XI-th International Workshop **High Energy Spin Physics**

Can the total angular momentum of u-quarks in the nucleon be accessed at HERMES?

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keywords:

- Generalized Parton Distributions
- Proton Spin

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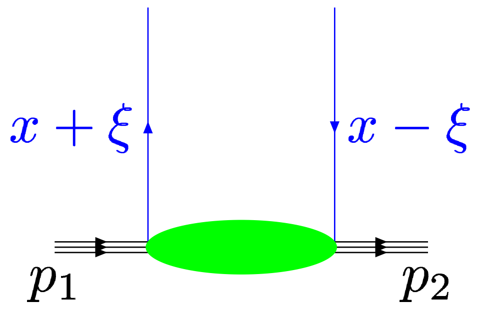
Generalized Parton Distributions



$$P^+\int\frac{dz^-}{2\pi}e^{\imath xP^+z^-}<p_2|\bar{q}(-\frac{z}{2})\gamma^+q(\frac{z}{2})|p_1>\Big|_{z^+=0,\vec{z}_\perp=0}=$$

$$=H_q(x,\xi,t)\bar{u}(p_2)\gamma^+u(p_1)+$$

$$+E_q(x,\xi,t)\bar{u}(p_2)\frac{\imath\sigma^{+\alpha}\Delta_\alpha}{2m}u(p_1)$$

Angular momentum sum rule [Ji,96]

$$J_q=\frac{1}{2}\int_{-1}^{1}x[H_q(x,\xi,0)+E_q(x,\xi,0)]dx$$

Ansatzing GPD H

$$H_q(x,\xi,t) = \frac{4m_p^2 - (1+\kappa^p)t}{4m_p^2 - t}\frac{1}{(1-t/0.71)^2}H_q(x,\xi)$$

$$H_q(x,\xi) \;=\; H_q^{DD}(x,\xi) \;+\; \theta(\xi - |x|)\,\frac{1}{N_f}\,D(\frac{x}{\xi})$$

$$H_q^{DD}(x,\xi) = \int_{-1}^{1} d\beta \;\int_{-1+|\beta|}^{1-|\beta|} d\alpha\;\delta(x-\beta-\alpha\xi)\;F_q(\beta,\alpha)$$

$$F_q(\beta,\alpha) = \frac{\Gamma(2b+2)}{2^{2b+1}\Gamma^2(b+1)}\;\frac{\left[(1-|\beta|)^2 - \alpha^2\right]^b}{(1-|\beta|)^{2b+1}}q(\beta)$$

$$D(z) = (1-z^2)\left[-4.0\;C_1^{3/2}(z) - 1.2\;C_3^{3/2}(z) - 0.4\;C_5^{3/2}(z)\right]$$

$$H_g^{DD}(x,\xi) = \int_{-1}^{1} d\beta \;\int_{-1+|\beta|}^{1-|\beta|} d\alpha\;\delta(x-\beta-\alpha\xi)\;\beta F_g(\beta,\alpha)$$

Provides polynomiality: $\int x^n H(x,\xi,t)dx = \sum_{i=0}^{n+1} \xi^i A_i(t)$

Ansatzing GPD E

$$E_q(x,\xi,t) = \frac{E_q(x,\xi)}{(1-t/0.71)^2}$$

$$E_q(x,\xi) = E_q^{DD}(x,\xi) - \theta(\xi - |x|) D_q\left(\frac{x}{\xi}\right)$$

$$E_q^{DD}(x,\xi) = \int_{-1}^{1} d\beta \int_{-1+|\beta|}^{1-|\beta|} d\alpha\, \delta(x-\beta-\alpha\xi)\, K_q(\beta,\alpha)$$

$$K_q(\beta,\alpha) = \frac{\Gamma(2b+2)}{2^{2b+1}\Gamma^2(b+1)} \frac{\left[(1-|\beta|)^2-\alpha^2\right]^b}{(1-|\beta|)^{2b+1}} e(\beta)$$

The spin-flip parton densities $e_q(x)$ can not be extracted from deep-inelastic scattering (DIS) data.

Inspired by the chiral quark soliton model,

$$e_q(x) = A_q q_{val}(x) + B_q \delta(x).$$

The coefficients A_q and B_q are constrained by Ji sum rule and the normalization condition

$$\int_{-1}^{+1} dx \; e_q(x) \;=\; \kappa_q$$

$$A_q = \frac{2\,J_q \;-\; M_q^{(2)}}{M_{q_{val}}^{(2)}}$$

$$B_u = 2\left[\frac{1}{2}\kappa_u - \frac{2J_u - M_u^{(2)}}{M_{u_{val}}^{(2)}}\right], \quad B_d = \kappa_d - \frac{2J_d - M_d^{(2)}}{M_{d_{val}}^{(2)}},$$

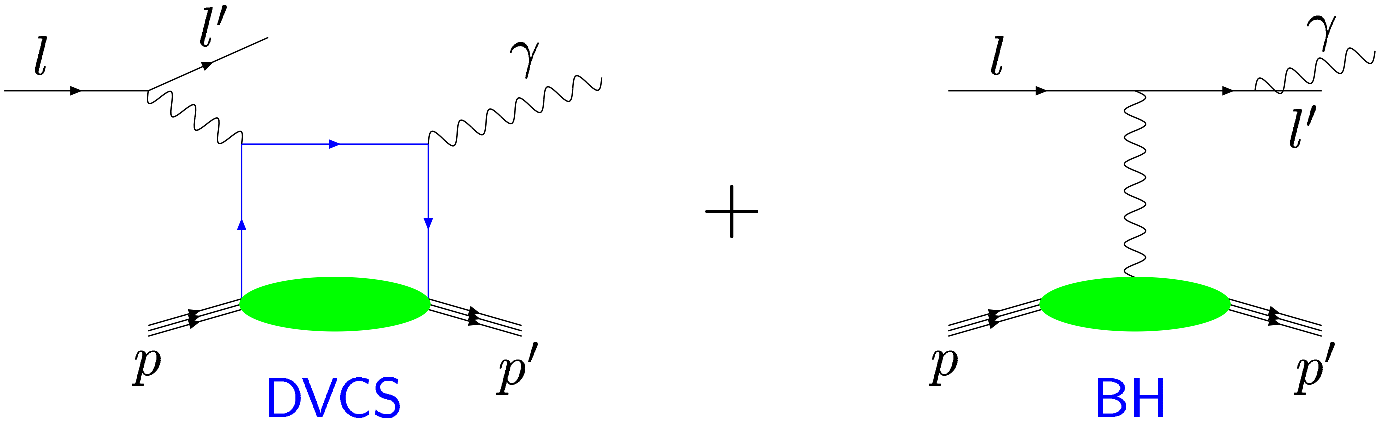
where

$$M_{q_{val}}^{(2)} = \int_0^1 x q_{val}(x) dx, \quad M_q^{(2)} = \int_0^1 x \left[q_{val}(x) + 2\bar{q}(x)\right] dx.$$

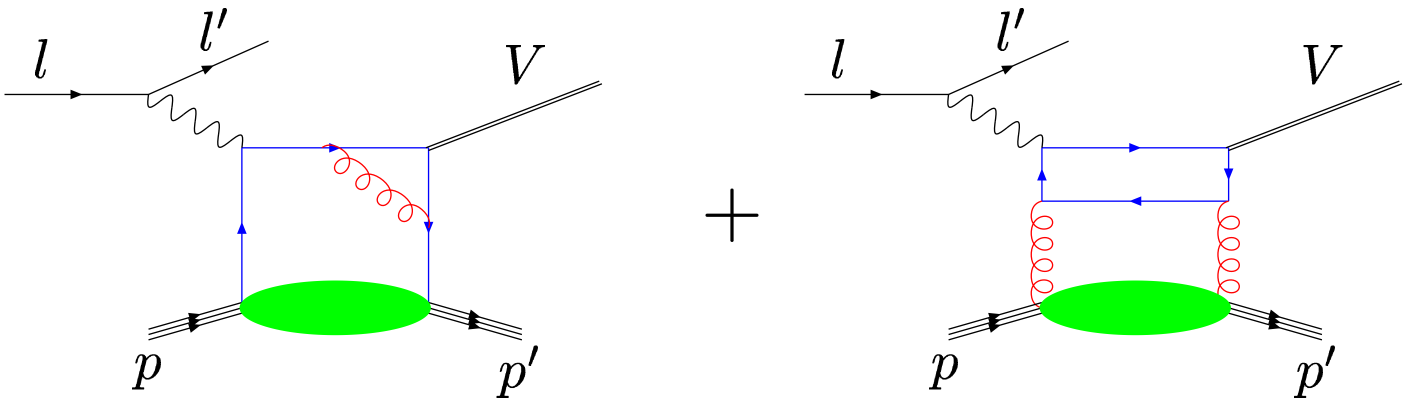
In the present calculation $E_g = 0$

GPDs at work:

i) $ep \to e'\gamma p'$



ii) $(\gamma_L^* p \to V p')$



In general

1)

$$\sigma_{DVCS}\,,\sigma_{VM} \quad \simeq \quad |H(\xi,\xi)|^2$$

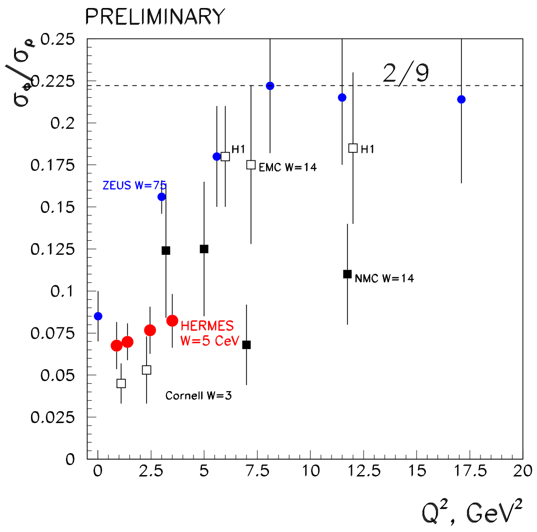
$$\mathrm{Transverse\ target-spin\ asymmetry}_{DVCS,VM} \quad \simeq \quad \frac{\int\, E(x,\xi)\,dx}{\int\, H(x,\xi)\,dx}$$

2)

$$ep \to e'\gamma p' : \qquad \sigma_{DVCS} \quad << \quad \sigma_{BH}(\mathrm{at\ HERMES})$$

$$\gamma_L^* p \to V p' : \qquad \sigma_{quark} \quad \approx \quad \sigma_{gluon}$$

Gluons in Vector Meson Electroproduction



$$\sigma_{\rho^0} = C|q+g|^2 = C(|q|^2+2|q||g|cos(\varphi_{qg})+|g|^2)$$

$$\sigma_\phi = \frac{2}{9}C|g|^2$$

$$\frac{\sigma_\phi}{\sigma_{\rho^0}} = \frac{2}{9}\frac{|g|^2}{|q|^2+2|q||g|+|g|^2}$$

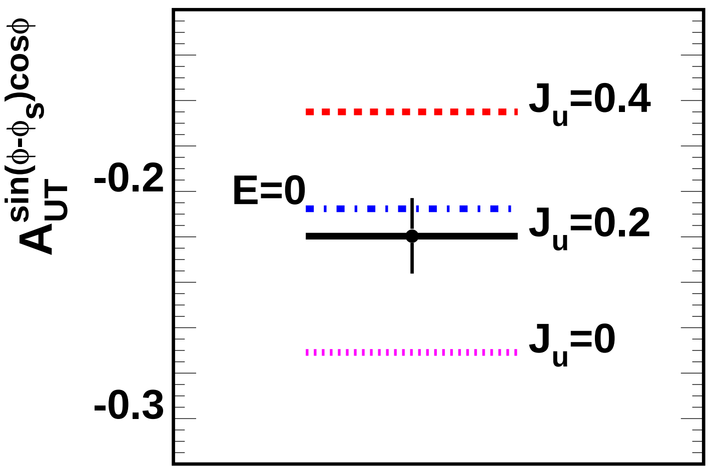
Using the value of $\sigma_\phi/\sigma_{\rho^0}$ measured at HERMES, one gets

$$\frac{|q|}{|g|}_{HERMES} \approx 0.7$$

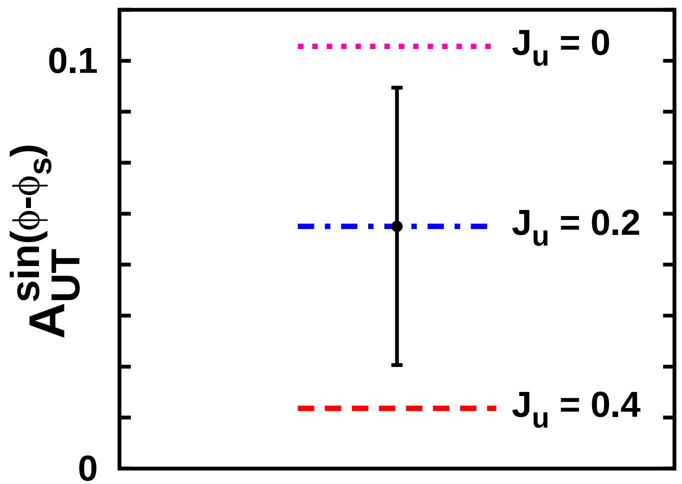
in line with the result of the present calculation, $|q|/|g|$=0.65÷0.8.

Expectations for the Transverse Target-Spin Asymmetry

$ep \to e'\gamma p'$



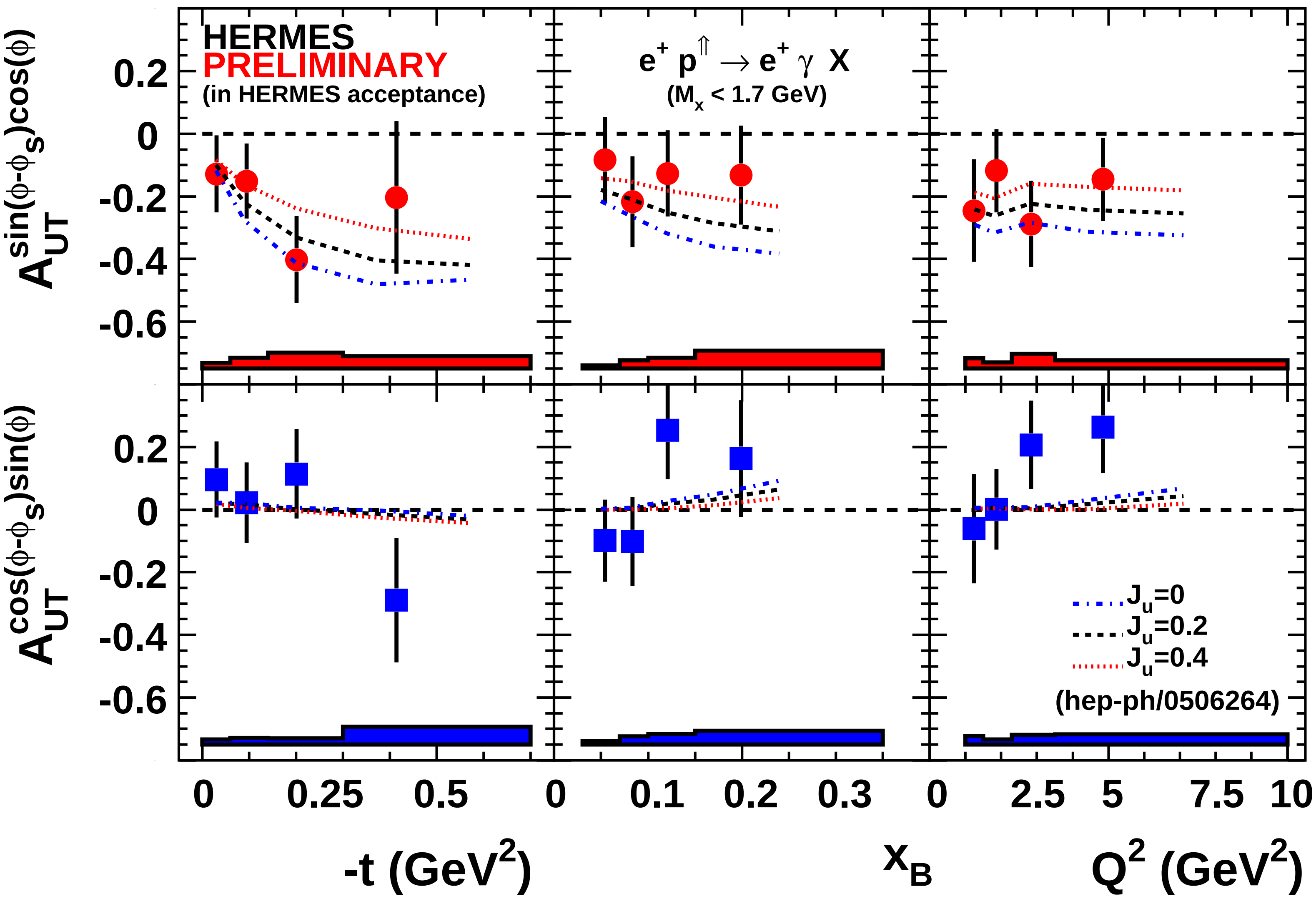
$\gamma_L^* p \to \rho^0 p'$



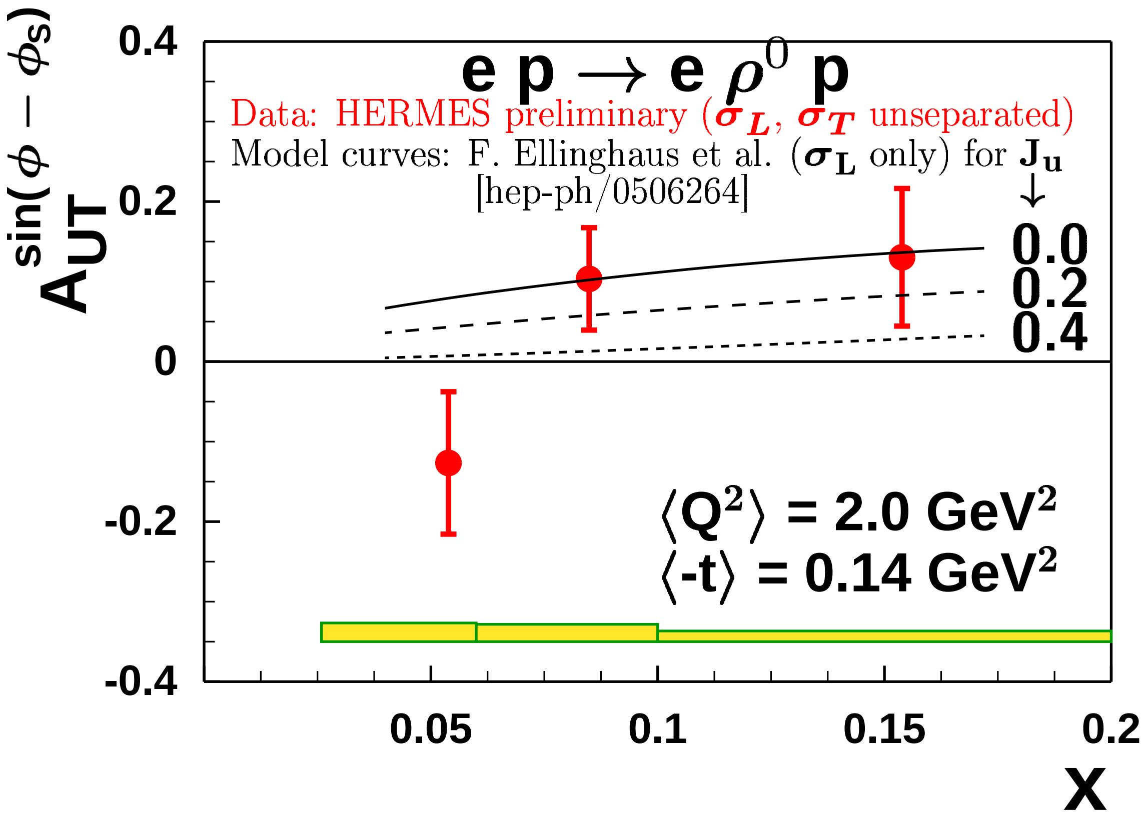
Difference in J_u from zero to 0.4 corresponds to a 4σ effect

Difference in J_u from zero to 0.4 corresponds to a 2σ effect

Note: the predictions are based on the model parameterization. The model, however, is reasonable. It provides: correct forward limit, form factors, magnetic moments, Ji sum rule, polynomiality, agreement with the chiral bag model.



HERMES
PRELIMINARY
(in HERMES acceptance)
$e^+ p^{\Uparrow} \rightarrow e^+ \gamma\ X$
(M_x < 1.7 GeV)
$A_{UT}^{\sin(\phi-\phi_S)\cos(\phi)}$
$A_{UT}^{\cos(\phi-\phi_S)\sin(\phi)}$
J_u=0
J_u=0.2
J_u=0.4
(hep-ph/0506264)
-t (GeV^2)
x_B
Q^2 (GeV^2)



e p → e ρ0 p
Data: HERMES preliminary (σL, σT unseparated)
Model curves: F. Ellinghaus et al. (σL only) for Ju
[hep-ph/0506264]
0.0
0.2
0.4
⟨Q2⟩ = 2.0 GeV2
⟨-t⟩ = 0.14 GeV2
A_UT^sin(φ − φs)
0.4
0.2
0
-0.2
-0.4
0.05
0.1
0.15
0.2
x

Conclusions

- Based on reasonable model parameterization of GPDs H and E the transverse target spin asymmetry for the $ep \to e'\gamma p'$ and $\gamma_L^* p \to \rho^0 p'$ processes in HERMES kinematics is calculated. It is found that a change in J_u from zero to 0.4 corresponds to a 4σ (2σ) difference in the calculated transverse target-spin asymmetry in deeply virtual Compton scattering (ρ^0 electroproduction), where σ is the total experimental uncertainty.

- Preliminary results from HERMES favor $J_u \approx 0.4$. The data are not precise enough yet, but more data with better quality (recoil detector) is expected.

- If the the values of J_u would be found different in DVCS and ρ^0 electroproduction, a straightforward explaination would be large E_g.