**Exclusive Meson Production at HERMES**

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Jeroen Dreschler

on behalf of the HERMES collaboration

- Cross section of exclusive $\pi^+$ production
- Transverse target spin asymmetry in excl. $\rho^0$ production
- Spin Density Matrix Elements (SDMEs) for exclusive $\rho^0$ production
GPDs & Exclusive Meson Production

Factorization of Amplitudes

Proven for Mesons in case of Longitudinal $\gamma^*$ Polarization


Final state determines sensitivity to different GPDs

$H, E :$ vector mesons ($\rho, \phi, \omega$)

$\tilde{H}, \tilde{E} :$ pseudoscalar mesons ($\pi, \eta$)
Exclusive Events Selection

\[ \gamma^* p \rightarrow \pi^+ X : \text{Missing Mass} \]

\[ M_X^2 = (P_{\gamma^*} + P_p - P_{\pi^+})^2 \]

- Non-exclusive background estimated with normalized \( \pi^- \) yields
Exclusive Events Selection

\[ \gamma^* p \rightarrow \pi^+ X : \text{Missing Mass} \]

\[ M_X^2 = (P_{\gamma^*} + P_p - P_{\pi^+})^2 \]

After background subtraction:

\[ M_X \text{ centered around } M_n \]
Exclusive Events Selection

$\gamma^* p \rightarrow \pi^+ X$: Missing Mass

$\gamma^* p \rightarrow \rho^0 X$: Missing Energy

\[ M_X^2 = (P_{\gamma^*} + P_p - P_{\pi^+})^2 \]

- After background subtraction: $M_X$ centered around $M_n$

\[ \Delta E = \frac{M_X^2 - M_p^2}{2M_p} \]

- Excl. $\rho^0$ data set: $\Delta E$ around 0.0 GeV
\( \gamma^* p \rightarrow \pi^+ n \) Cross Section Measurements

\[ \sigma_{tot} = \sigma_T + \epsilon \sigma_L \]

- Regge model: dominance of \( \sigma_L \) over \( \sigma_T \) \((\text{Laget: PRD 70 (2004) 054023})\)
- \( Q^2 \) dependence agrees with GPD model calculations \((\text{Vanderhaegen, Guichon, Guidal: PRD 60 (1999) 094017})\)
Reduced Cross Section: $Q^2$ dependence

Fit of data with:

\[ \sigma_{\text{reduced}} \sim \frac{1}{Q^p} \]

- $p = 1.9 \pm 0.5$
- $p = 1.7 \pm 0.6$
- $p = 1.5 \pm 1.0$

Definition:

\[ \sigma_{\text{reduced}} = \sigma_{\gamma^* p \rightarrow n \pi^+} \left/ \left( \frac{1}{16\pi} \frac{x^2}{1-x} \frac{1}{Q^4} \frac{1}{\sqrt{1+\frac{4m^2x^2}{Q^2}}} \right) \right. \]

Expectation:

\[ \sigma_L \sim \frac{1}{Q^6} \rightarrow \sigma_{\text{reduced},L} \sim \frac{1}{Q^2} \]

$\sigma_T$ suppressed by $1/Q^2$
Transverse Target Spin Asymmetry in $\gamma^* p \rightarrow \rho^0 p$

- Sensitive to $EH$ interference term

$$A_{UT} \sim \sin(\phi - \phi_s) EH$$

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

- Dependence on $J^u$

Goeke, Polyakov, Vanderhaeghen:

$$\mathcal{A}_{theory} \sim -A_{UT}^{\sin(\phi - \phi_s)} \sim EH$$
Kinematic Dependence of $A_{UT}^\sin(\phi - \phi_s)$

Results consistent with GPD model calculations
(Vinnikov: hep-ph / 0506264)

To be done:
- Include 2005 data (statistics increase by factor 2)
- $\sigma_L - \sigma_T$ separation
SDME Extraction for $\gamma^* N \rightarrow \rho^0 N$

- SDMEs extraction from angular distribution $W(\cos \theta, \phi, \Phi)$
- Spin state of $\rho^0$ is reflected in orbital angular momentum of decay $(\pi^+\pi^-)$ system $\rightarrow W(\cos \theta, \phi, \Phi)$

Recent results for 23 SDMEs measured at HERMES:
- 8 Polarized / 15 Unpolarized SDMEs
- Used targets: Hydrogen / Deuterium
Extracted SDMEs (proton)

- SDMEs, obtained from a 3D maximum likelihood fit of $W(\cos \theta, \phi, \Phi)$
- Dependences on kinematical variables $x_B, Q^2, t'$ determined
\[ R = \frac{\sigma_L}{\sigma_T} \text{ for exclusive } \rho^0 \text{ production} \]

At HERMES:
Assuming s-channel helicity conservation:
\[
R = \frac{1}{\epsilon} \frac{\tau_{00}^{04}}{1 - \tau_{00}^{04}}
\]

\[ \sigma_L - \sigma_T \] separation:
\[
\sigma_L = \frac{R}{1 + \epsilon R} \sigma_{\gamma^* p \rightarrow \rho^0 p}
\]
Conclusion

Summary

- Cross section measured for exclusive $\pi^+$ production
- $Q^2$ dependence in agreement with GPD model calculations
- First results shown for $A_{UT}$ in exclusive $\rho^0$ production
- Sensitivity to GPD $E$ and angular momentum $J^u$
- Recent results: SDMEs for $\rho^0$ production obtained using 3D maximum likelihood fit of angular distributions

Outlook

- More transversely polarized target data
- $\sigma_L - \sigma_T$ separation for $A_{UT}$ in exclusive $\rho^0$ production
- Cross sections $\sigma_{\rho^0}, \sigma_{\phi} \rightarrow$ ratio $\sigma_{\phi}/\sigma_{\rho^0}$