Transverse Target spin asymmetry of exclusive production of ρ^0 mesons

DIS 07, Munich

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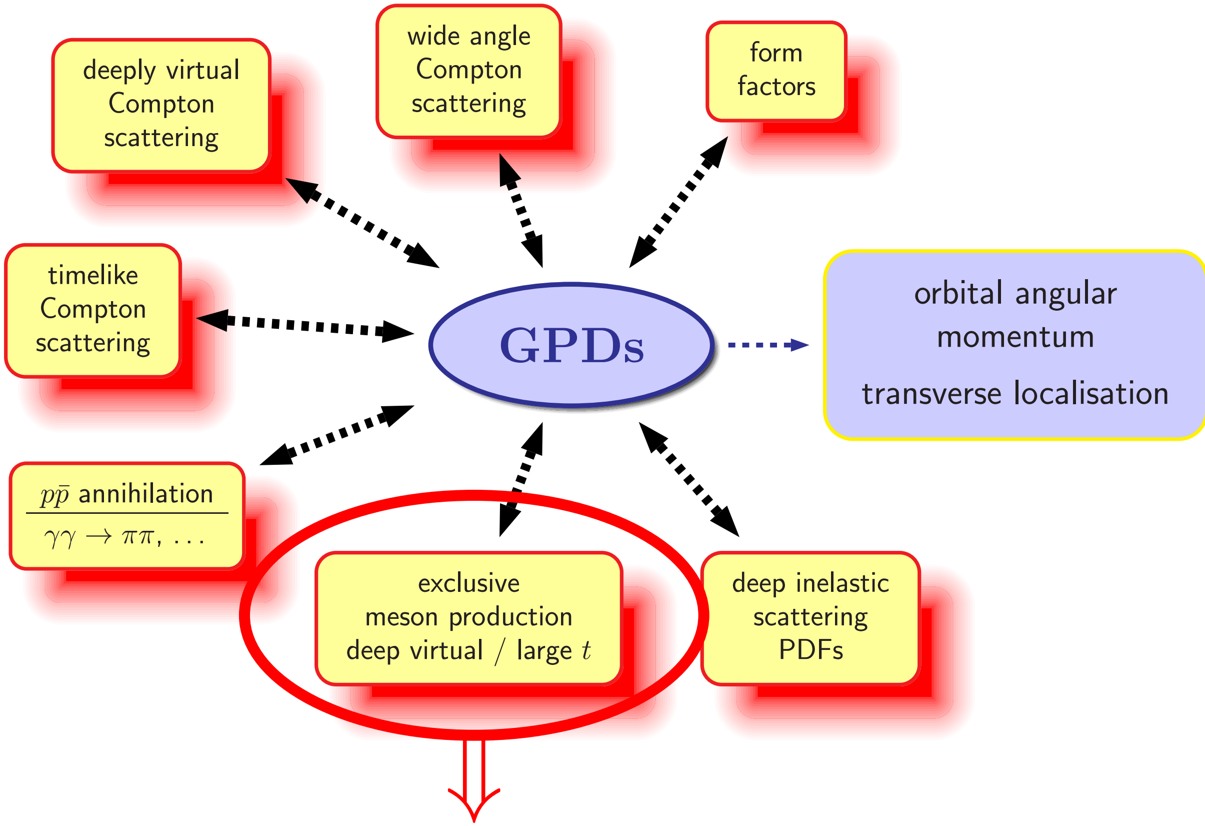
(on behalf of the HERMES collaboration)

(DESY, NIKHEF)

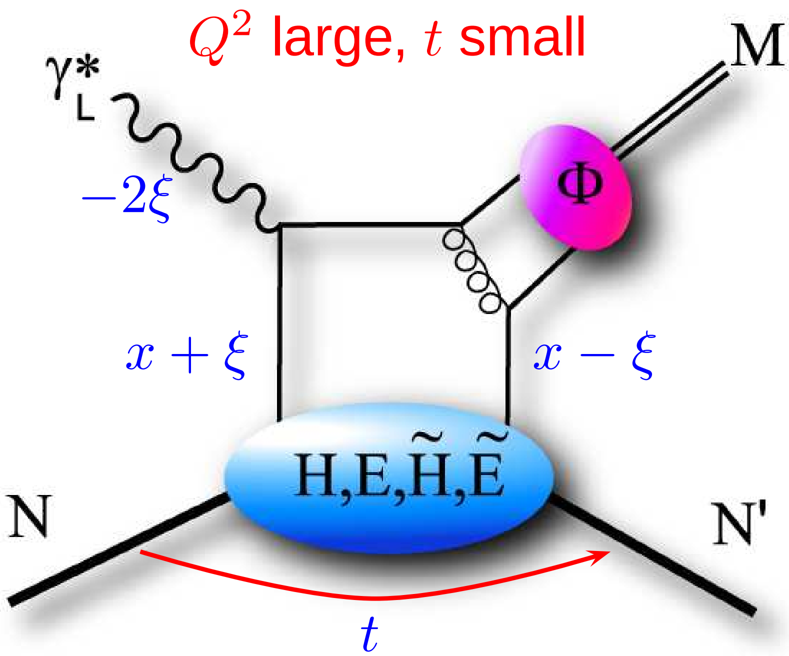
Access to GPDs



- vector mesons (ρ, ω, ϕ): unpolarized GPDs: H, E
- Ji sum rule: *- Ji,PRL 78 (1997) 610 -*

$$\frac{1}{2}\int_{-1}^{1} dx\, x\, [H(x,\xi,t) + E(x,\xi,t)] \stackrel{t\to 0}{=} J_q \;=\; \frac{1}{2}\Delta\Sigma + L_q$$

Factorization theorem



-Collins, Frankfurt, Strikman (1997)-

$x+\xi$	longitudinal momentum fraction of the quark
-2ξ	exchanged longitudinal momentum fraction
t	squared momentum transfer

- Factorization for longitudinal photons only
- Suppression of transverse component of the X-section:

$$\frac{\sigma_T}{\sigma_L} \sim \frac{1}{Q^2}$$

- for HERMES kinematics ($< Q^2 >= 2$ GeV^2):

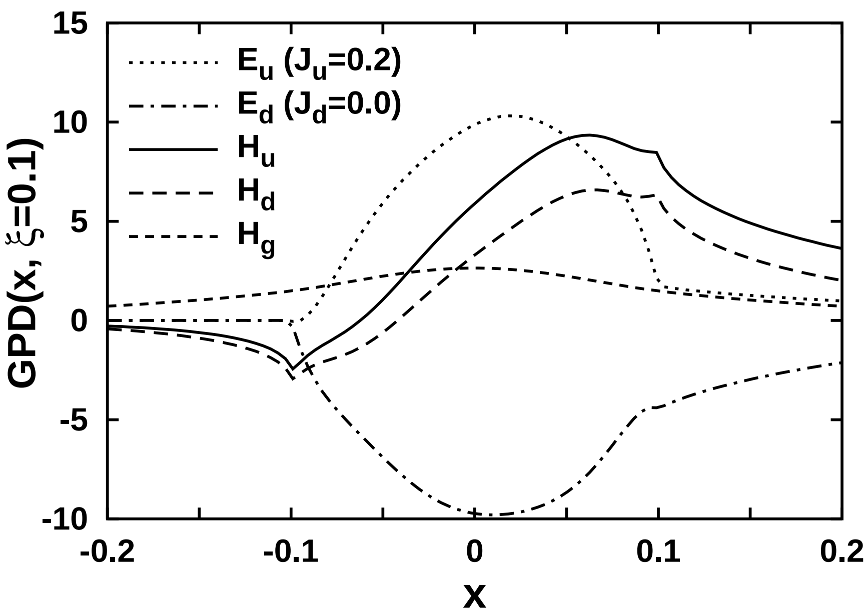
$$R = \frac{\sigma_L}{\sigma_T} \approx 1$$

Advantage of exclusive ρ^0 production

- gluons and quarks enter at the same order of α_s
- gluon GPDs can be probed (for $x_B < 0.2$)

no model for E_g

-Ellinghaus,Nowak,Vinnikov,Ye (2005)-



-VGG code-

- expectation: E_g is not large

- Diehl (2003) -

$$\int_0^1 dx\, E_g + \sum_q \int_{-1}^1 dx\, xE_q = 0$$

- $E_u \approx -E_d$
- E_s - small
- $E_g = 0$: 'passive' gluons

Advantage of TTSA

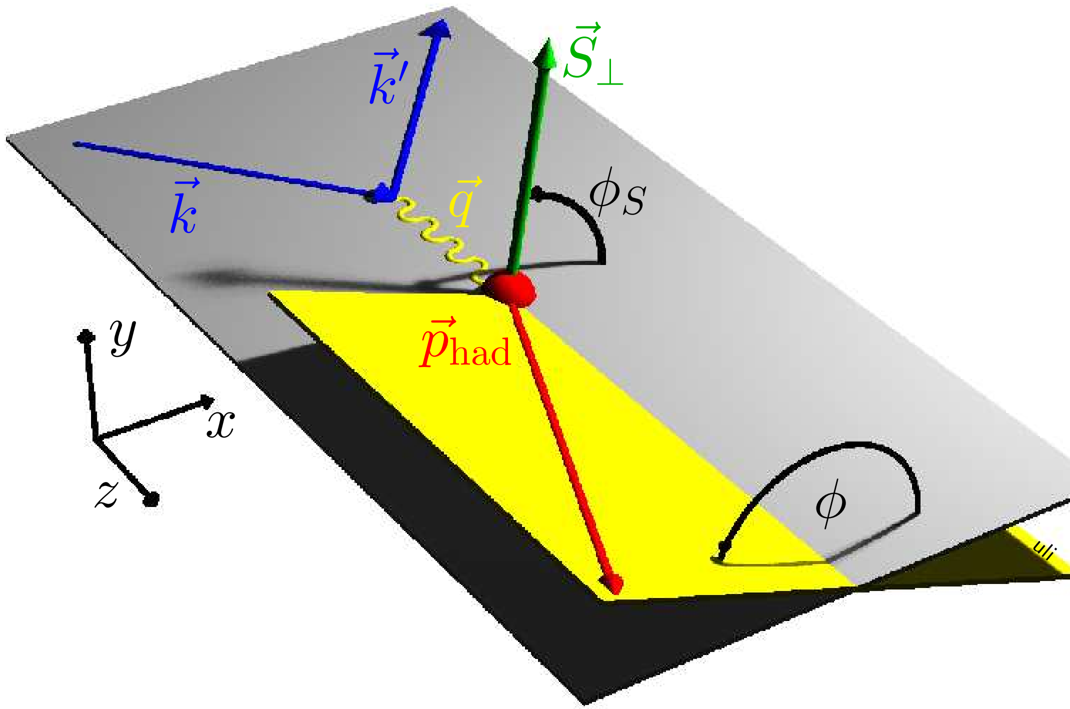
- higher order corrections in α_s cancel
- E is kinematically not suppressed
- linear dependence on GPDs:

$$A_{UT}^{\sin(\phi-\phi_s)} \sim \frac{E}{H} \sim \frac{E_q + E_g}{H_q + H_g}$$

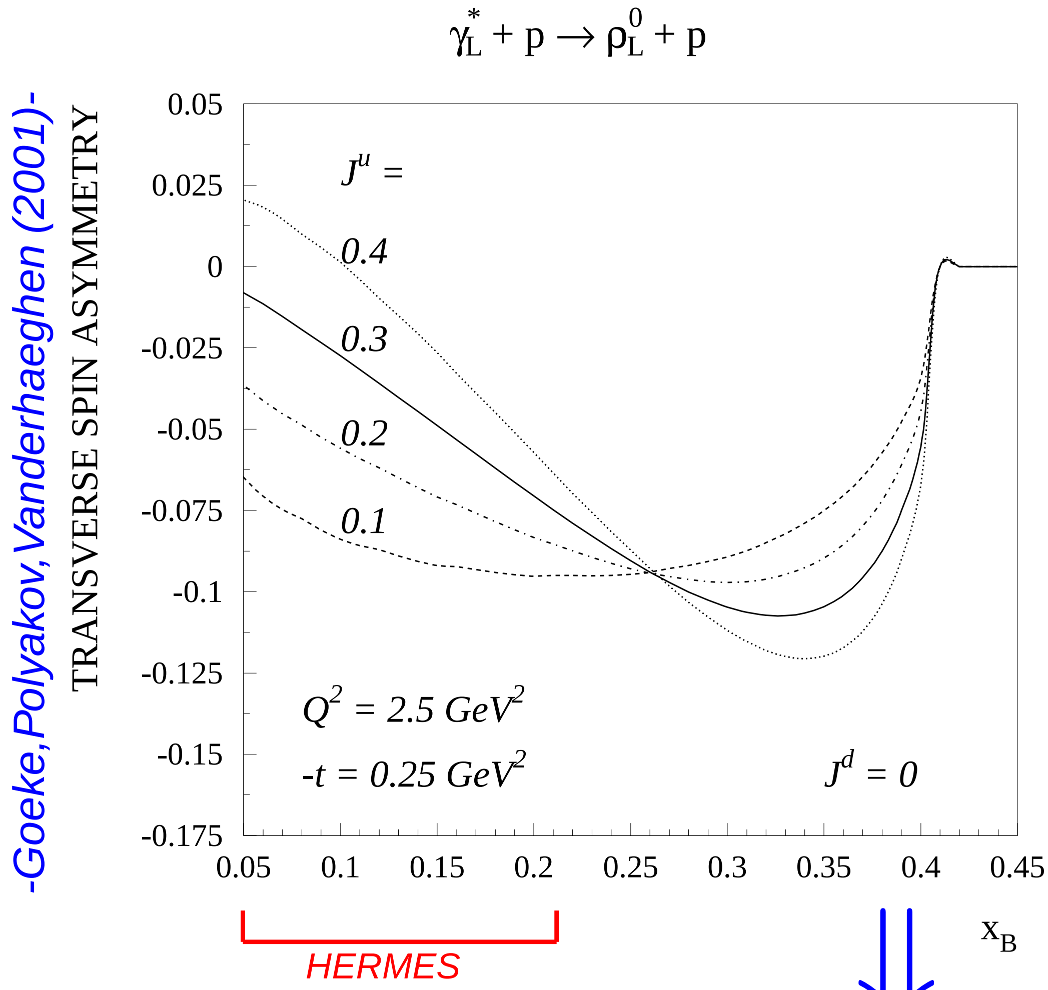
- all the calculations:

$$E_q = E_u + E_d \qquad E_g = 0$$

- Transverse target spin asymmetry (TTSA) is promising observable which allow an access to E

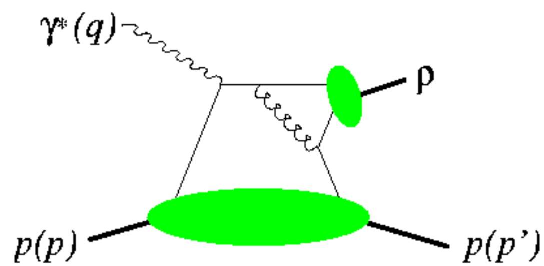


Available theoretical predictions



$\Rightarrow$

- quark exchange dominance



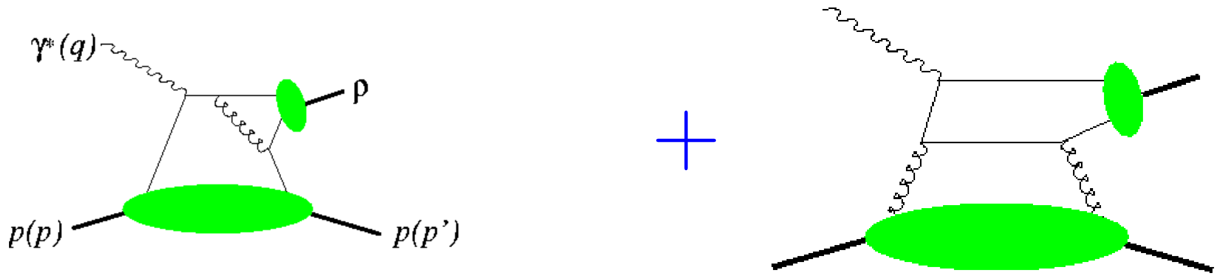
- Trento convention:

$$A_{UT,Trento}^{\sin(\phi-\phi_s)} = -\frac{\pi}{2}\mathcal{A}_{GPV}^{\sin(\phi-\phi_s)}$$

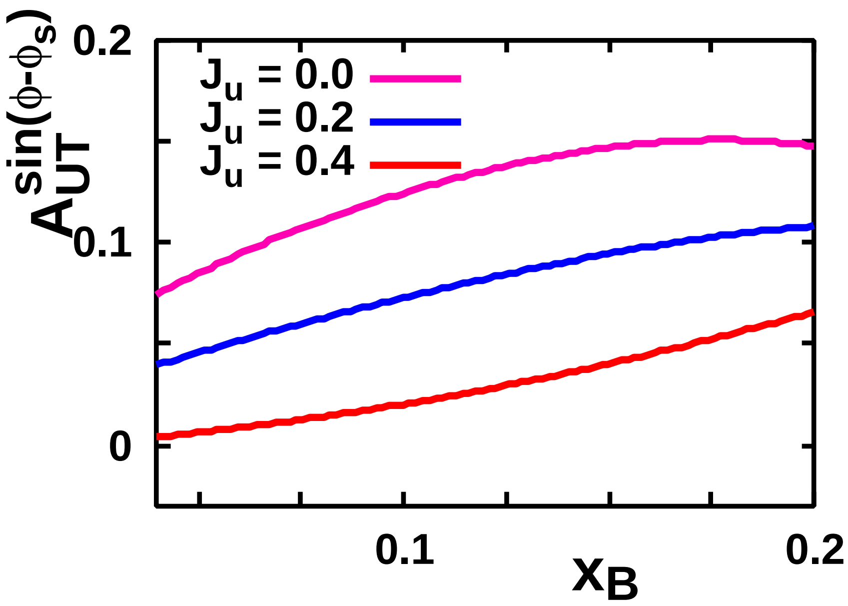
E is sensitive to $2J^u + J^d$

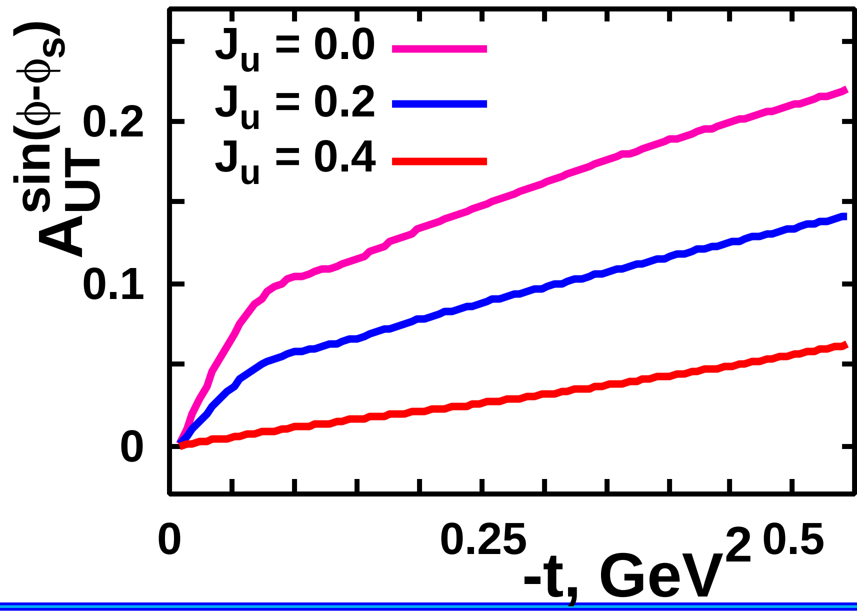
Alternative theoretical predictions

- quark and gluon exchange mechanisms are taken into account



- all following plots use Trento conventrion
- $E_g = 0,\ H_g \neq 0$





-Ellinghaus,Nowak,Vinnikov,Ye (2005)-

Definition of TTSA

- The asymmetry defined w.r.t. the virtual photon direction:

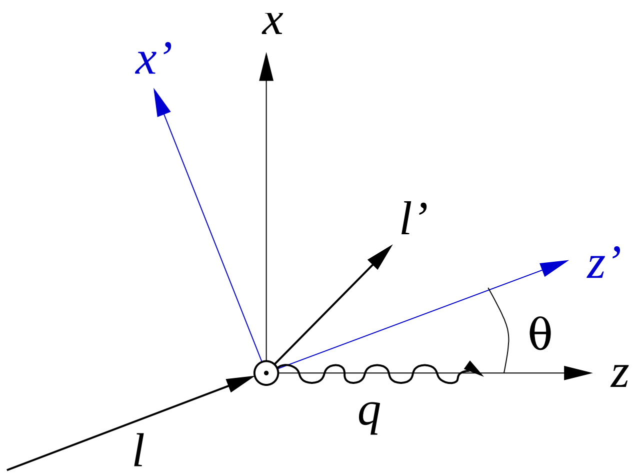
$$A_{UT}^{\gamma^*}(\phi_s) = \frac{1}{S_T}\frac{d\sigma(\phi,\phi_s) - d\sigma(\phi,\phi_s+\pi)}{d\sigma(\phi,\phi_s) + d\sigma(\phi,\phi_s+\pi)}$$

- The asymmetry defined w.r.t. the lepton beam direction:

$$A_{UT}^{l}(\phi_s) = \frac{1}{P_T}\frac{d\sigma(\phi,\phi_s) - d\sigma(\phi,\phi_s+\pi)}{d\sigma(\phi,\phi_s) + d\sigma(\phi,\phi_s+\pi)}$$

$$S_T = \frac{\cos\theta_\gamma}{\sqrt{1-\sin^2\theta_\gamma\,\sin^2\phi_S}}P_T$$

$$S_L = \frac{\sin\theta_\gamma\,\cos\phi_S}{\sqrt{1-\sin^2\theta_\gamma\,\sin^2\phi_S}}P_T$$



lepton plane

$$P_T A_{UT}^{l}(\phi_s) = S_T A_{UT}^{\gamma^*}(\phi_s) + S_L A_{UL}^{\gamma^*}$$

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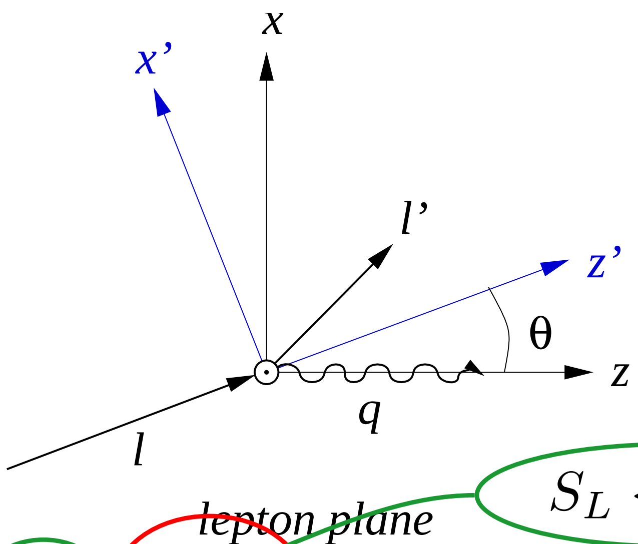
$$S_L = \frac{\sin\theta_\gamma\,\cos\phi_S}{\sqrt{1-\sin^2\theta_\gamma\,\sin^2\phi_S}}P_T$$



$$P_T A_{UT}^{l}(\phi_s) = S_T A_{UT}^{\gamma^*}(\phi_s) + S_L\, A_{UL}^{\gamma^*}$$

$S_L << S_T$

$A_{UL}^{\gamma^*} \approx 0$

Polarized Cross Section

$$\left[\frac{\alpha_{\rm em}}{8\pi^3}\,\frac{y^2}{1-\varepsilon}\,\frac{1-x_B}{x_B}\,\frac{1}{Q^2}\right]^{-1}\frac{d^4\sigma}{dx_B\,dQ^2\,d\phi\,d\phi_s}=$$

$$\frac{1}{2}\left(\sigma_{++}^{++}+\sigma_{++}^{--}\right)+\varepsilon\,\sigma_{00}^{++}$$

$$-\varepsilon\cos(2\phi)\,\Re\sigma_{+-}^{++}-\sqrt{\varepsilon(1+\varepsilon)}\cos\phi\,\Re(\sigma_{+0}^{++}+\sigma_{+0}^{--})$$

$$-\frac{P_T}{\sqrt{1-\sin^2\theta_\gamma\,\sin^2\phi_S}}\Bigg[\sin\phi_S\,\cos\theta_\gamma\sqrt{\varepsilon(1+\varepsilon)}\,\Im\sigma_{+0}^{+-}$$

$$+\sin(\phi-\phi_S)\left(\cos\theta_\gamma\,\Im(\sigma_{++}^{+-}+\varepsilon\,\sigma_{00}^{+-})+\frac{1}{2}\sin\theta_\gamma\sqrt{\varepsilon(1+\varepsilon)}\,\Im(\sigma_{+0}^{++}-\sigma_{+0}^{--})\right)$$

$$+\sin(\phi+\phi_S)\left(\cos\theta_\gamma\,\frac{\varepsilon}{2}\,\Im\sigma_{+-}^{+-}+\frac{1}{2}\sin\theta_\gamma\sqrt{\varepsilon(1+\varepsilon)}\,\Im(\sigma_{+0}^{++}-\sigma_{+0}^{--})\right)$$

$$+\sin(2\phi-\phi_S)\left(\cos\theta_\gamma\sqrt{\varepsilon(1+\varepsilon)}\,\Im\sigma_{+0}^{-+}+\frac{1}{2}\sin\theta_\gamma\,\varepsilon\,\Im\sigma_{+-}^{++}\right)$$

$$+\sin(2\phi+\phi_S)\,\frac{1}{2}\sin\theta_\gamma\,\varepsilon\,\Im\sigma_{+-}^{++}+\sin(3\phi-\phi_S)\,\cos\theta_\gamma\,\frac{\varepsilon}{2}\,\Im\sigma_{+-}^{-+}\Bigg]$$

-Diehl, Sapeta (2005)-

X-section decomposition in terms of:

$\sigma_{mn}^{ij}\ (\gamma^* p \to \rho^0 p)$

virtual photon helicity: $m, n = 0, \pm 1$

proton spin state: $i, j = \pm(\frac{1}{2})$

L/T separation of the $\gamma^* p$ X-section

$$\Im(\sigma_{++}^{+-} + \epsilon\sigma_{00}^{+-})$$

$$d\sigma(\phi,\phi_s) = \sigma_0 + \sigma_1|\vec{S}_\perp|\sin(\phi-\phi_s) + \sigma_2|\vec{S}_\perp|\frac{\epsilon}{2}\sin(\phi+\phi_s)\ldots$$

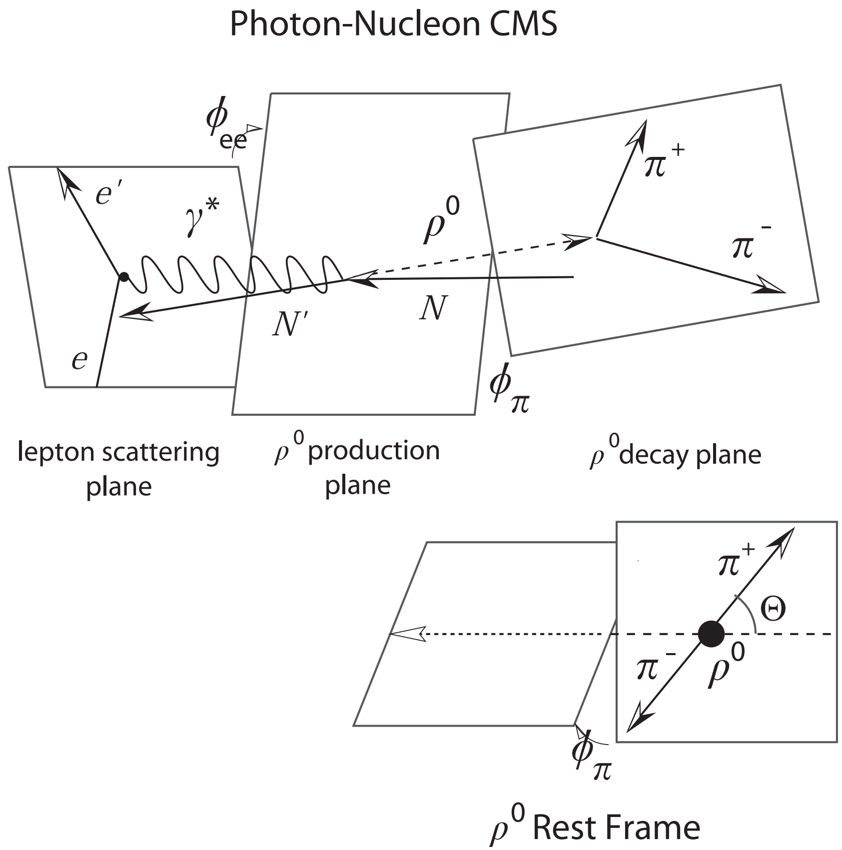
$$\sigma_T + \epsilon\sigma_L$$

- Diehl, Sapeta (hep-ph/0503023) -

σ_{mn}^{ij}: different dependences on $\cos\theta$

$$\frac{d\sigma_{mn}^{ij}(\gamma^* p \to \pi^+\pi^- p)}{d(\cos\theta)} = \frac{3\cos^2\theta}{2}\sigma_{mn}^{ij}(\gamma^* p \to \rho_L^0 p) + \frac{3\sin^2\theta}{4}\sigma_{mn}^{ij}(\gamma^* p \to \rho_T^0 p)$$

Under the assumption of SCHC a ρ_L^0, ρ_T^0 is equivalent γ_L^*, γ_T^*, separation



TTSA and ρ^0_L/ρ^0_T separation

Angular distribution $W(P_T, \cos\theta, \phi, \phi_s)$ can be written in terms of asymmetries:

$$W(P_T, \cos\theta, \phi, \phi_s) \;\propto$$

$$\Big[\quad \cos^2\theta \;\; r^{04}_{00} \;\; \Big(1 + A_{UU,\rho_L}(\phi) + P_T A^l_{UT,\rho_L}(\phi, \phi_s)\Big) \; +$$

$$\frac{1}{2}\sin^2\theta \; (1 - r^{04}_{00})\Big(1 + A_{UU,\rho_T}(\phi) + P_T A^l_{UT,\rho_T}(\phi, \phi_s)\Big) \quad \Big]$$

TTSA and ρ^0_L/ρ^0_T separation

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$$\frac{1}{2}\sin^2\theta \; (1 - r^{04}_{00})\Big(1 + A_{UU,\rho_T}(\phi) + P_T A^l_{UT,\rho_T}(\phi, \phi_s)\Big) \Big]$$

where $A_{UU}(\phi)$ and $A^l_{UT}(\phi, \phi_s)$ are parametrized as:

$$A_{UU}(\phi) = A^{\cos(\phi)}_{UU} \cos(\phi) + A^{\cos(2\phi)}_{UU} \cos(2\phi)$$

TTSA and ρ_L^0/ρ_T^0 separation

Angular distribution $W(P_T, \cos\theta, \phi, \phi_s)$ can be written in terms of asymmetries:

$$W(P_T, \cos\theta, \phi, \phi_s) \;\propto$$

$$\Big[\quad \cos^2\theta \;\; r_{00}^{04} \; \Big(1 + A_{UU,\rho_L}(\phi) + P_T \; A_{UT,\rho_L}^{l}(\phi,\phi_s)\Big) +$$

$$\frac{1}{2}\sin^2\theta \; (1 - r_{00}^{04})\Big(1 + A_{UU,\rho_T}(\phi) + P_T \; A_{UT,\rho_T}^{l}(\phi,\phi_s)\Big) \qquad \Big]$$

where $A_{UU}(\phi)$ and $A_T^l(\phi,\phi_s)$ are parametrized as:

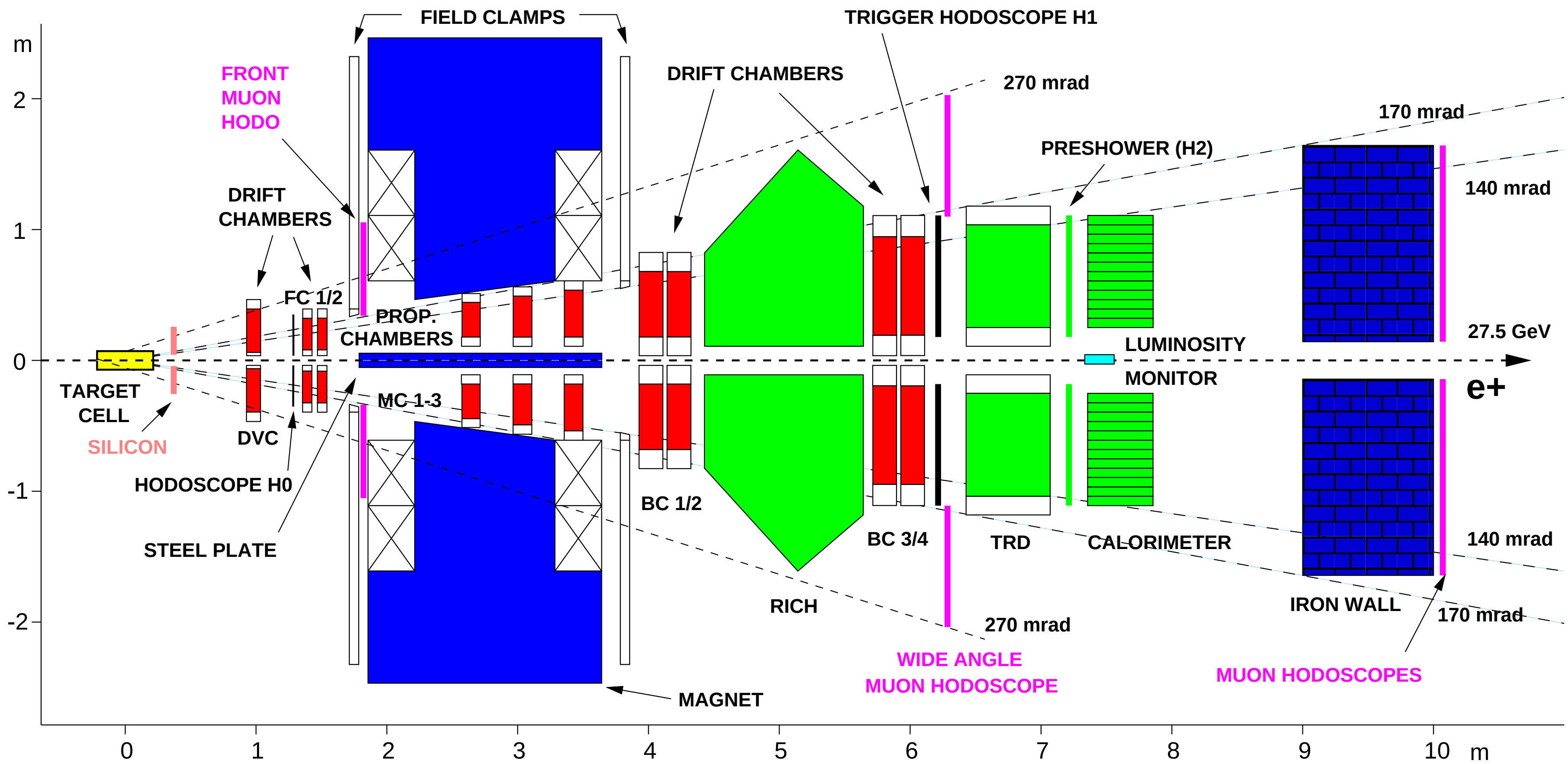
$$A_{UU}(\phi) = A_{UU}^{\cos(\phi)} \cos(\phi) + A_{UU}^{\cos(2\phi)} \cos(2\phi)$$

$$A_{UT}^{l}(\phi,\phi_s) \;\; = \;\; A_{UT}^{\sin(\phi_s)} \sin(\phi_s) \; + \; A_{UT}^{\sin(\phi-\phi_s)} \sin(\phi-\phi_s) \; +$$

$$A_{UT}^{\sin(\phi+\phi_s)} \sin(\phi+\phi_s) \; + \; A_{UT}^{\sin(2\phi-\phi_s)} \sin(2\phi-\phi_s) \; +$$

$$A_{UT}^{\sin(2\phi+\phi_s)} \sin(2\phi+\phi_s) \; + \; A_{UT}^{\sin(3\phi-\phi_s)} \sin(3\phi-\phi_s)$$

The HERMES spectrometer



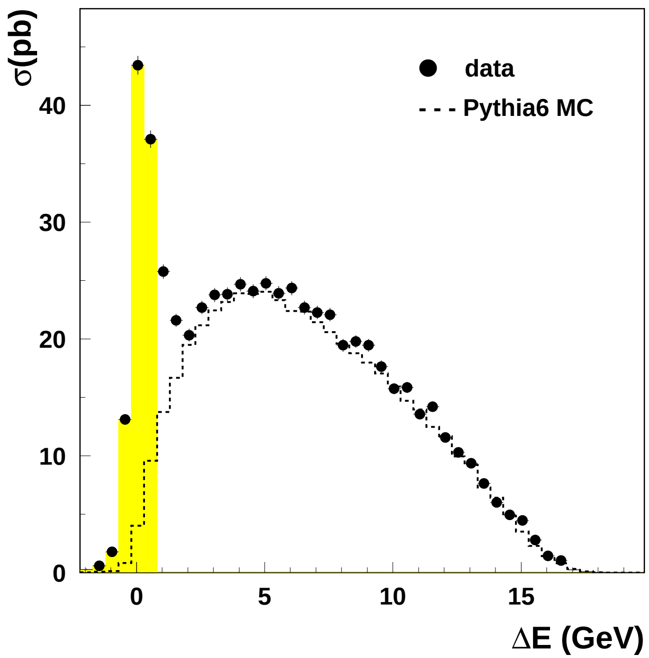
- fixed target experiment
- forward spectrometer
- transverse target (2002-2005): $P_T = 72.4\%$

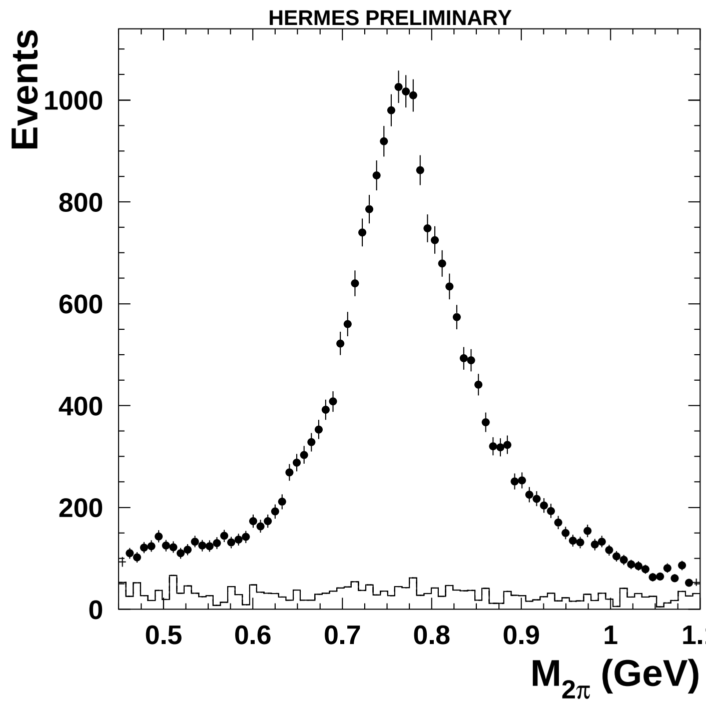
Exclusive production: ($ep \to e'p\rho^0$)

$\rho^0 \to \pi^+ \pi^-$

- no recoil detection at this time
- exclusive ρ^0 sample through the energy and momentum transfer:

$$\Delta E = \frac{M_x^2 - M_p^2}{2M_p} \qquad t' = t - t_0$$





Asymmetry extraction

Asymmetries are extracted with Unbinned Maximum Likelihood fit

$$W(P_T, \cos\theta, \phi, \phi_s) \propto$$

$$\Big[\quad \cos^2\theta \;\; r^{04}_{00} \; \Big(1 + A_{UU,\rho_L}(\phi) + P_T A^l_{UT,\rho_L}(\phi, \phi_s)\Big) \; +$$

$$\frac{1}{2}\sin^2\theta \; (1 - r^{04}_{00})\Big(1 + A_{UU,\rho_T}(\phi) + P_T A^l_{UT,\rho_T}(\phi, \phi_s)\Big) \quad \Big]$$

- $2 \times 6 = 12$ free parameters for $A^l_{UT,\rho_L/\rho_T}$
- $A_{UU,\rho_L/\rho_T}(\phi)$ terms are obtained from SDMEs: $r^5_{00}, r^5_{11}, r^1_{00}, r^1_{11}$

in leading twist:

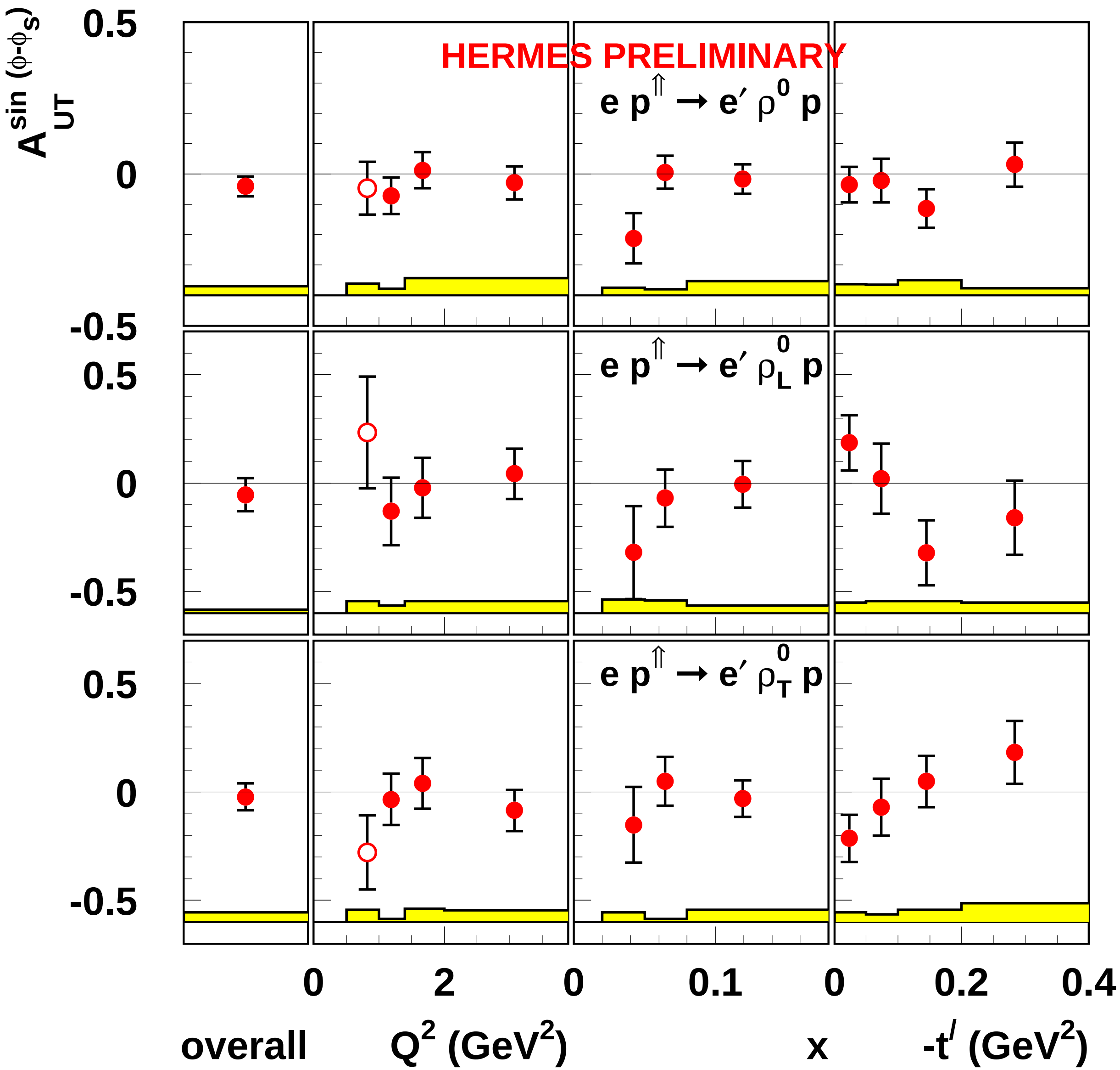
$$A^{\gamma^* \; \sin(\phi-\phi_s)}_{UT,\rho_L} = -\frac{1}{S_T}\frac{\sigma^{+-}_{00,\rho_L}}{\sigma_{L,\rho_L}}$$

Systematic Uncertainty

Considered sources of systematic uncertainty:

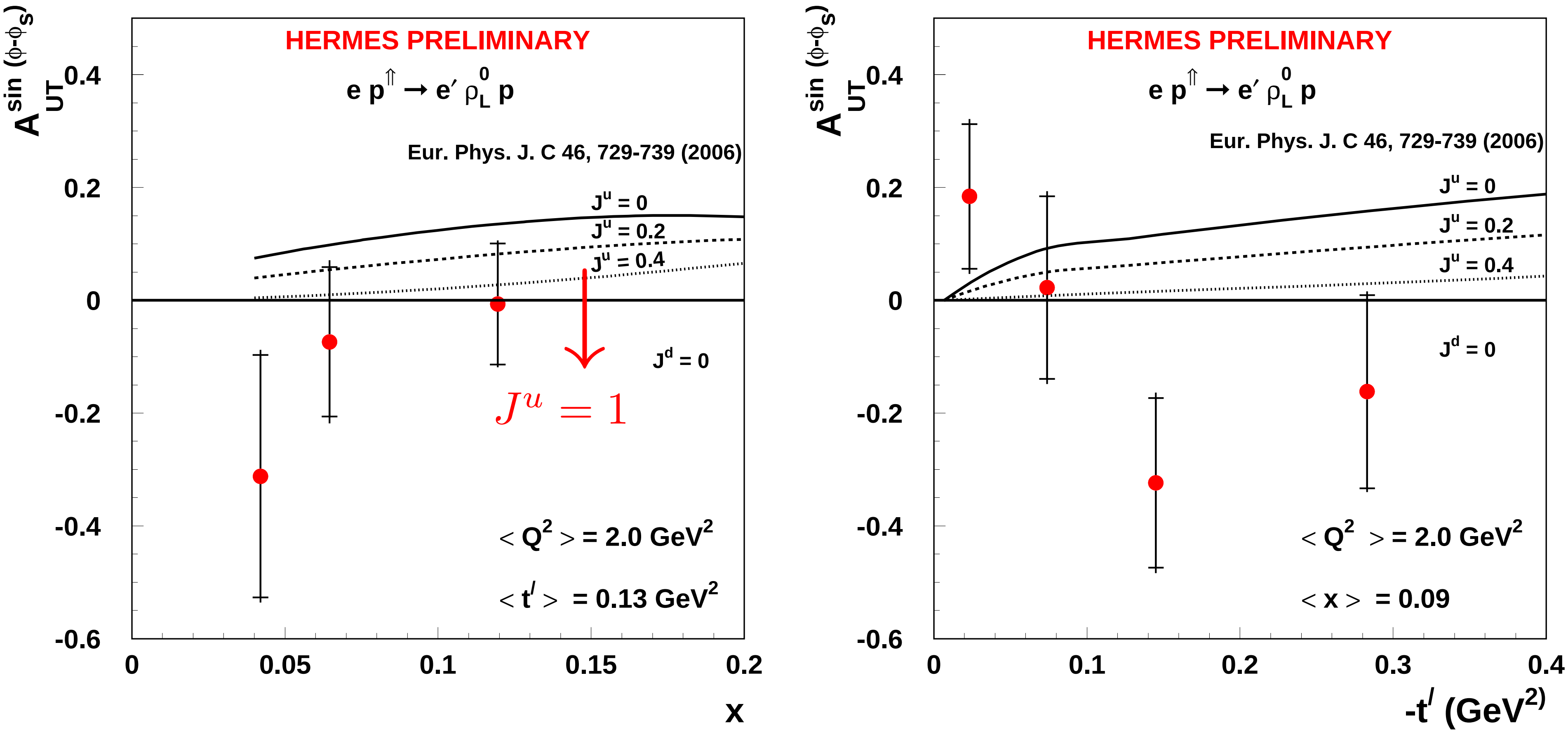
- the target polarization
- the uncertainty of BG correction
- the accuracy of the measured unpolarized SDMEs
- the beam polarization
- the extraction method

Results



$A_{UT}^{\sin(\phi-\phi_S)}$
0.5
0
-0.5
HERMES PRELIMINARY
$e\, p^{\Uparrow} \rightarrow e'\, \rho^0\, p$
$e\, p^{\Uparrow} \rightarrow e'\, \rho^0_L\, p$
$e\, p^{\Uparrow} \rightarrow e'\, \rho^0_T\, p$
0 2 0 0.1 0 0.2 0.4
overall
Q^2 (GeV^2)
x
$-t'$ (GeV^2)

Comparison with theory



- data faviours positive J^u
- more effort is needed to make a statement about J^u

Summary

- for the first time the TTSA of exclusive ρ^0 mesons is extracted separately for ρ_L^0 and ρ_T^0
- under the assumption of SCHC, is equivalent to γ_L^*, γ_T^*, separation
- data faviours positive J^u
- in agreement with DVCS results from HERMES

  see A. Mussgiller's talk

- rapid developments in theory, results will be available soon
- together with model predictions will allow to draw a conclusion about J^u