

Exclusive Meson Production at HERMES

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On behalf of the HERMES Collaboration

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Outline

- 1 Introduction
- 2 Pseudoscalar Mesons
- 3 Vector Mesons
- 4 Outlook
- 5 Summary

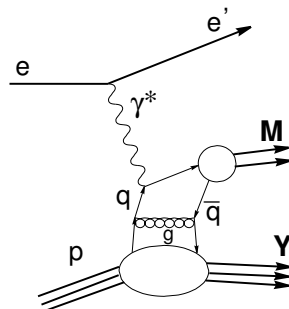
Exclusive Leptoproduction of Mesons

- Collins, hep-ph/9907513 -

- Collins, Frankfurt, Strikman, hep-ph/9709336 -

- In the case of large Q^2 and for γ_L^* a Factorization can be applied for exclusive processes:

- a hard part
- a meson wave function
- a soft part providing information about the nucleon in terms of Generalized Parton Distributions



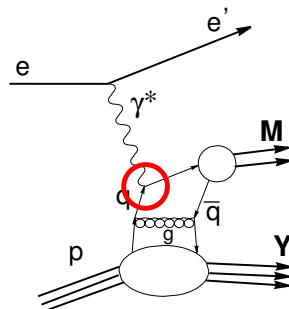
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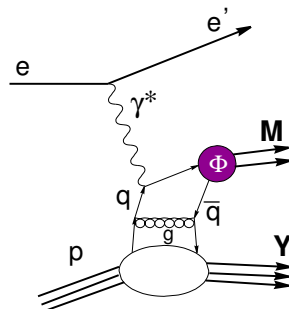


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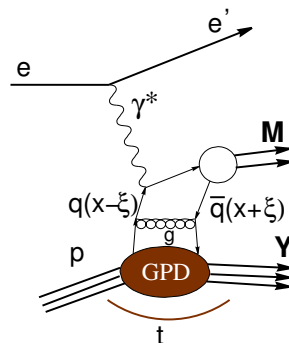


Exclusive Leptoproduction of Mesons

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- In the case of **large Q^2** and for **γ_L^***
a **Factorization** can be applied for exclusive processes:
- a hard part
- a **meson wave function**
- a soft part providing information about the nucleon in terms of **Generalized Parton Distributions**



$$\text{GPD}(x, \xi, t)$$

Generalized Parton Distributions

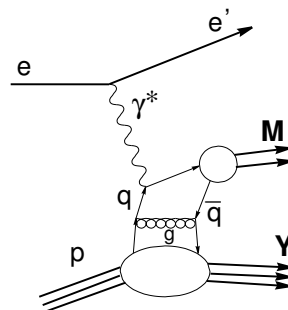
- $\tilde{H}^q, \tilde{E}^q$ accessible via **pseudoscalar** meson production, $\tilde{E}^q$ is the **pseudoscalar** contribution, related to the **pion pole**
 - $\sigma_{\pi^+}, A_{UT}, A_{UL}$
- H^q, E^q accessible through **vector** meson production:
 - $\frac{\sigma_\rho}{\sigma_\phi}, A_{UT}, A_{UL}$
- Both **different mesons** and different **observables** select different combinations of GPD's
- $\sigma_L - \sigma_T$ separation:
 - **Vector Mesons**: Separation in principle possible
 - **Pseudoscalars**: Prove separation by Q^2 dependence

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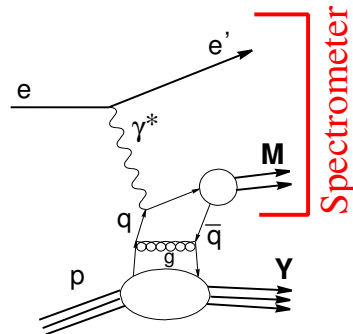
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- Initial and Final State *fully known*
- Scattered Lepton and produced meson in *Hermes acceptance*
- Select Exclusive reactions by putting *constraints* to the missing mass, or missing energy



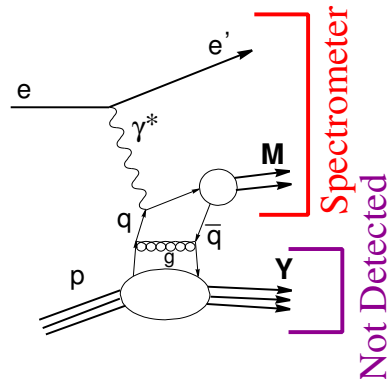
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Pseudoscalar Mesons

$\Rightarrow$ *Probe $\tilde{E}$ and $\tilde{H}$*

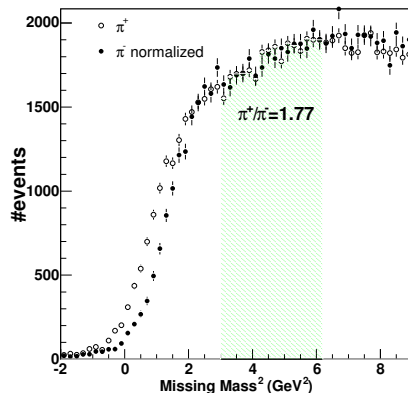
$$e + p \rightarrow e + X + \pi^+$$

⌋ $M_X^2 = (P_e + P_p - (P_{e'} + P_h))^2$
doesn't allow separation of **ex-**
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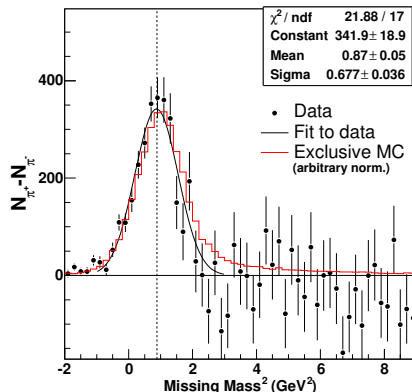




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⌋ **Exclusive Peak** at **nucleon mass**,
 mean and width like **exclusive**
Monte Carlo, based on a GPD
 model



Cross Section: $\sim (\tilde{H} + \tilde{E})^2$

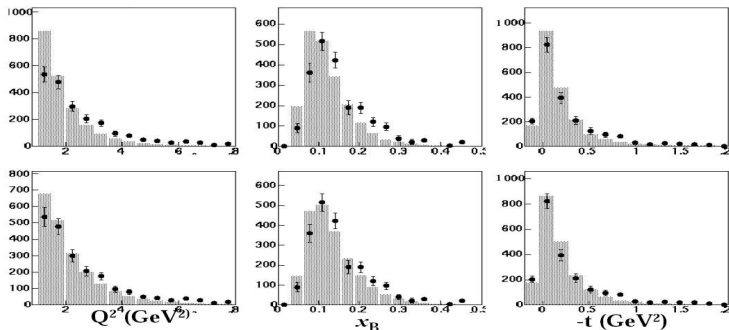
Cross Section:

$$\sigma_{\gamma^* p \rightarrow n + \pi^+}(x, Q^2) = \frac{N_{\text{excl}}^{\pi^+}}{L \cdot \Delta x \Delta Q^2 \cdot \kappa(x, Q^2) \cdot \Gamma(< x >, < Q^2 >)}$$

- L: Integrated luminosity 1996-2000 : 283 pb^{-1}
- $\kappa(x, Q^2)$: Detection probability (from MC)
- $\Gamma(< x >, < Q^2 >)$: virtual photon flux factor

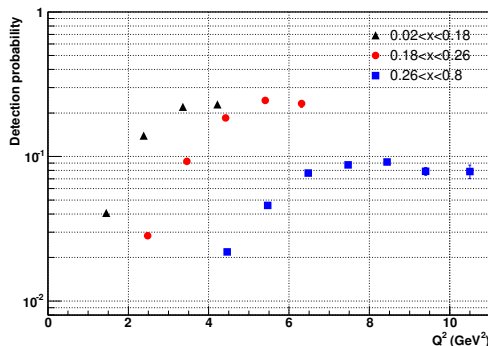
Extracting a Cross Section

- Acceptance correction is strongly model dependent, therefore a comparison with 2 different models was made:
 - Mankiewicz, Piller & Radyushkin (1999)
 - Vanderhaeghen, Guichon & Guidal (1999)



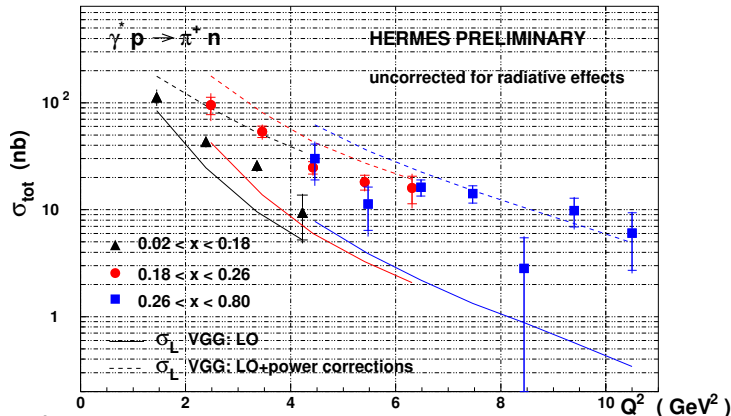
Extracting a Cross Section

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- Detection probability has to be taken into account



σ_{tot} : Q^2 dependence in x bins: $\sim (\tilde{H} + \tilde{E})^2$

- Q^2 behavior with respect to $\sigma_L - \sigma_T$



- Q^2 dependence is **consistent** with LO expectations, however Vanderhaeghen, Guidal, Guichon model too small
- Power corrections (k_T , soft overlap) overestimate data

σ_{reduced} : Separate QCD - QED components

- Factorization theorem predicts a $\frac{1}{Q^6}$ dependence for σ_L at fixed x and t
- Cross Section can be written as (M. Diehl, Phys. Rept. 388 (2003))

$$d\sigma = \frac{1}{16\pi} \frac{x^2}{1-x} \frac{1}{Q^4} \frac{1}{\sqrt{1 + \frac{4m^2 x^2}{Q^2}}} \sum_{\text{spin}} |\mathcal{A}(\gamma^* p \rightarrow pM)|^2$$

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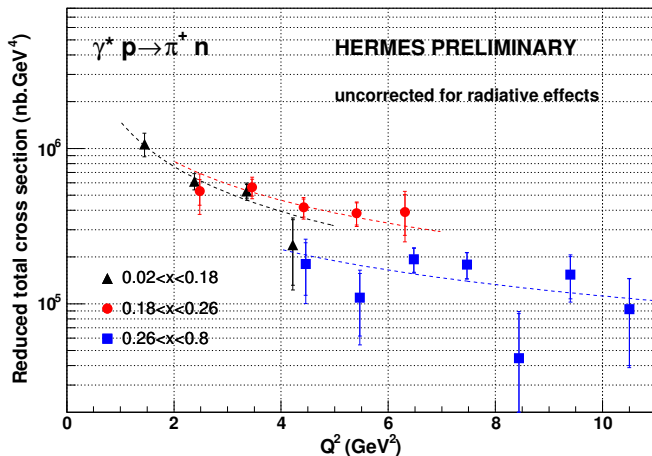
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$$\text{pure } \gamma_L^* + \text{LO} \Rightarrow d\sigma_{\text{red}} \sim \frac{1}{Q^2}$$

σ_{reduced} : Separate QCD - QED components



Fit To data of a $\frac{1}{Q^p}$ function:

$$p = 1.9 \pm 0.5$$

$$p = 1.7 \pm 0.6$$

$$p = 1.5 \pm 1.0$$

Asymmetries

- Target Related Single Spin Asymmetry $\sim \tilde{E} \cdot \tilde{H}$
- Theoretical expectation for asymmetries: Scaling region reached at lower Q^2

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Transverse Spin Asymmetry:

$$\sigma^{U\uparrow} - \sigma^{U\downarrow} \sim |S_{\perp}| \sin \phi \cdot A_{UT} \sim |S_{\perp}| \sin \phi \cdot \tilde{E} \cdot \tilde{H}$$

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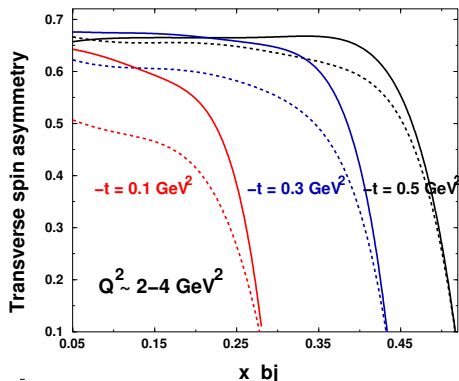
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- 2002-2005: HERMES run with **transversely polarized target**
- Analysis ongoing !

Asymmetries

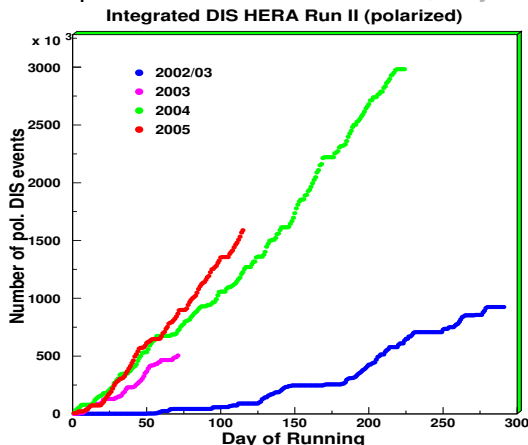
- Theoretical prediction – Frankfurt et Al., Phys. Rev. D60 (1999), 2 models with different pion form factor



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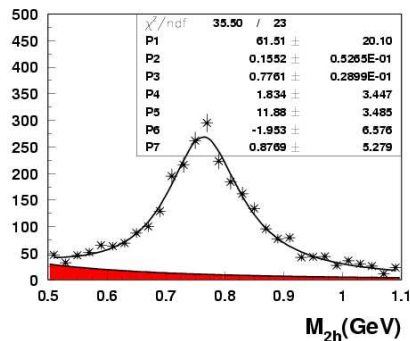
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Vector Mesons

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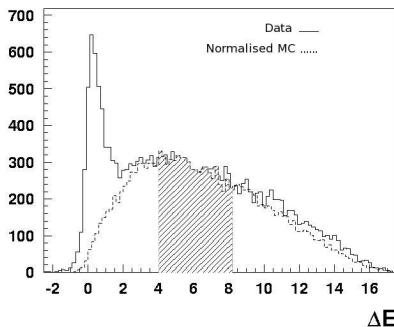
$$e + p \rightarrow e + p + \rho^0$$

- ρ^0 reconstructed from $h^+ h^-$ pairs
- Exclusivity constraints by requiring Missing Energy ΔE to be 0, describe background shape by MC
- Evidence of exclusive ρ^0 production



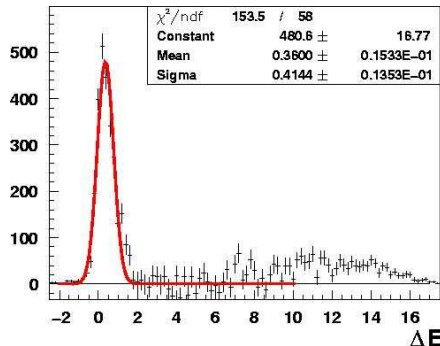
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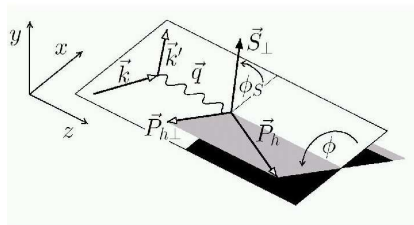


Target Spin Asymmetry A_{UT}

- Experimentally:

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

- $A_{UT} \sim \text{GPD}$ E



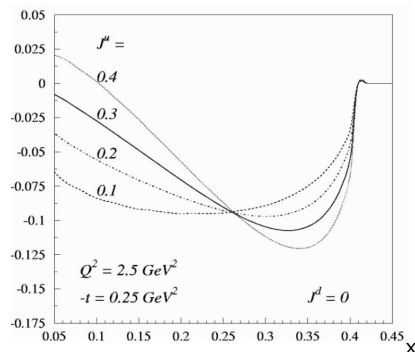
$\sin(\phi - \phi_S)$ amplitude of asymmetry: $A_{UT}^{\sin(\phi - \phi_S)}$

Target Spin Asymmetry A_{UT}

$$\mathcal{A} = \frac{1}{|S_{\perp}|} \frac{\int_0^{\pi} \sigma(\beta) d\beta - \int_{\pi}^{2\pi} \sigma(\beta) d\beta}{\int_0^{2\pi} \sigma(\beta) d\beta}$$

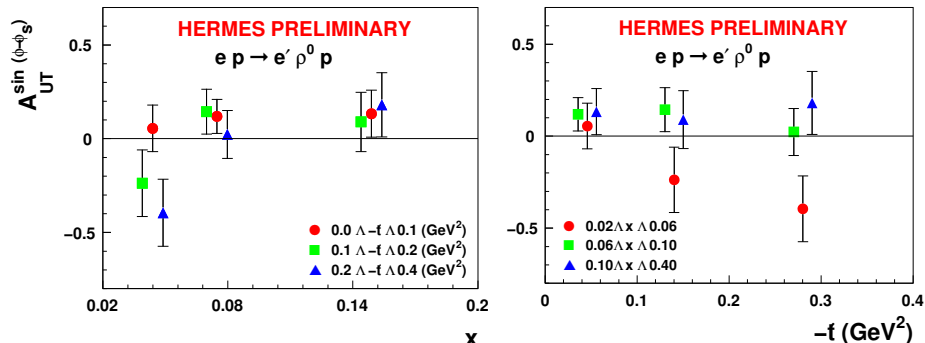
- Sensitivity to J^u
- At Hermes asymmetry slope is positive

Goeke et al., Prog. Part. Nucl. Phys. 47 (2001)



$\sin(\phi - \phi_S)$ amplitude of asymmetry $A_{UT}^{\sin(\phi - \phi_S)} \sim -\mathcal{A}$

A_{UT} for exclusive ρ^0 production

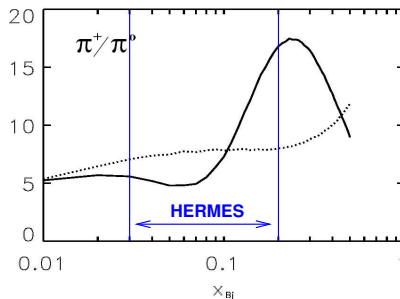


- Data consistent with theory predictions
- Increasing statistics by including all transverse data will allow for an $\sigma_L - \sigma_T$ separation

Stay Tuned !

- Exclusive π^0 production analysis ongoing
 - no pion-pole contribution
 - information about pseudovector $\tilde{H}$ only

Mankiewicz et. al.
Eur. Phys. J. C10 (1999)



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- This fall a **Recoil Detector** will be installed around the target cell

Summary

- 1 Factorization theorem for hard exclusive processes allows GPD's to be probed
- 2 Cross Section for exclusive π^+ production
 - Comparison with GPD based model
 - Q^2 dependence in agreement with theory
- 3 First measurement of A_{UT} for exclusive ρ^0 production
- 4 Ongoing Analysis: A_{UT} for π^+ , ratio π^+/π^0

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Last Word:

Thanks for Listening !