

Exclusive Meson Production at HERMES

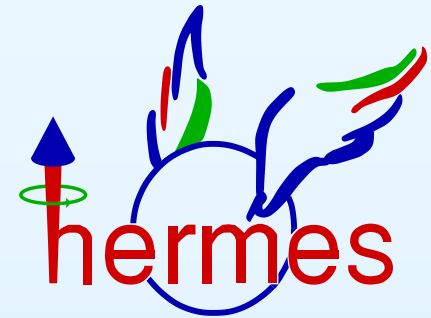
Pan-Pacific 2005, Tokyo, Japan

Armine Rostomyan

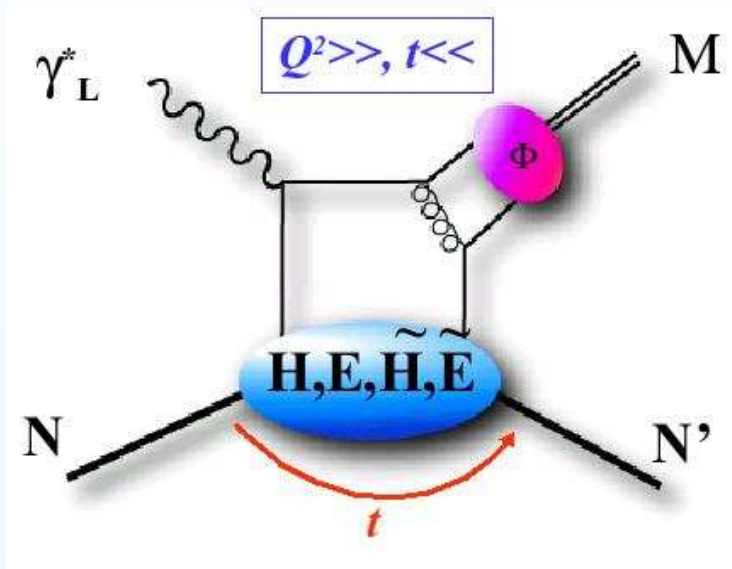
on behalf of the HERMES collaboration

(DESY)

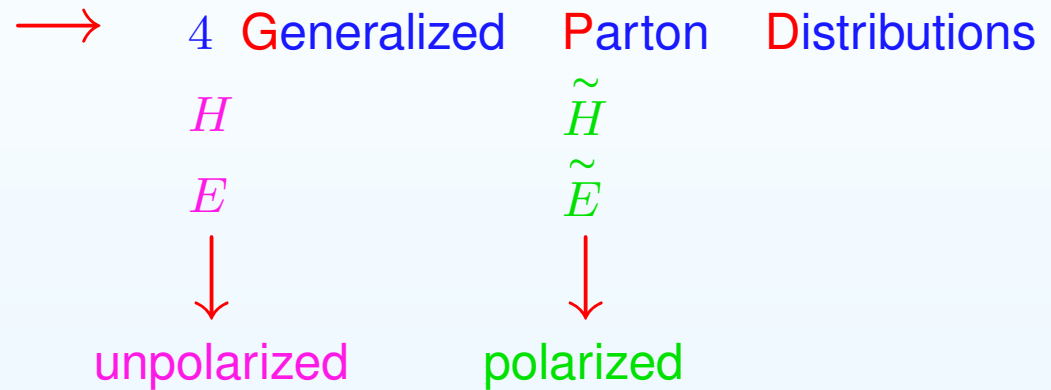
- Motivation
- Exclusive π^+ production cross-section
- Exclusive ρ^0 production cross-section
- The cross-section ratio of $\frac{\sigma_\phi}{\sigma_\rho}$
- Transverse target spin asymmetry of ρ^0 and π^+



Factorization theorem for meson production



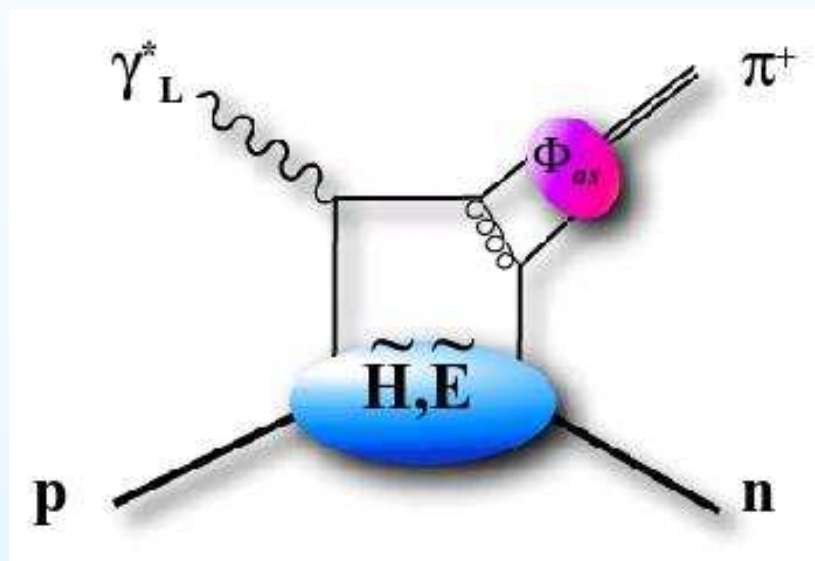
-Collins, Frankfurt, Strikman (1997)-



- Quantum numbers of final state selects different GPDs
 - ⊗ **vector mesons** (ρ, ω, ϕ): unpolarized GPDs H, E
 - ⊗ **pseudoscalar mesons** (π, η): polarized GPDs \tilde{H}, \tilde{E}
- Factorization for **longitudinal** photons only

$$\frac{d\sigma_L}{dt} \rightarrow \frac{1}{Q^6} \quad \frac{\sigma_T}{\sigma_L} \sim \frac{1}{Q^2}$$

EXCLUSIVE π^+



Exclusivity for $ep \rightarrow e'\pi^+(n)$

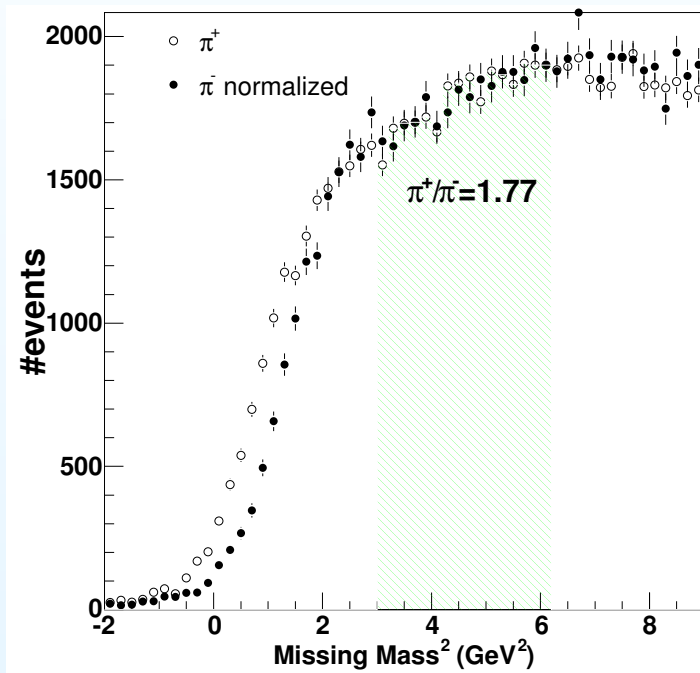
- for existing data no **recoil** nucleon detection yet
- select exclusive π^+ reaction through the **missing mass** technique:

$$M_x^2 = (P_e + P_p - P_{e'} - P_{\pi^+})^2$$

Exclusivity for $ep \rightarrow e'\pi^+(n)$

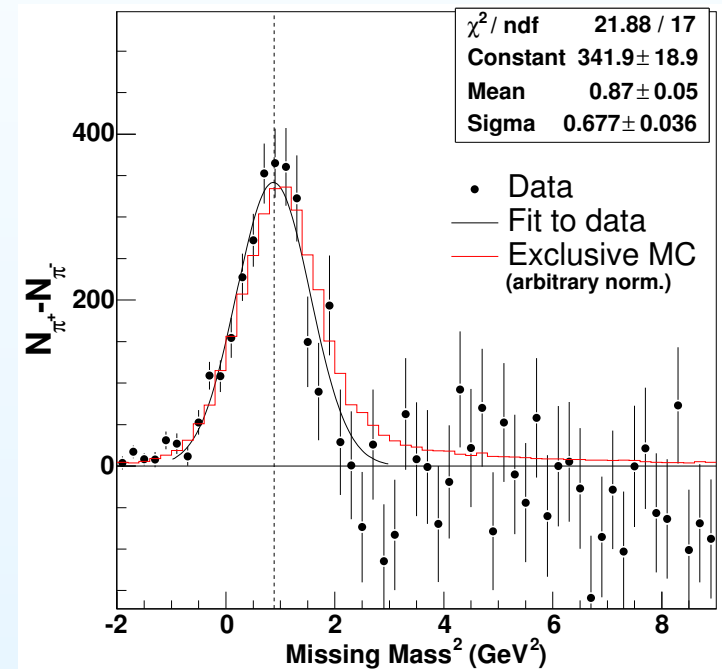
$$M_x^2 = (P_e + P_p - P_{e'} - P_{\pi^+})^2$$

$ep \rightarrow e\pi^+ X$



- π^- yield was used to subtract the non exclusive background

$ep \rightarrow e\pi^+ n$



- exclusive peak centered at the nucleon mass
- MC is based on GPD model

Cross-section determination

$$\sigma^{\gamma^* p \rightarrow \pi^+ n}(x, Q^2) = \frac{N_{\pi}^{excl}}{L \Delta x \Delta Q^2 \Gamma(\langle x \rangle, \langle Q^2 \rangle) \kappa(x, Q^2)}$$

→ $\kappa(x, Q^2)$: detection probability was calculated using VGG exclusive MC

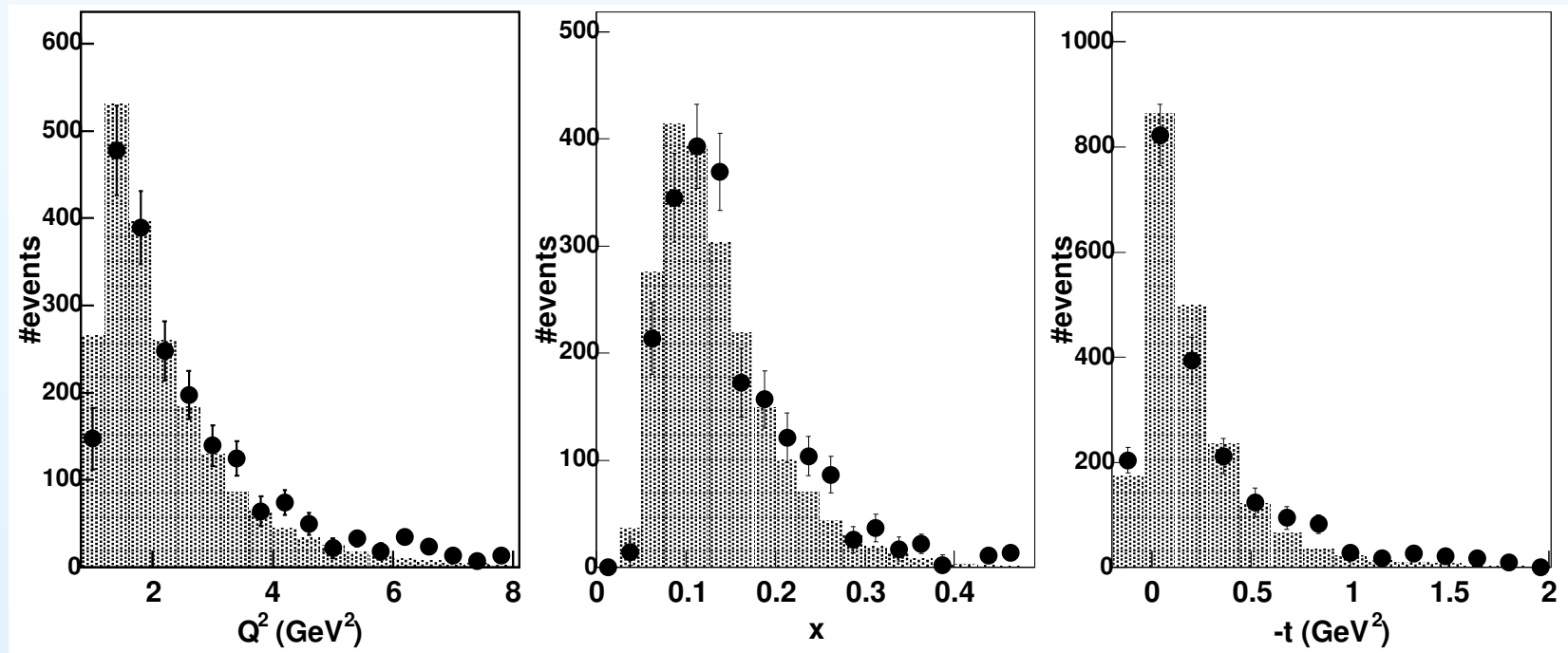
-Vanderhaeghen, Guichon, Guidal (1999)-

Cross-section determination

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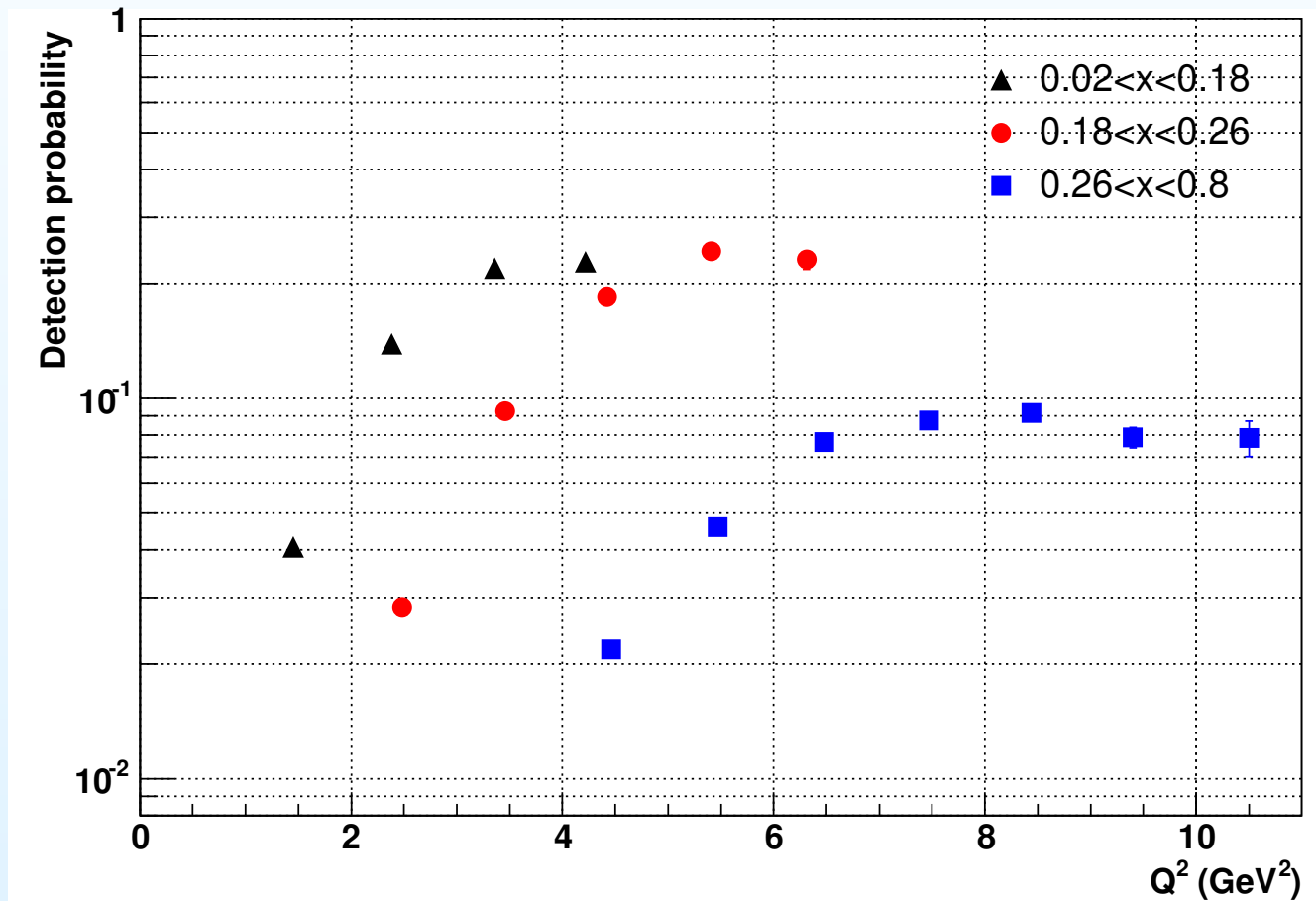
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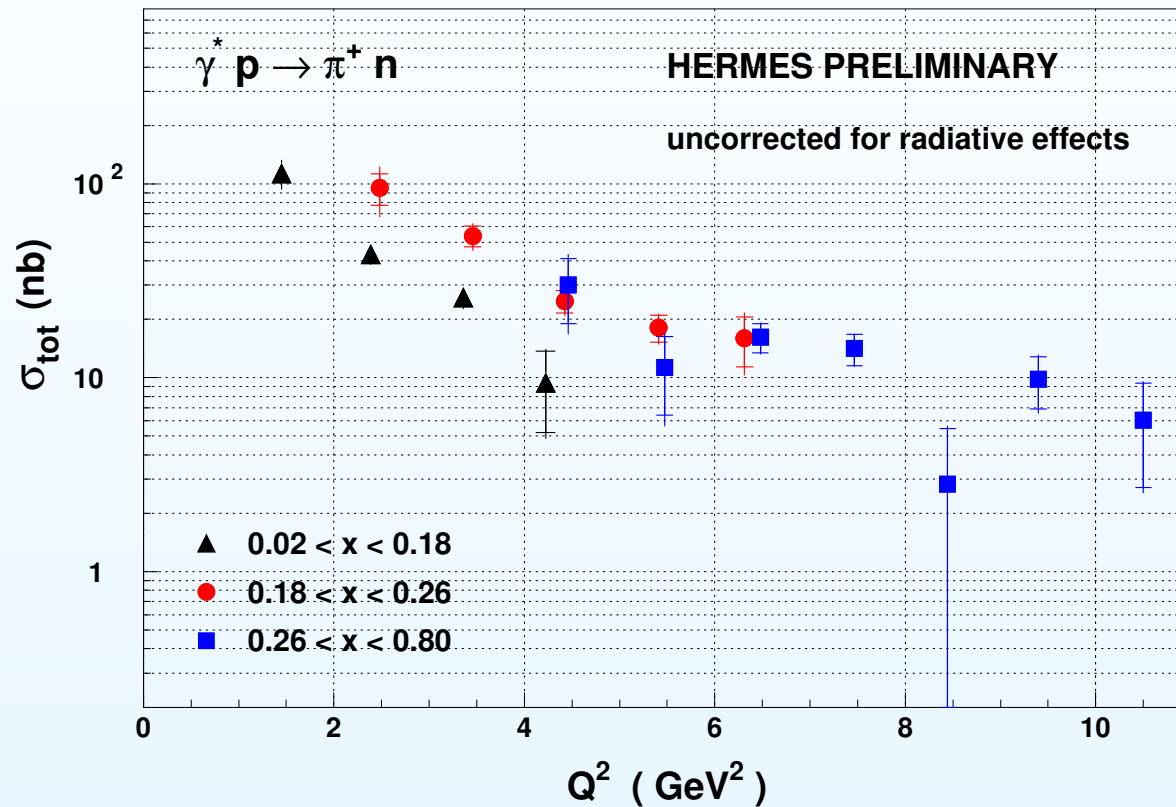


Cross-section determination

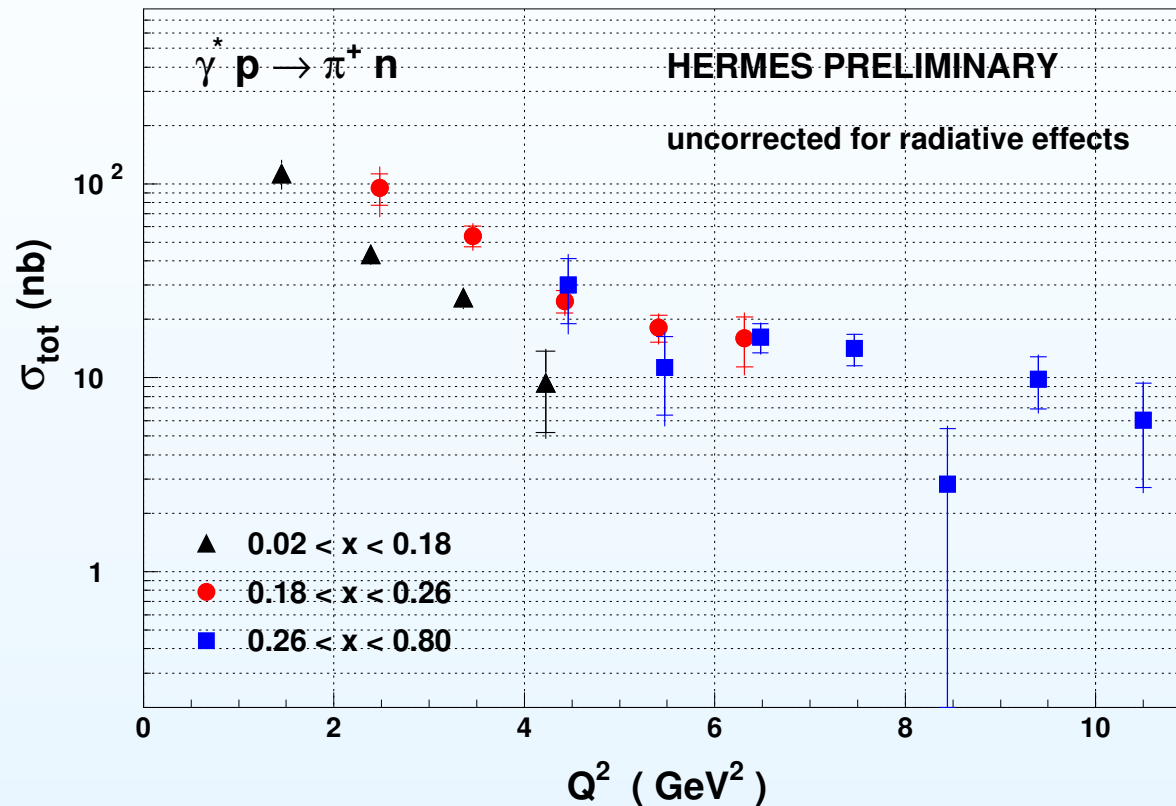
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Cross-section: Q^2 dependence for different x ranges



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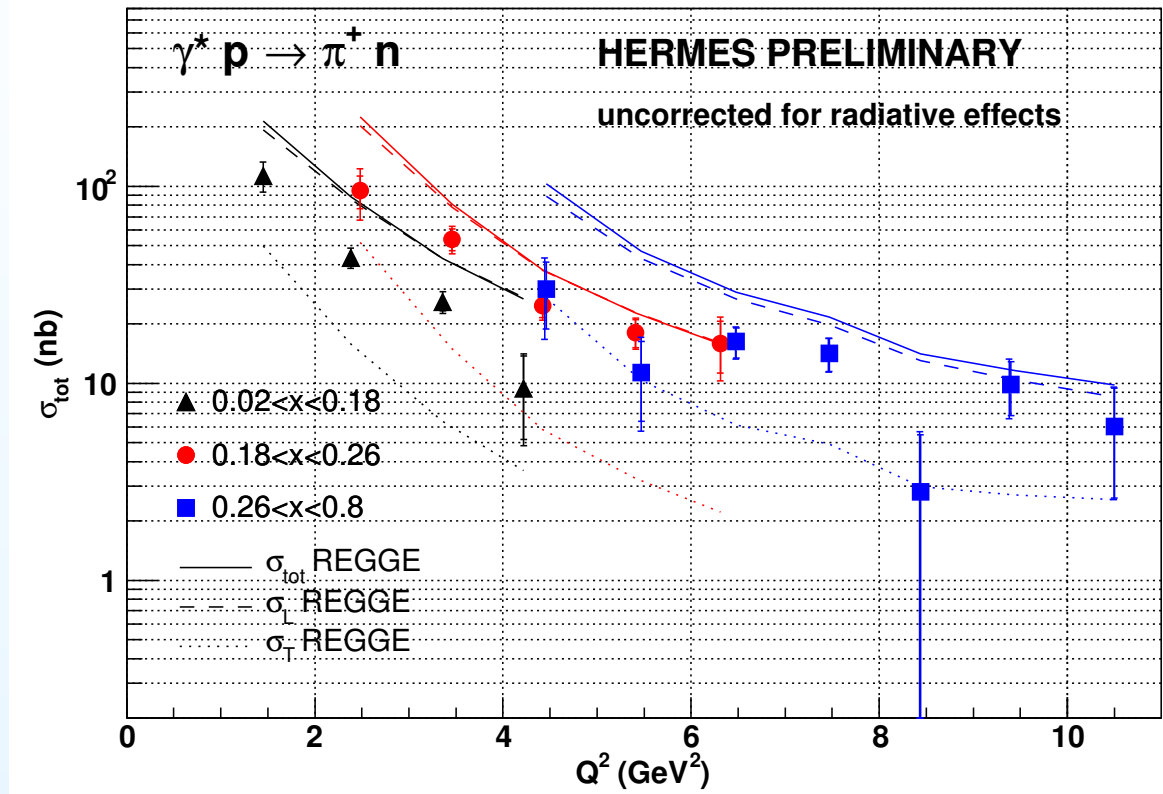


$$\sigma_{\text{tot}} = \sigma_T + \epsilon \sigma_L$$

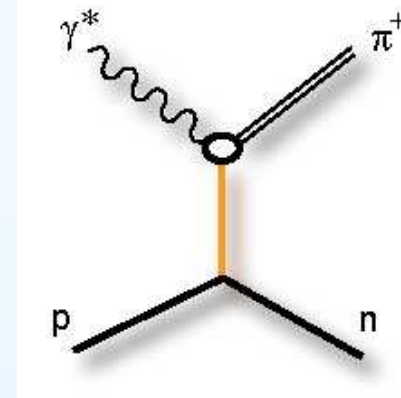
- L/T separation not possible
- BUT σ_T suppressed by $1/Q^2$
- for HERMES kinematics:
 $0.80 < \epsilon < 0.96$

σ_L dominates at large Q^2

Cross-section: Q^2 dependence for different x ranges



$$\sigma_{tot} = \sigma_T + \epsilon\sigma_L$$

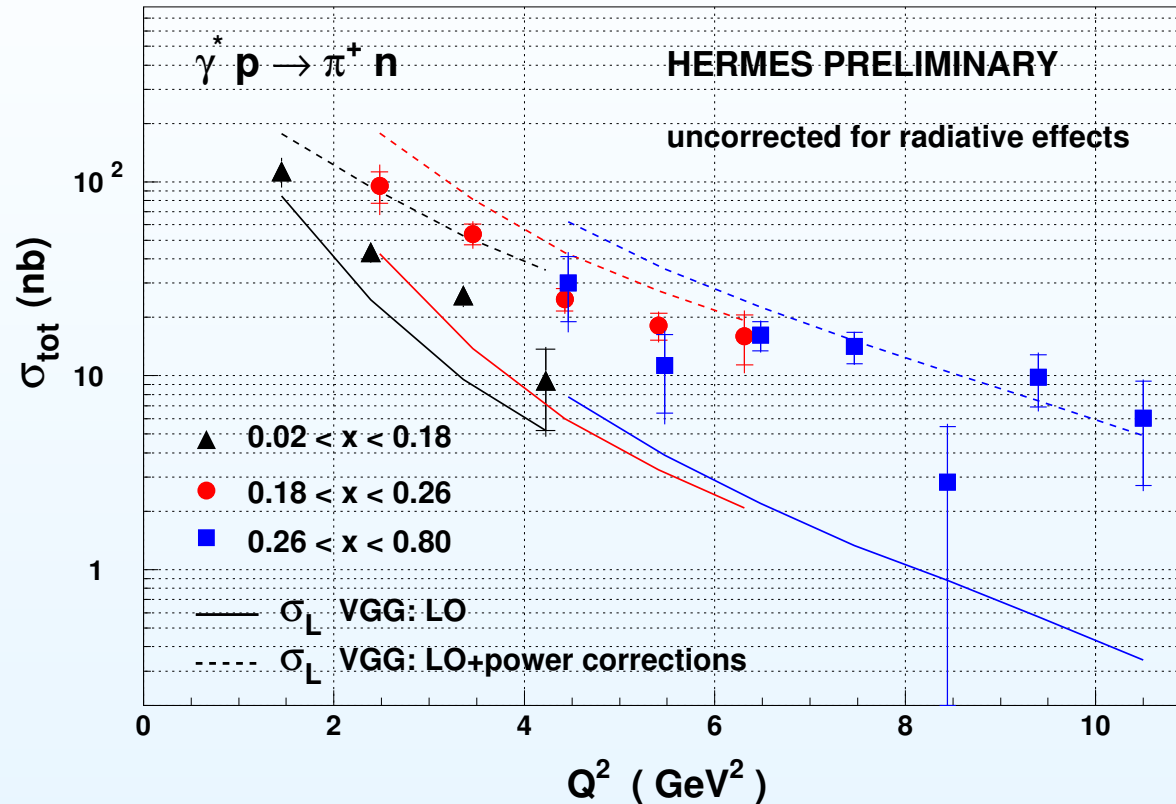


-J.M. Laget (2004)-

\Rightarrow small contribution from σ_T is predicted

$\Rightarrow \sigma_L \approx \sigma_{tot}$

Cross-section: Q^2 dependence for different x ranges



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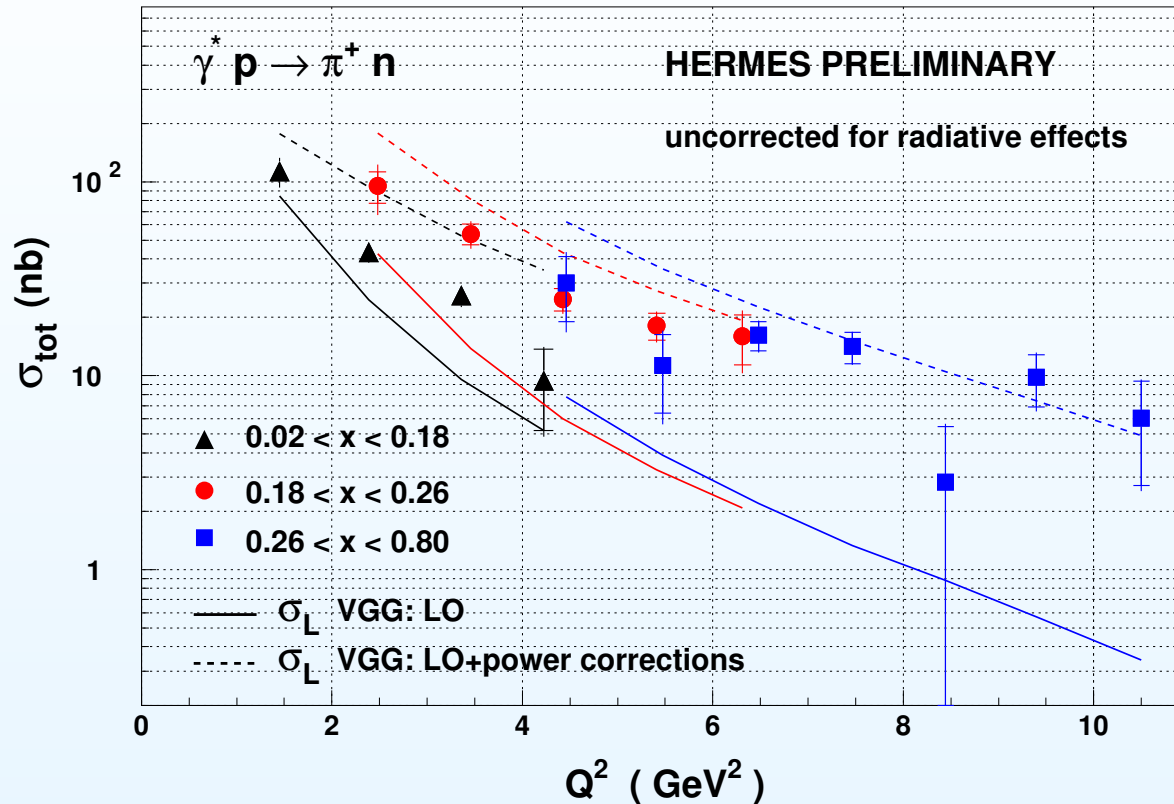
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-Vanderhaeghen, Guichon, Guidal (1999)-



access to \tilde{H} and \tilde{E}

Cross-section: Q^2 dependence for different x ranges



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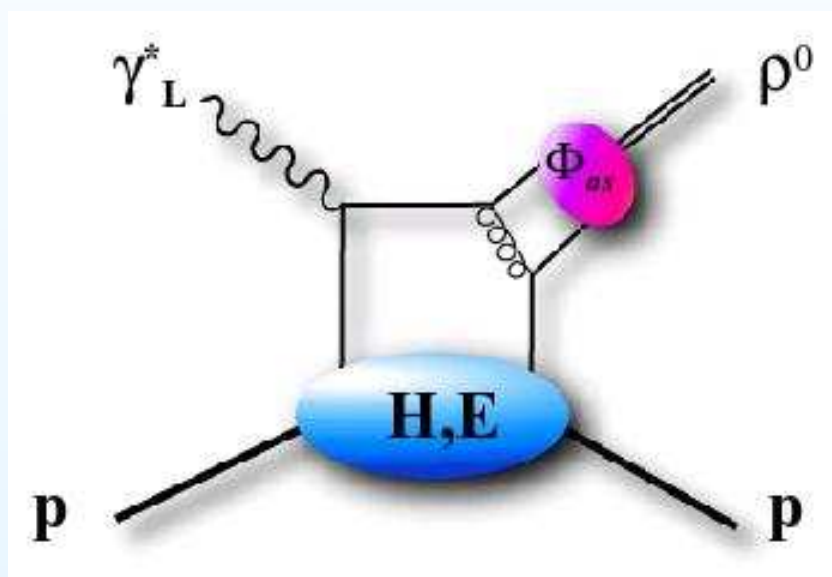
-Vanderhaeghen, Guichon, Guidal (1999)-

access to \tilde{H} and \tilde{E}

⇒ LO calculations underestimate the data

⇒ Evaluation of the power correction (k_{\perp} and soft overlap) appears too large

EXCLUSIVE VECTOR MESONS



Exclusive Vector Meson Selection $ep \rightarrow e'V(p)$

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

$$\phi \rightarrow K^+ K^-$$

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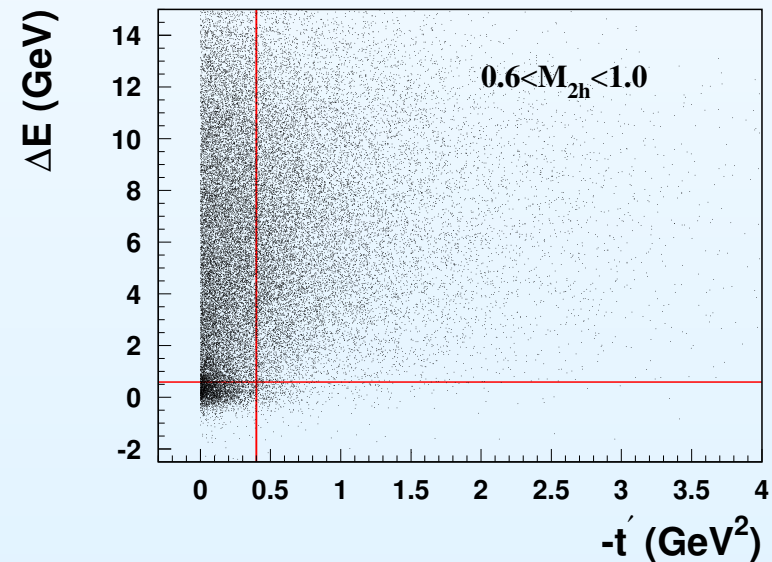
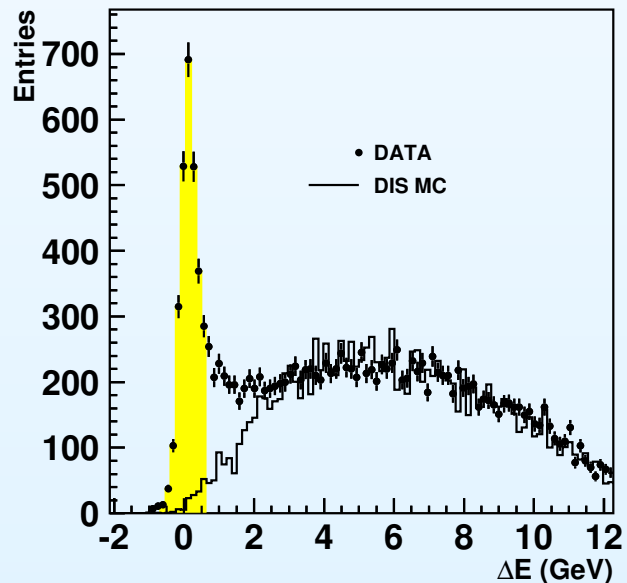
$$\rho^0 \rightarrow \pi^+ \pi^-$$

$$\phi \rightarrow K^+ K^-$$

- no recoil detection
- exclusive ρ^0 and ϕ reaction through the energy and momentum transfer:

$$\Delta E = \frac{M_x^2 - M_p^2}{2M_p}$$

$$t' = t - t_0$$

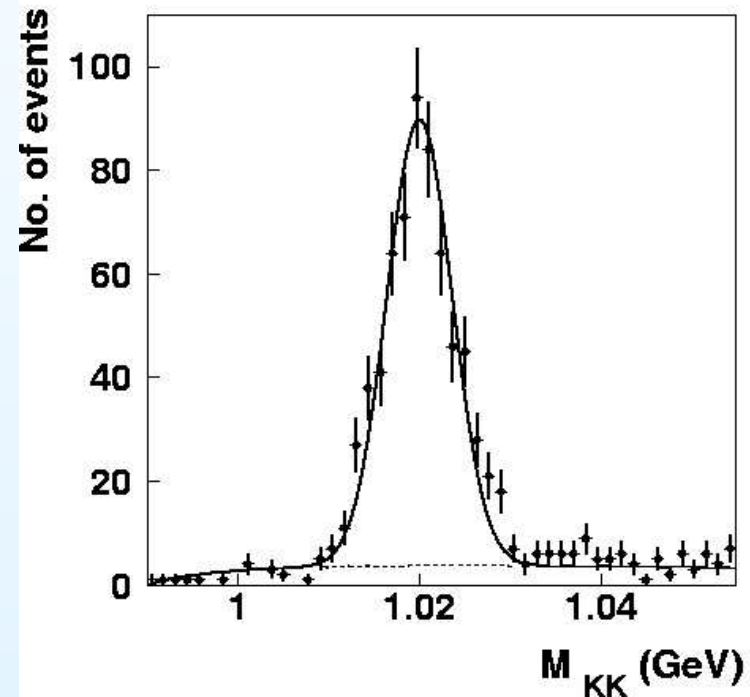
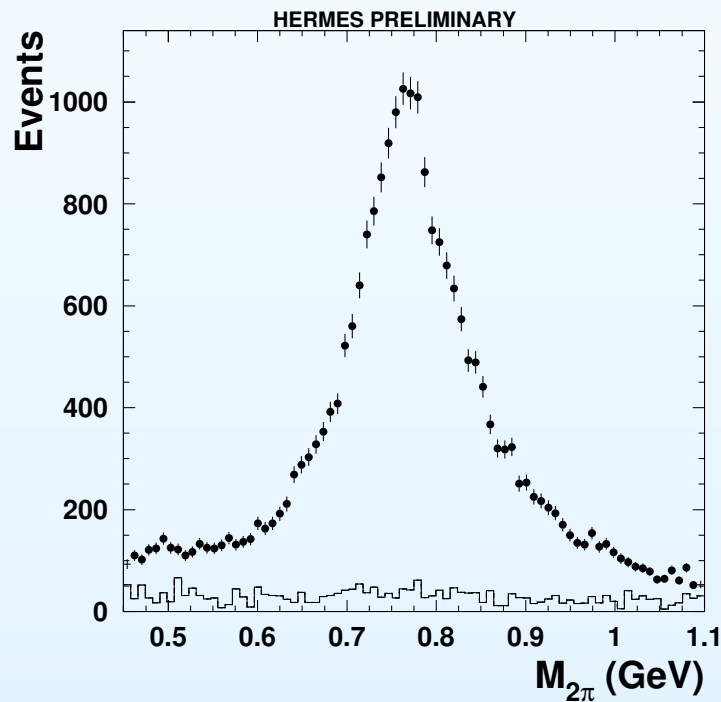


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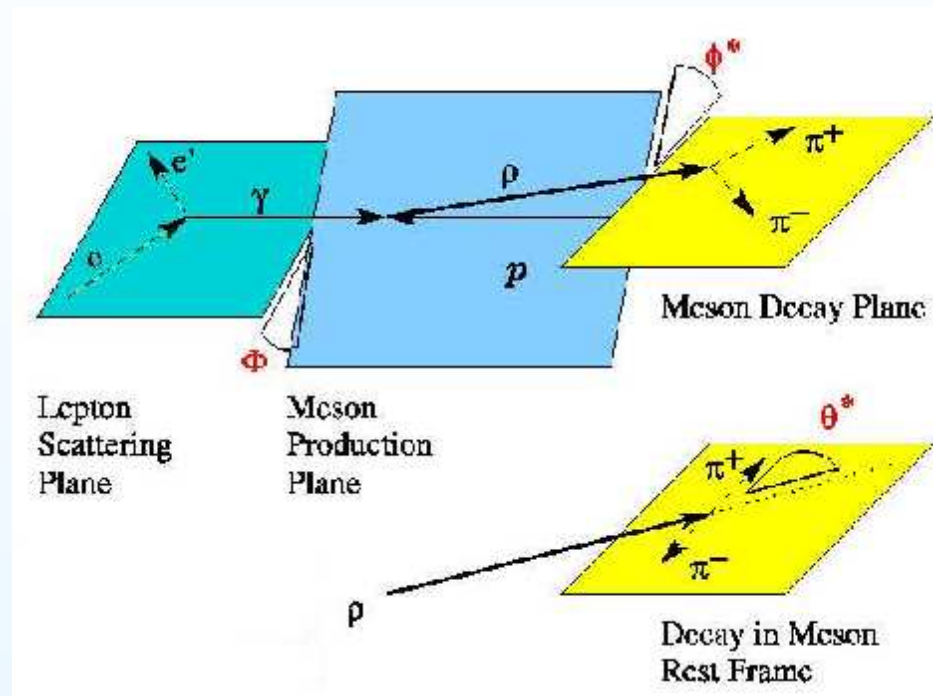
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$$W(\cos\theta, \Phi, \phi)$$



separation of longitudinal and transverse components

$$W(\cos\theta, \phi, \Phi) \Rightarrow 23 \text{ SDME}$$

- describe the helicity transfer from virtual photon to the vector meson
- describe the parity of the diffractive exchange process

σ_L/σ_T separation

- GPD calculations only for longitudinal component of cross section (σ_L).

$$\sigma_L = \frac{R}{1 + \epsilon R} \sigma_{\gamma^* p \rightarrow V p}$$

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

ϵ — polarization of γ^*

- assuming s-channel helicity conservation

$$R = \frac{1}{\epsilon} \frac{r_{00}^{04}}{1 - r_{00}^{04}}$$

$$r_{00}^{04} \rightarrow W(\cos\theta)$$

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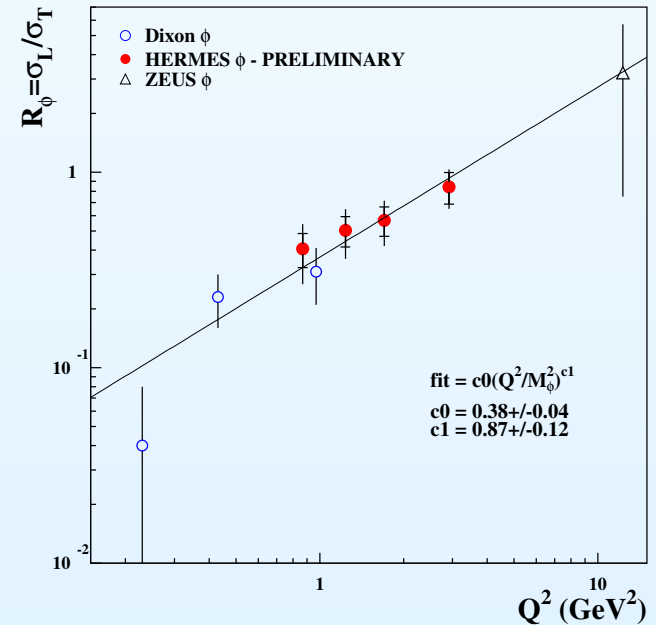
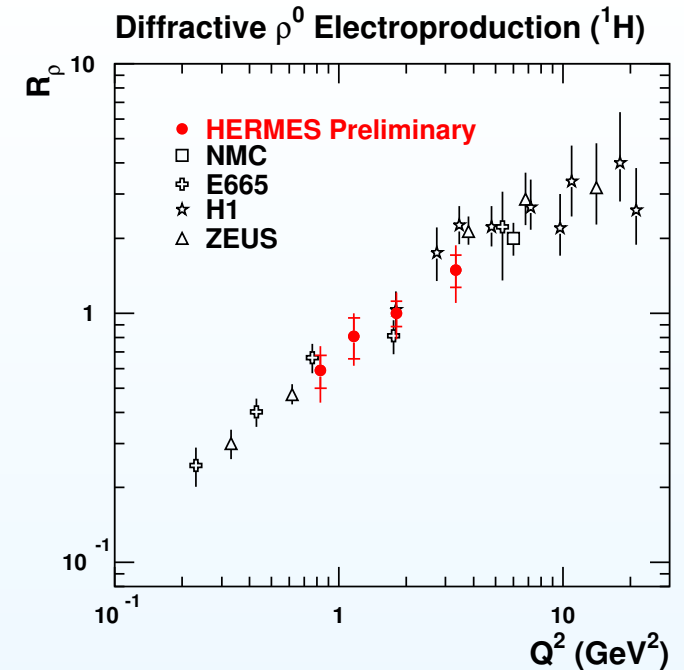
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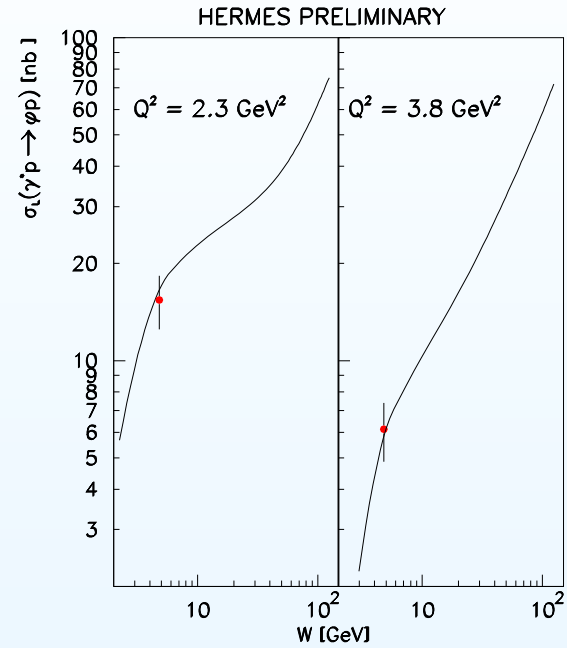
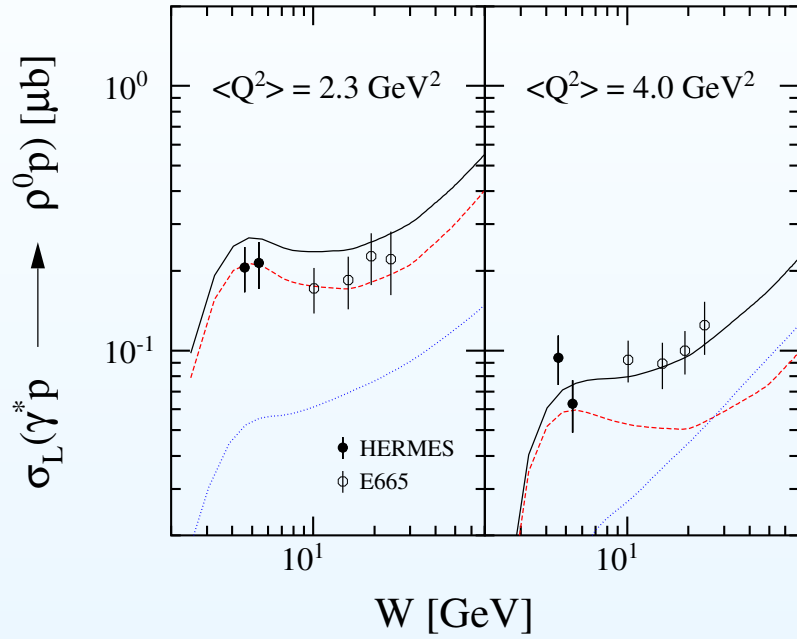
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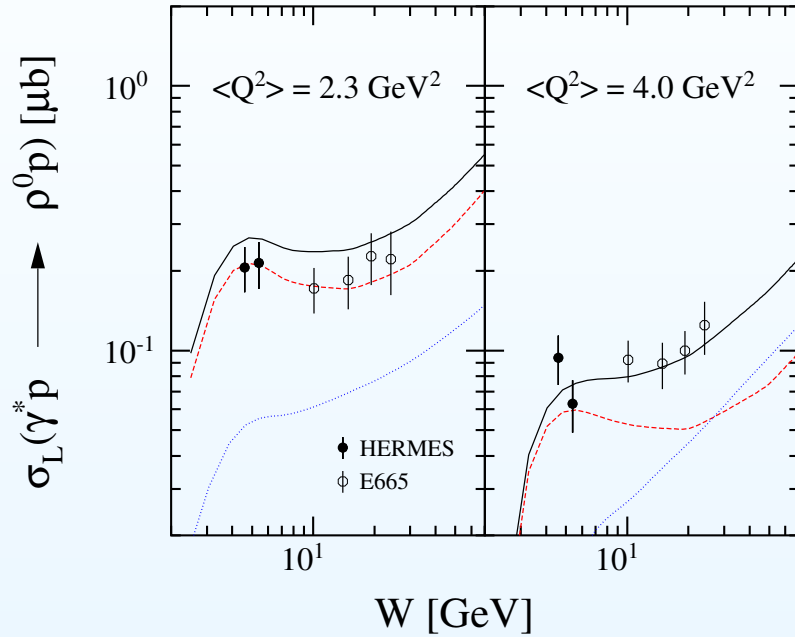
$\sigma_{\gamma_L^* p \rightarrow \rho^0 p}$ and $\sigma_{\gamma_L^* p \rightarrow \phi p}$

-Vanderhaeghen, Guichon, Guidal (1999)-



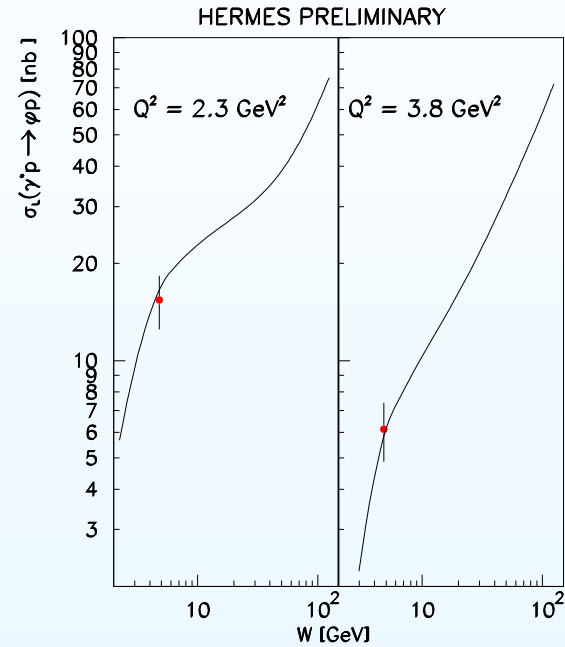
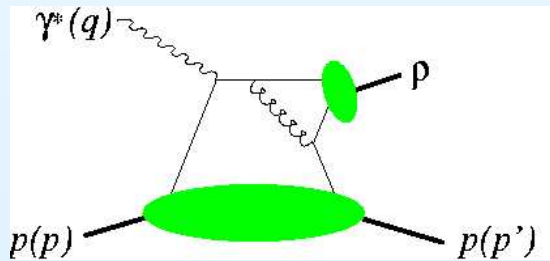
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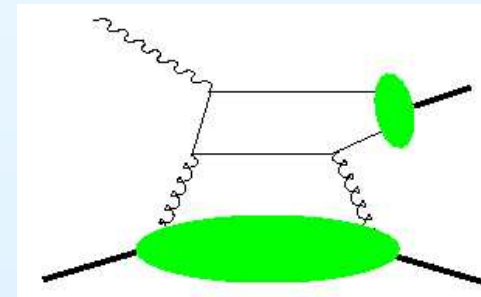


dominated by quark exchange

$$|\tau_g/\tau_q| \simeq 0.3$$

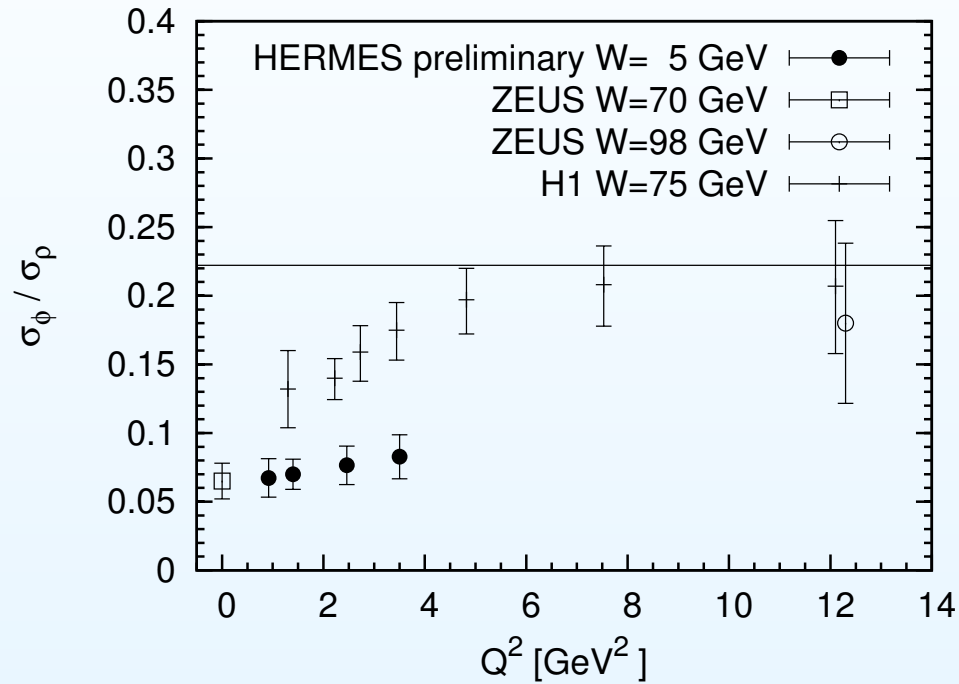


gluon exchange



σ_ϕ/σ_ρ

-Diehl, Vinnikov (2005)-

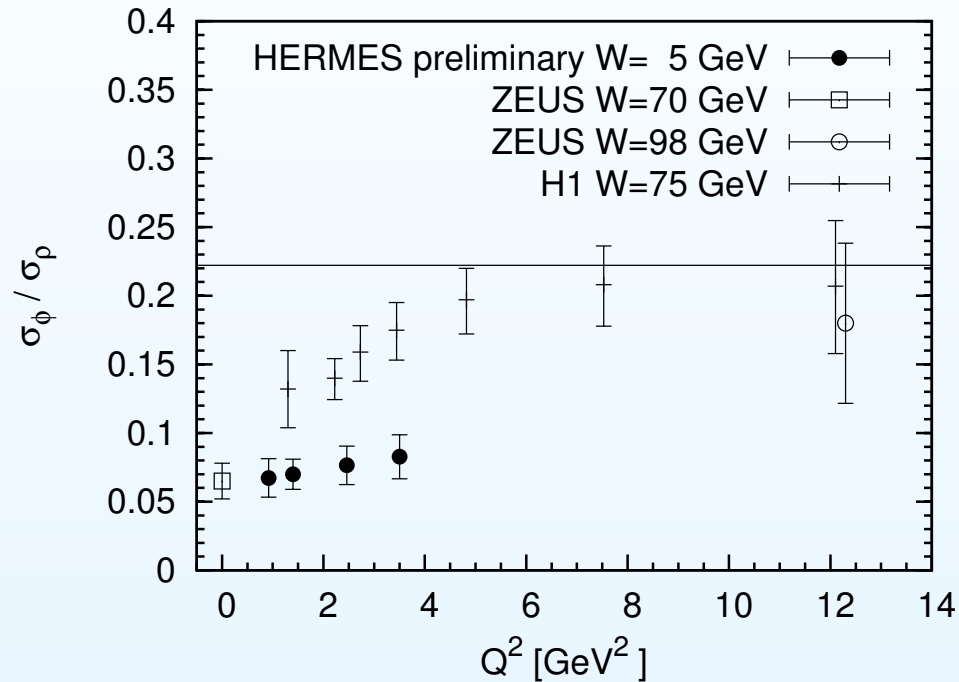


$$\frac{\sigma_\phi}{\sigma_\rho} \approx \frac{2}{9} \frac{|\tau_g|^2}{|\tau_q|^2 + 2|\tau_q||\tau_g|\cos\phi_{qg} + |\tau_g|^2}$$

$$0.38 \leq |\tau_g/\tau_q| \leq 1.5$$

σ_ϕ/σ_ρ

-Diehl, Vinnikov (2005)-



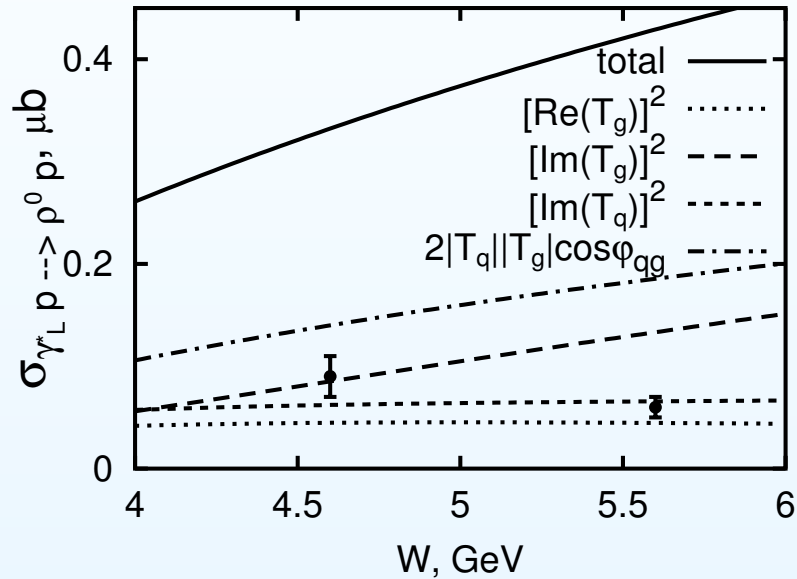
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⇒ gluon contribution and quark-gluon interference can not be neglected

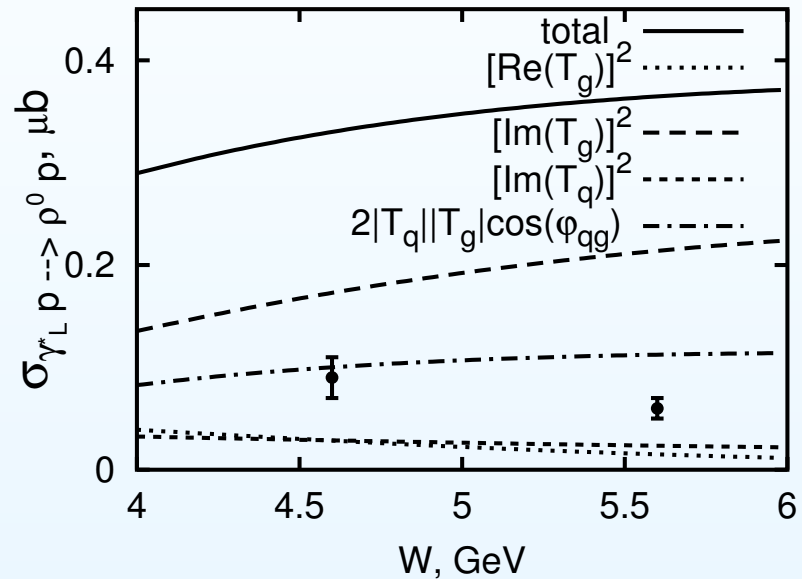
$$\sigma_{\gamma_L^* p \rightarrow \rho^0 p}$$

factorized GPD model



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

Regge GPD model

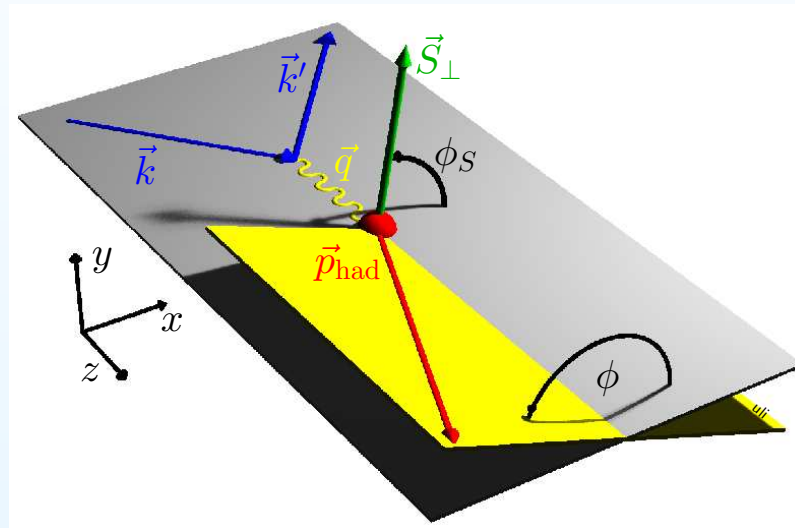


HERMES data at $Q^2 = 4\text{GeV}^2$

- the calculation **overshoots** the experimental data
- k_{\perp} is not taken into account yet

⇒ quark and gluon amplitudes have to be scaled down in a similar proportion
 ⇒ a factor of 5 suppression of the cross section at $Q^2 = 4\text{GeV}^2$

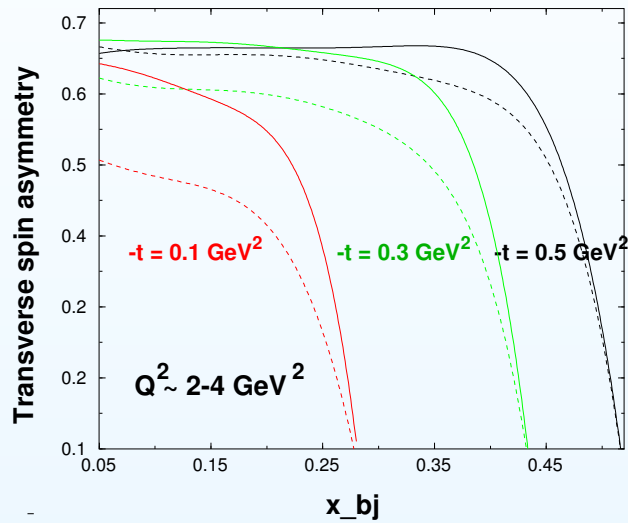
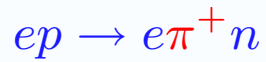
TRANSVERSE TARGET SPIN ASYMMETRIES



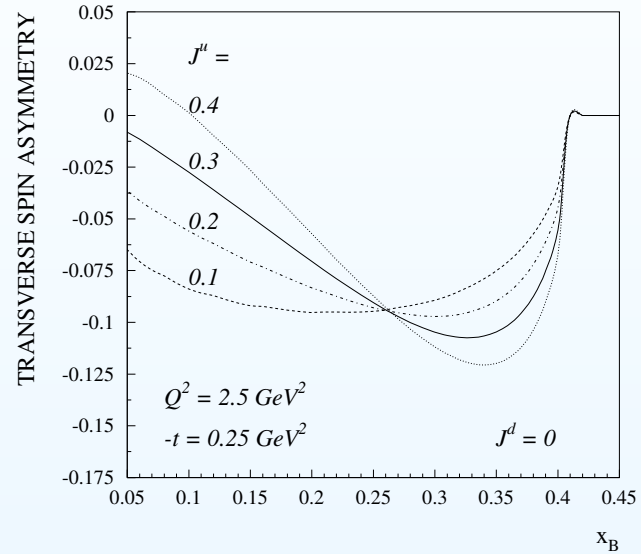
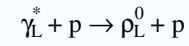
Transverse spin asymmetries of exclusive π^+ and ρ^0

- the scaling region is reached at low Q^2
- not sensitive to NLO corrections

Transverse spin asymmetries of exclusive π^+ and ρ^0

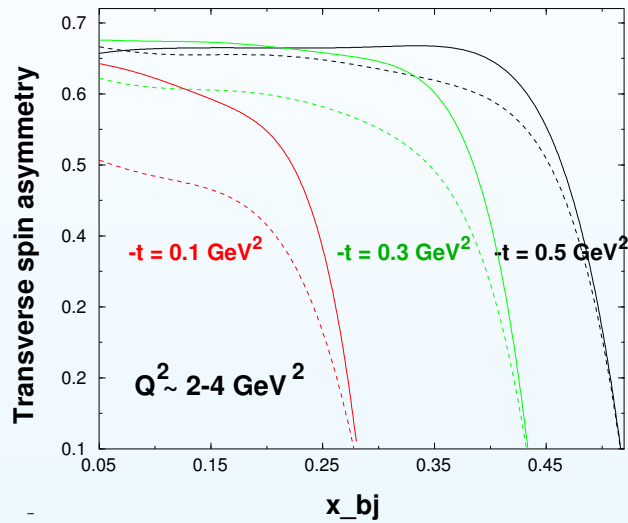


-Frankfurt, Polyakov, Strikman, Vanderhaeghen (2000)-



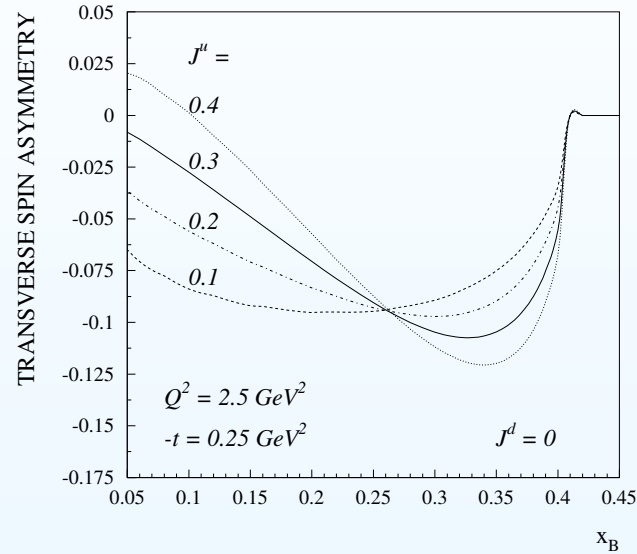
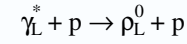
-Goeke, Polyakov, Vanderhaeghen (2001)-

Transverse spin asymmetries of exclusive π^+ and ρ^0



-Frankfurt, Polyakov, Strikman, Vanderhaeghen (2000)-

- $\sigma : |S_T| \sin(\phi - \phi_s) \tilde{E} \tilde{H}$



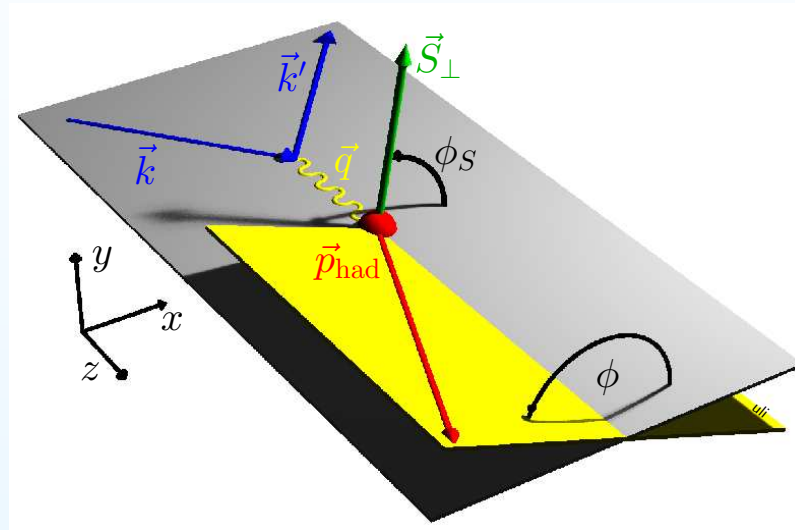
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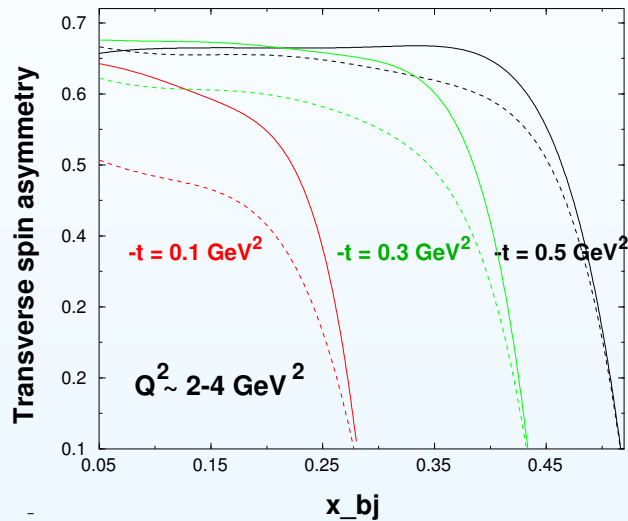
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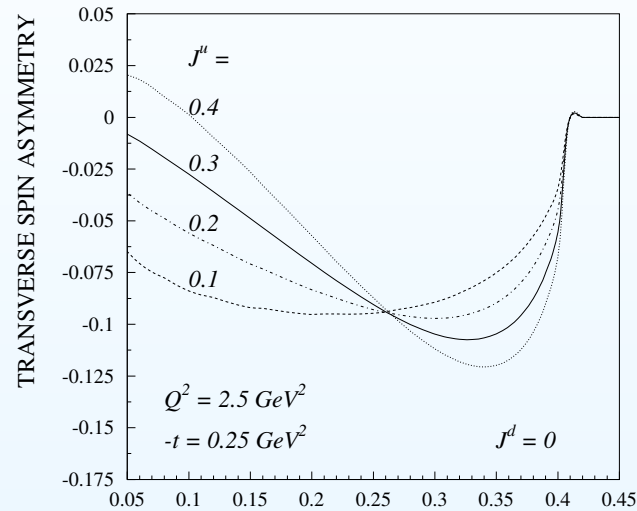
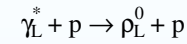
$$A_{UT} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{\sigma_1}{\sigma_0} = -\frac{\pi}{2} \mathcal{A}_{thoer.}$$

Transverse spin asymmetries of exclusive π^+ and ρ^0



-Frankfurt, Polyakov, Strikman, Vanderhaeghen (2000)-

- $\sigma : |S_T| \sin(\phi - \phi_s) \tilde{E} \tilde{H}$
- sensitive to different distribution amplitudes



-Goeke, Polyakov, Vanderhaeghen (2001)^B

- $\sigma : |S_T| \sin(\phi - \phi_s) E H$
- $E \rightarrow 2J^u + J^d$

Asymmetry determination

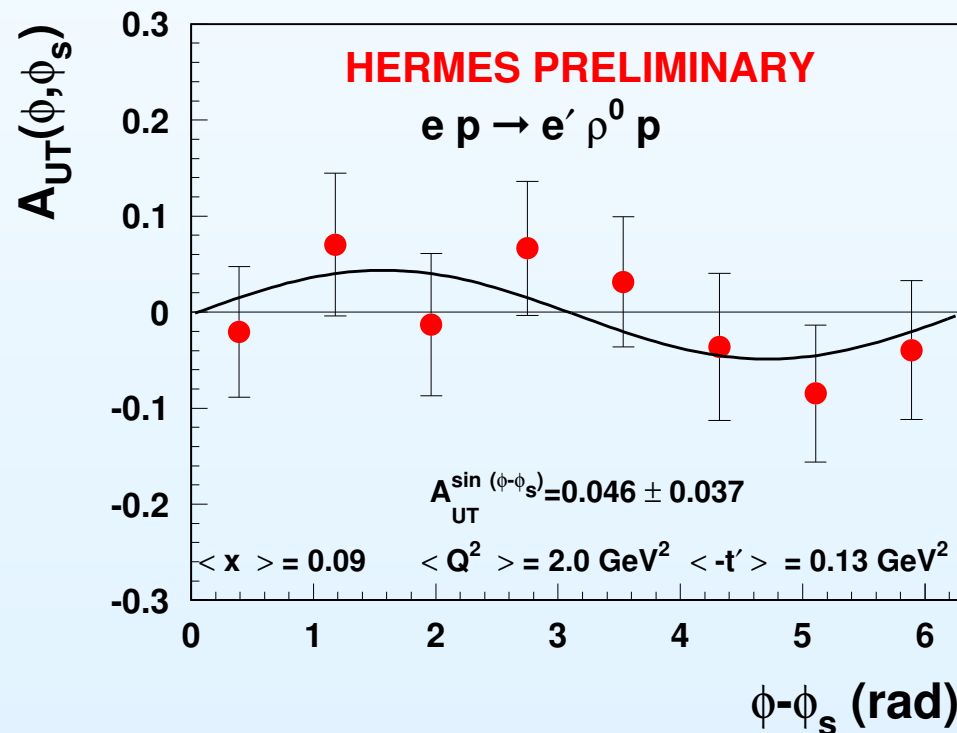
$$A_{UT}(\phi - \phi_s) = \frac{1}{|P|} \frac{N^\uparrow(\phi - \phi_s) - N^\downarrow(\phi - \phi_s)}{N^\uparrow(\phi - \phi_s) + N^\downarrow(\phi - \phi_s)},$$

$$A_{UT}(\phi - \phi_s) = A_{UT}^{\sin(\phi - \phi_s)} \cdot \sin(\phi - \phi_s) + \text{constant}$$

Asymmetry determination

$$A_{UT}(\phi - \phi_s) = \frac{1}{|P|} \frac{N^\uparrow(\phi - \phi_s) - N^\downarrow(\phi - \phi_s)}{N^\uparrow(\phi - \phi_s) + N^\downarrow(\phi - \phi_s)},$$

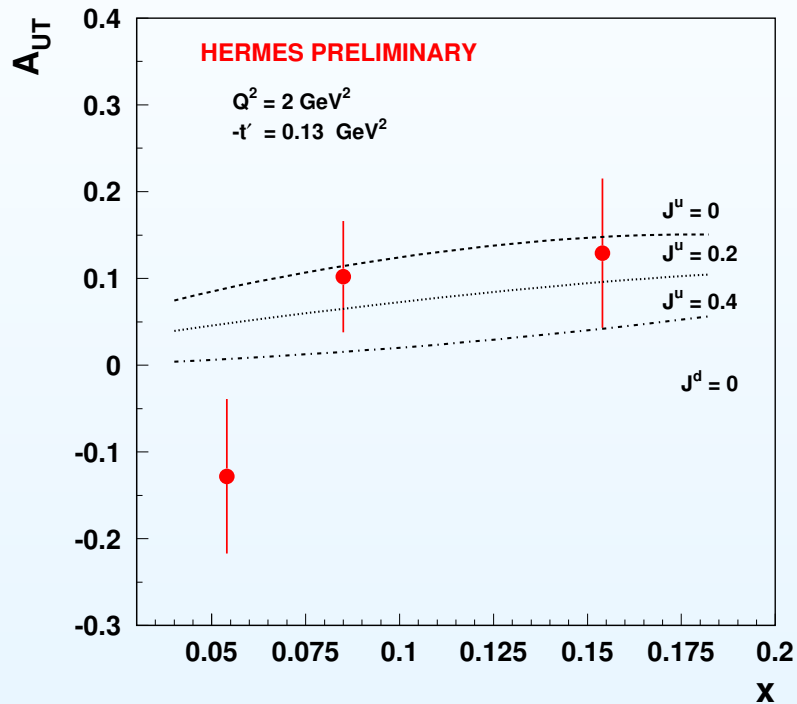
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$$A_{UT}^{\sin(\phi - \phi_s)} = 0.046 \pm 0.037$$

Kinematic Dependences

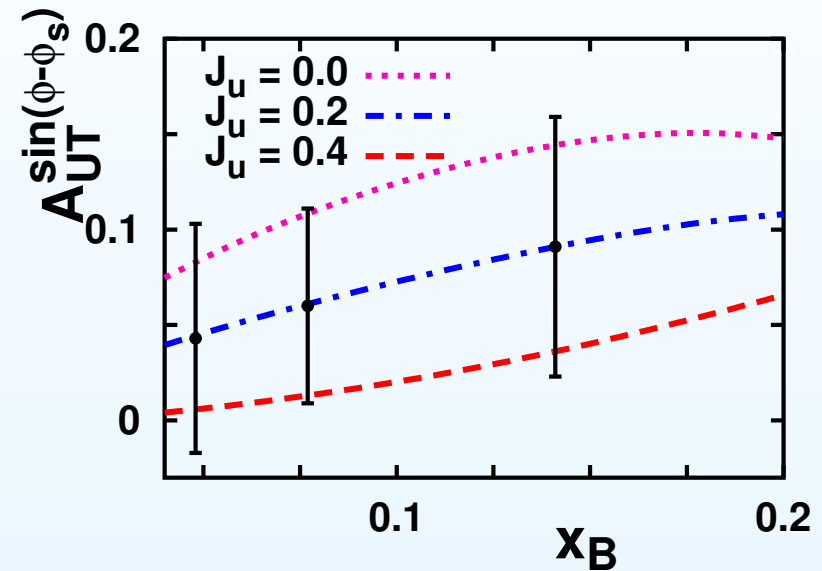
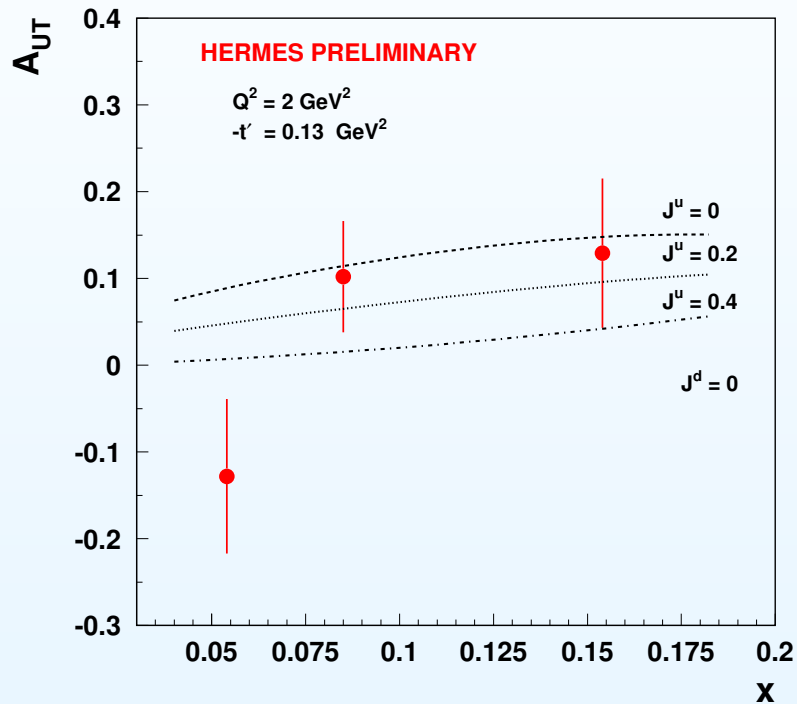
- Ellinghaus, Nowak, Vinnikov, Ye (2005)



- within the statistical errors in agreement with theoretical calculations
- the statistics is not enough to make statement about J^u

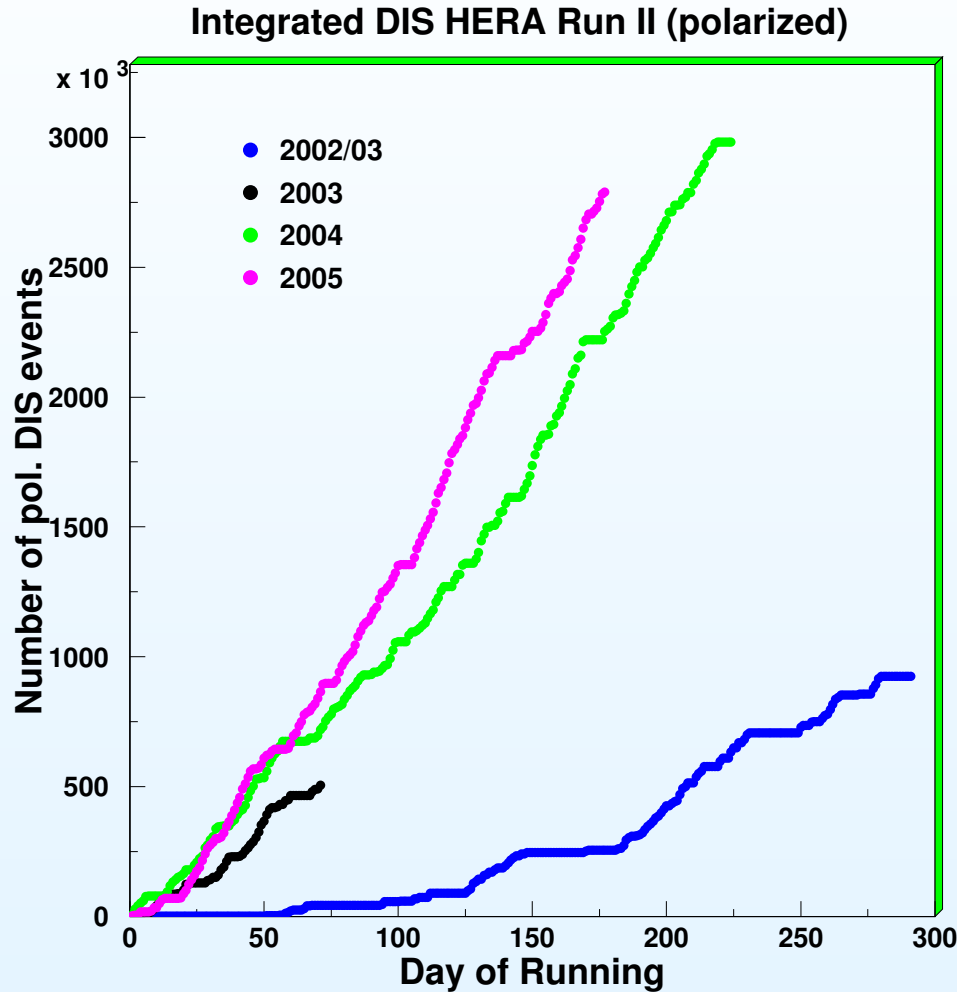
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- Ellinghaus, Nowak, Vinnikov, Ye (2005)



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Future...



2002-2005: run with a transversely polarized target

by now we already have:

4M DIS
1k exclusive π^+
2.5k exclusive ρ^0

2005: still running with transversely polarized target

from 2005: recoil detector will be installed: more statistics from exclusive reactions

Outlook

- the cross-section of exclusive π^+
→ the Q^2 dependence of the cross section is in general agreement with GPD theory
- the cross-section of exclusive ρ^0
→ the gluon contribution can not be neglected
→ new calculations taking into account k_{\perp}
- The transverse target spin asymmetry of exclusive π^+
→ will come soon
- The transverse target spin asymmetry of exclusive ρ^0
→ L/T separation
- More data is coming

STAY TUNED