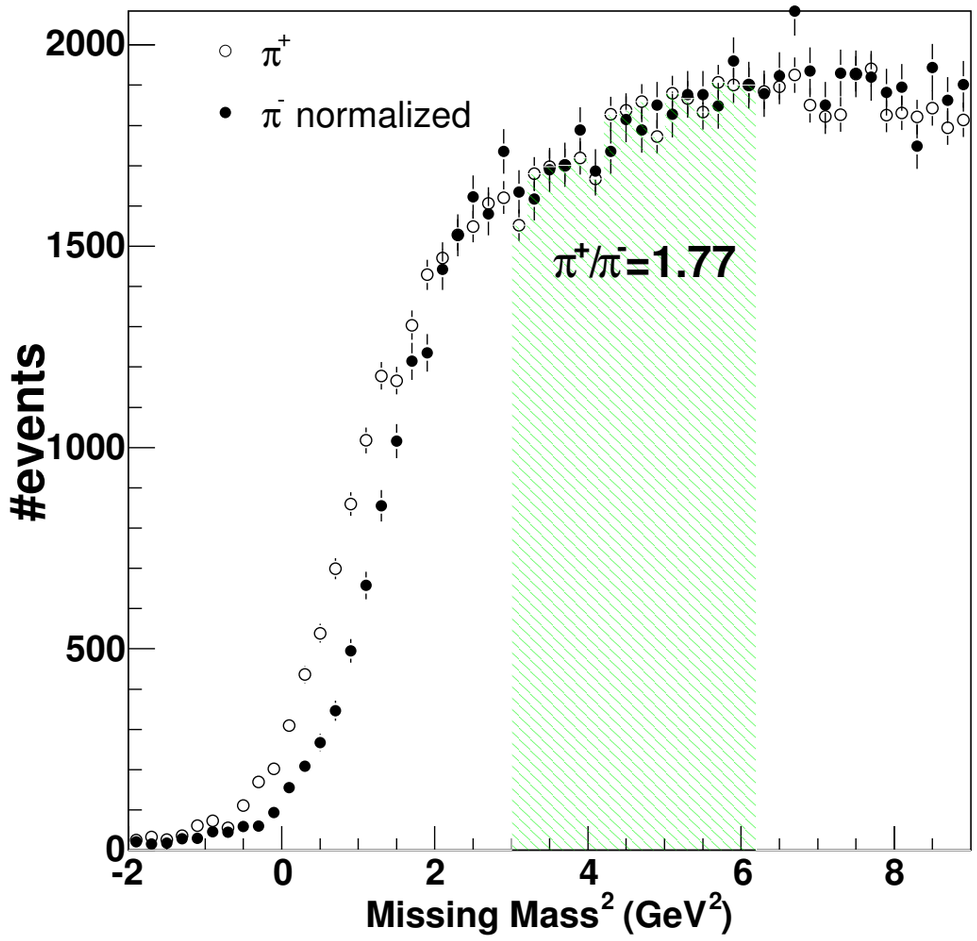
Longitudinal Target Spin Asymmetry

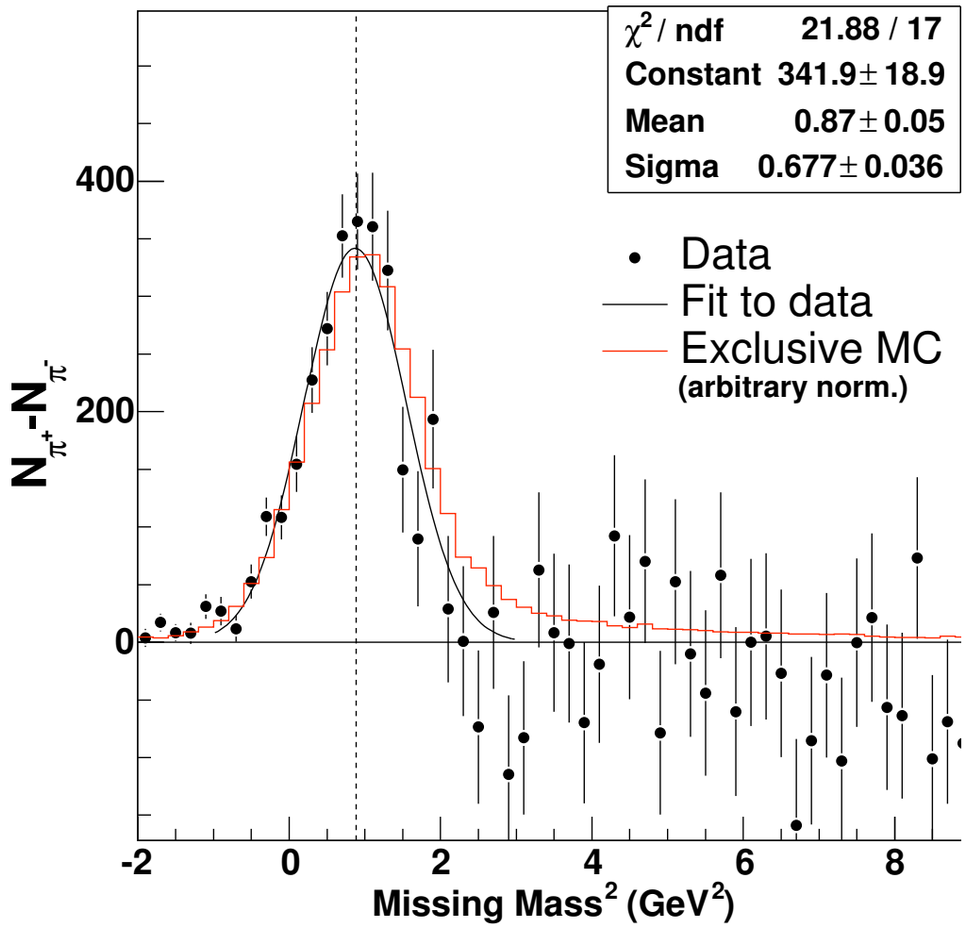




- first experimental observation of LTSA
- sizeable sin(ϕ) and sin(2ϕ) contributions
- sin(ϕ) gives access to $\tilde{H}$

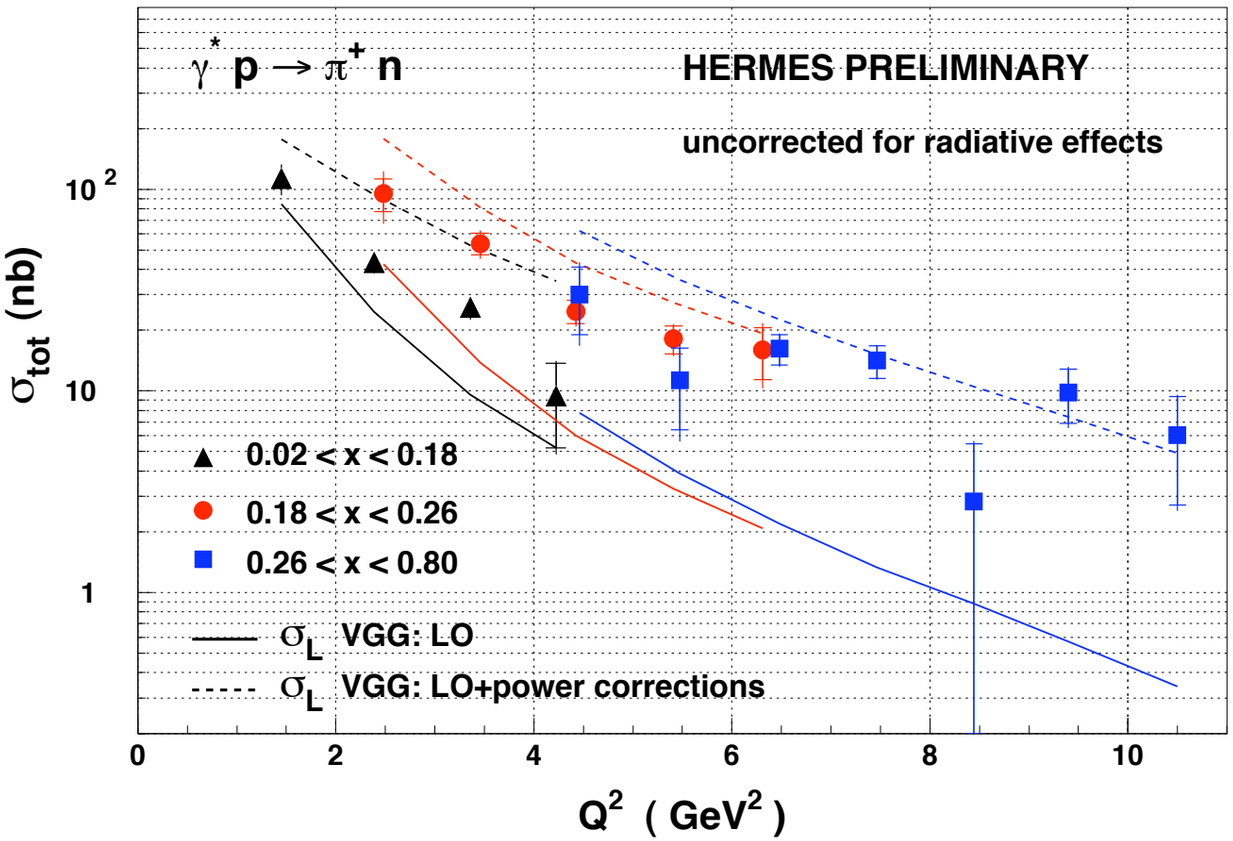
Exclusive Pion Production

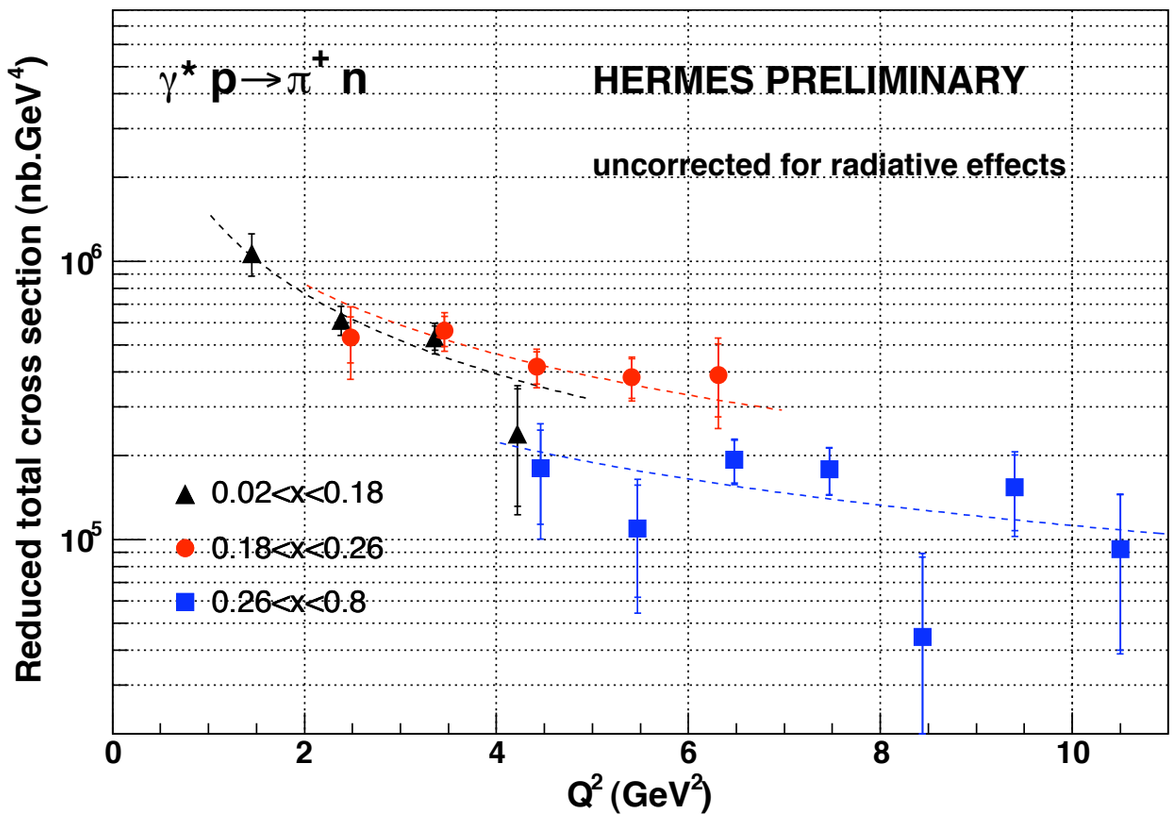




- sensitive to GPDs $\tilde{H}$ and $\tilde{E}$
- exclusivity by missing mass and subtraction of normalized π^- background
- cross checked by Monte Carlo based on GPD models

Cross Section Measurement

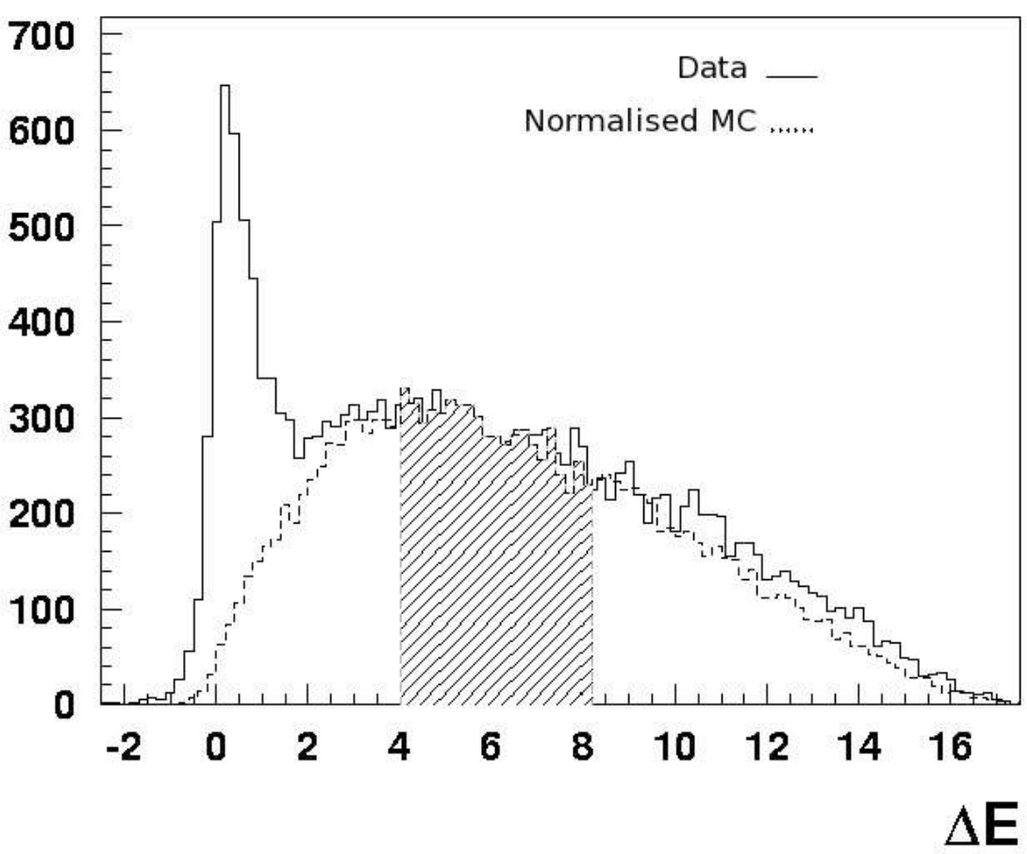


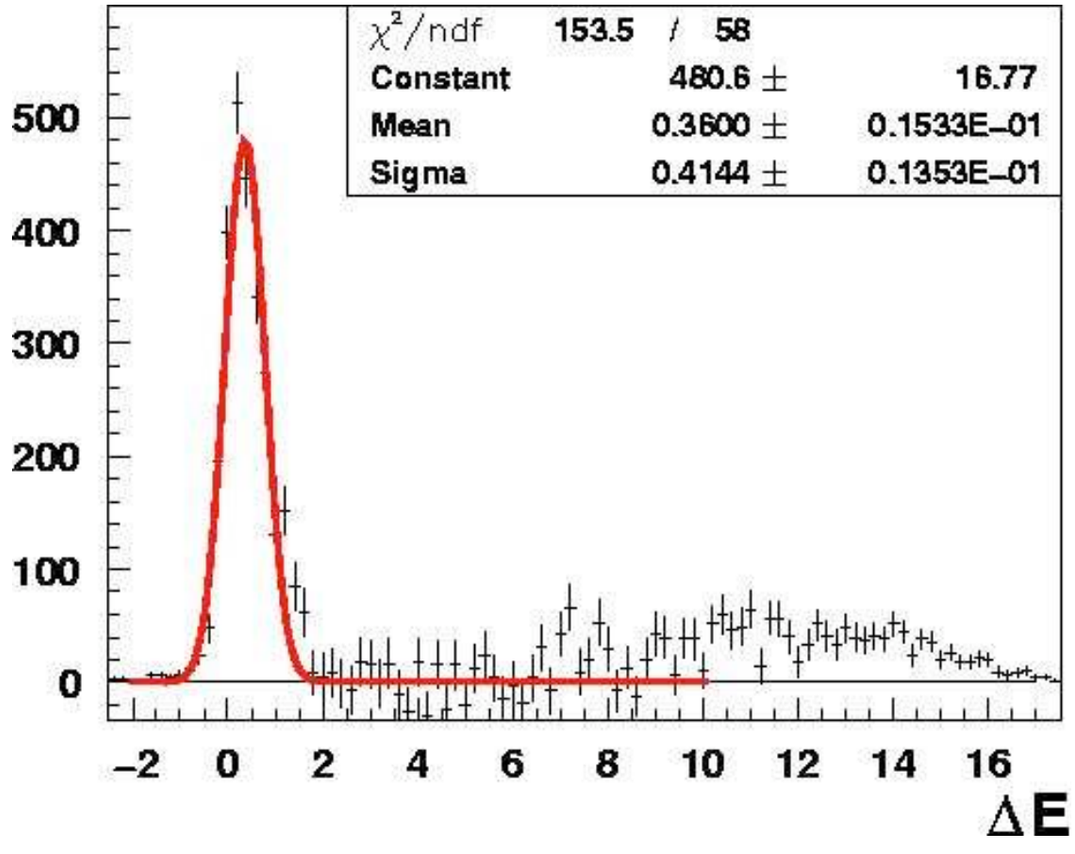


- dependence consistent with LO expectations, power corrections overestimate data
- reduced cross section in agreement with expectations

$$d\sigma = \frac{1}{16\pi}\frac{x^2}{1-x}\frac{1}{Q^4}\frac{1}{\sqrt{1+\frac{4M^2x^2}{Q^2}}}\sigma_{\text{reduced}} \qquad \sigma_{\text{reduced}} \propto \frac{1}{Q^2}$$

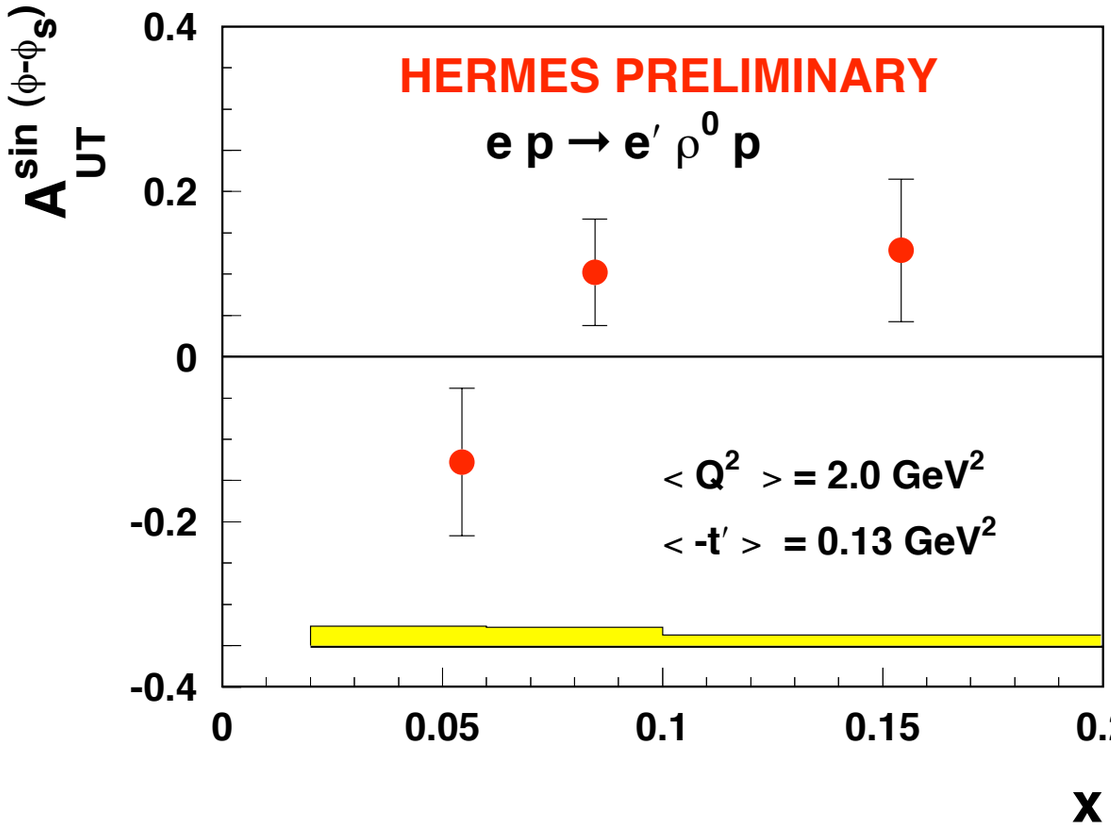
Exclusive ρ Production

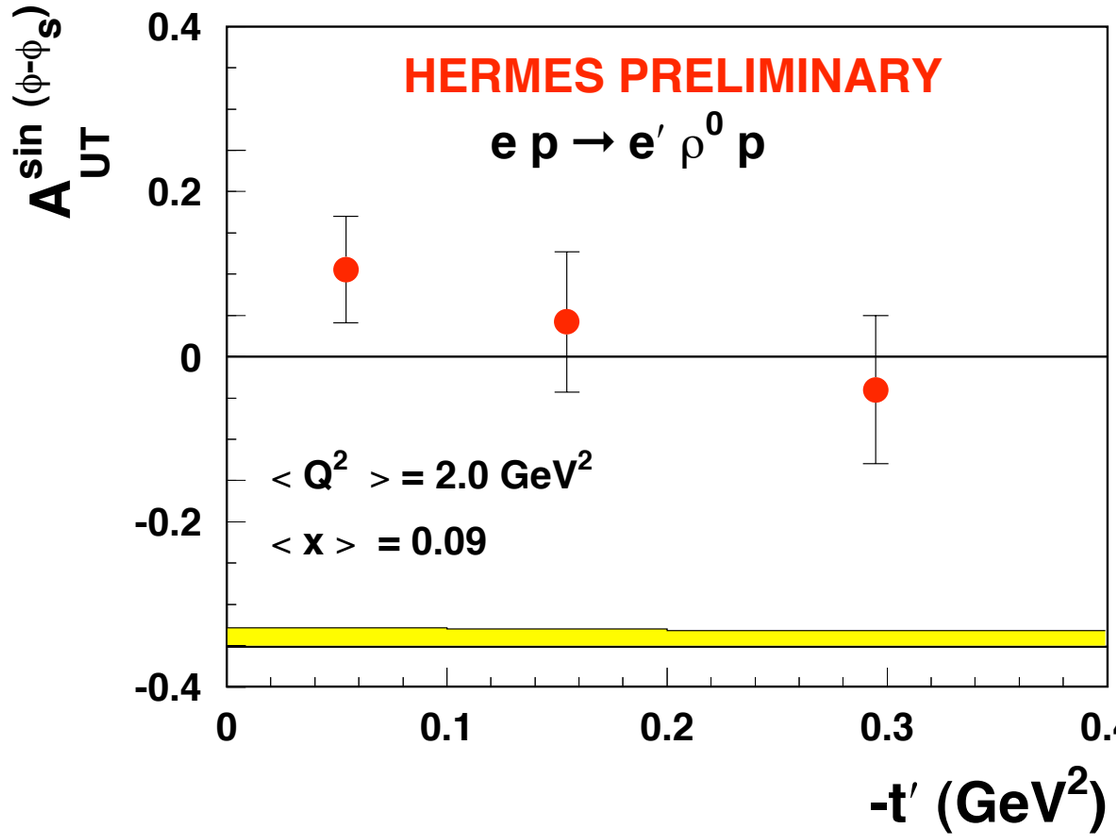




- filter for GPDs H and E
- identification using invariant mass of 2π system
- exclusivity established by ΔE cut and background subtraction

Target SSA in ρ production





- first measurement of A_{UT} for ρ production
- A_{UT} sensitive to total angular momentum of u-Quarks
- expect positive slope in x distribution; data consistent with theory predictions
- LT separation awaiting more statistics

Summary

- First measurements of transverse target asymmetries in DIS
- Non-zero Collins effect observed, hints at $H_d/H_f < 0$
- First evidence for non-zero Sivers function
- Subleading twist term dominate measurement with longitudinally polarised target
- access to GPDs in DVCS and HEMP
- BCA, BSA and LTSA measured in DVCS providing input to GPD models
- cross section of π production measured; allows model comparison
- first measurement of A_{UT} sensitive to total angular momentum of u-Quarks in ρ production

Outlook

- more data on tape for transversity analysis
- studies on extracting Sivers function and transversity
- transverse target spin asymmetries for DVCS
- target spin asymmetries for exclusive pion production to come soon
- LT separation for ρ under analysis
- study of hard exclusive reaction will be the main focus of HERMES after the installation of a dedicated recoil detector system this year