L-T Separation of Transverse Target Spin Asymmetry In Exclusive Rho Production

Nora Estrada
Avetik Hairapetyan and Wouter Deconinck

HERMES Summer Students Session
13th September 2006
The measurement of the Transverse Target Spin Asymmetry (TTSA) $A_{UT}$ in the exclusive production of longitudinally polarized $\rho^0$ mesons on hydrogen, is a good tool to access the generalized parton distribution (GPD) function $E$. Moreover, it might give us some insight in the GPDs of the gluons, because the production amplitude involves exchange processes of quarks and gluons simultaneously.

In this work we contribute releasing the moment $A_{UT}^{\sin(\phi-\phi_s)}$ for the process $\gamma^*p^\uparrow \rightarrow \rho^0p$, separated over $\rho^0_L$ and $\rho^0_T$, using the latest data produced by HERMES.
Data Selection

- 2005 running period
- Hydrogen polarized gas target

- More than two trajectories from vertex (target region $-18 < Z < 18$)
- 2 oppositely-charged hadrons
- It was also checked that the tracks were not kaons from a $\phi$
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The relevant 4-momenta are:

- Incident electron: $k$, scattered electron: $k'$
- Photon: $q \equiv k - k'$
- Struck nucleon: $P$
- Detected hadrons: $P_{h^+}$ and $P_{h^-}$
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HERMES Apparatus

- HERMES Apparatus Diagram
  - Introduction
  - Data Selection
  - Methodology
  - Results
  - Conclusions

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General cuts

- **Data quality cuts.** Properly working detector components and reasonable beam-target polarization (official burst list was used with DQ pattern 401ffffd”)

- **Vertex cut**

- **Particle identification and exclusive cuts.**

Particular cuts

- **T-prime cut.** 4 bins with same statistics.
- **Target bit cut.** Spin up, down.
- **$\cos \theta$ cut** Further application in analysis
General cuts

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Particular cuts

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THE Method

Determination of $\beta_1$ and $\beta_2$

Determination of $A_{UT}$ inner and outer

$\rho^0$ Reconstruction

TMC1: 1st version of transverse magnet correction (TMC)

TMC2: 2nd version of transverse magnet correction (TMC)
Method Description

We use the decay angle $\theta$ of the $\pi^+$ to get information about the longitudinal polarization of the $\rho^0$ meson. Assuming that the helicity of the virtual photon is transferred completely to the produced $\rho^0$ meson.

$$W(\theta) = \frac{3}{4} (1.0 - r_{00}^0 + (3.0 r_{00}^0 - 1) \cos^2(\theta))$$

$r_{00}^0$: Longitudinal polarization of the $\rho^0$
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$$W(\theta) = \frac{3}{4} (1.0 - r_{00}^{04} + (3.0r_{00}^{04} - 1)\cos^2(\theta))$$

$r_{00}^{04}$: Longitudinal polarization of the $\rho^0$
In principle, with unlimited statistics when we determine the asymmetry $A_{UT}$ for events with $\cos(\theta) = 0$, we have selected the process $\gamma^* p^\uparrow \to \rho_T^0 p$. For events satisfying $|\cos(\theta)| = 1$, the process $\gamma^* p^\uparrow \to \rho_L^0 p$ is selected.
Determination of $\beta_1$ and $\beta_2$
Determination of $A_{UT}$ inner and outer

\[ W(\theta, r_{00}^{04}) \]

\[ r_{00}^{04} \rightarrow 0 \quad W(\theta)^T \]

\[ r_{00}^{04} \rightarrow 1 \quad W(\theta)^L \]
\[ A_{UT}^{inner} = \beta_1 A_{UT}^T + (1 - \beta_1) A_{UT}^L \]

\[ A_{UT}^{outer} = \beta_2 A_{UT}^L + (1 - \beta_2) A_{UT}^T \]
THE Method
Determination of $\beta_1$ and $\beta_2$

Determination of $A_{UT}$ inner and outer

\[ A_{UT}^{inner} = \beta_1 A_{UT}^{T} + (1 - \beta_1) A_{UT}^{L} \]

\[ A_{UT}^{outer} = \beta_2 A_{UT}^{L} + (1 - \beta_2) A_{UT}^{T} \]

\[ A_{UT}^{L} = \frac{A_{UT}^{outer} \beta_1 + A_{UT}^{inner} (\beta_2 - 1)}{\beta_1 + \beta_2 - 1} \]

\[ A_{UT}^{T} = \frac{A_{UT}^{inner} \beta_2 + A_{UT}^{outer} (\beta_1 - 1)}{\beta_1 + \beta_2 - 1} \]
The Method

Determination of $\beta_1$ and $\beta_2$

Determination of $A_{UT}$ inner and outer

\[ A_{UT}^{inner} = \beta_1 A_{UT}^T + (1 - \beta_1) A_{UT}^L \]

\[ A_{UT}^{outer} = \beta_2 A_{UT}^L + (1 - \beta_2) A_{UT}^T \]

\[ A_{UT}^L = \frac{A_{UT}^{outer} \beta_1 + A_{UT}^{inner} (\beta_2 - 1)}{\beta_1 + \beta_2 - 1} \]

\[ A_{UT}^T = \frac{A_{UT}^{inner} \beta_2 + A_{UT}^{outer} (\beta_1 - 1)}{\beta_1 + \beta_2 - 1} \]
Determination of $\beta_1$ and $\beta_2$

\[ \beta_1 = \frac{\int_{-0.5}^{0.5} (1 - X)W(\theta)^T d\theta}{\int_{-0.5}^{0.5} (XW(\theta)^L + (1 - X)W(\theta)^T) d\theta} \]

\[ \beta_2 = \frac{\int_{-1}^{-0.5} XW(\theta)^L d\theta}{\int_{-1}^{-0.5} (XW(\theta)^L + (1 - X)W(\theta)^T) d\theta} \]

\[ X = r_{00}^{04} \]
Assuming that $r_{00}^{04}$ is the same for polarized target as for unpolarized target...

\[ \chi^2/\text{ndf} \quad 0.2353 / 2 \]

\[ P1 \quad 0.4132 \]

\[ P2 \quad 0.1416 \]
## The Method

Determination of $\beta_1$ and $\beta_2$

Determination of $A_{UT}$ inner and outer

### Table

#### TMC1

<table>
<thead>
<tr>
<th></th>
<th>Bin 1</th>
<th>Bin 2</th>
<th>Bin 3</th>
<th>Bin 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{\text{prime}}$</td>
<td>0.02141</td>
<td>0.07620</td>
<td>0.1581</td>
<td>0.2898</td>
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<tr>
<td>$r_{00}^{04}$</td>
<td>0.41623</td>
<td>0.42399</td>
<td>0.43558</td>
<td>0.45423</td>
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<tr>
<td>$\beta_1$</td>
<td>0.88524</td>
<td>0.88196</td>
<td>0.87695</td>
<td>0.86856</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>0.66626</td>
<td>0.67331</td>
<td>0.68362</td>
<td>0.69973</td>
</tr>
</tbody>
</table>

#### TMC2

<table>
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</thead>
<tbody>
<tr>
<td>$T_{\text{prime}}$</td>
<td>0.02063</td>
<td>0.07515</td>
<td>0.1560</td>
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<tr>
<td>$r_{00}^{04}$</td>
<td>0.41612</td>
<td>0.42384</td>
<td>0.43528</td>
<td>0.453796</td>
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<tr>
<td>$\beta_1$</td>
<td>0.88528</td>
<td>0.88202</td>
<td>0.87708</td>
<td>0.86876</td>
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<tr>
<td>$\beta_2$</td>
<td>0.66616</td>
<td>0.67317</td>
<td>0.68336</td>
<td>0.69936</td>
</tr>
</tbody>
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THE Method
Determination of $\beta_1$ and $\beta_2$
Determination of $A_{UT}^{inner}$ and outer

TMC1 $A_{UT}^{inner}$
TMC1 $A_{UT}^{outer}$

**Figure 1:**
- **Left:** Graph showing $A_{UT}$ versus $\Phi - \Phi_S$ (rad) for TMC1. The data points are represented with error bars, and the trend line is shown in blue. The equation fitted to the data is $Y = Atan(\Phi - \Phi_S) + Const$, with parameters $A = 0.131593 \pm 0.000053$, $Const = 0.00161703 \pm 0.0568573$.
- **Right:** Similar graph for TMC1 with slightly different parameters: $A = 0.055153 \pm 0.099028$, $Const = 0.0696139$.

**Figure 2:**
- **Left:** Graph showing $A_{UT}$ versus $\Phi - \Phi_S$ (rad) for TMC1. The data points are represented with error bars, and the trend line is shown in blue. The equation fitted to the data is $Y = Atan(\Phi - \Phi_S) + Const$, with parameters $A = 0.015553 \pm 0.099028$, $Const = 0.0696135$.
- **Right:** Similar graph for TMC1 with slightly different parameters: $A = 1.38191 \pm 0.104523$, $Const = 0.034623 \pm 0.016878$.
THE Method
Determination of $\beta_1$ and $\beta_2$
Determination of $A_{UT}$ inner and outer

TMC2 $A_{UT}^{inner}$

\begin{align*}
Y_{\text{data}}(\Phi,\Phi_S) & \pm \text{error} \\
& = A_{UT}(\Phi,\Phi_S) + \text{error}
\end{align*}

\begin{align*}
A_{UT} & = 0.161 \pm 0.079 \\
\Phi & = \text{error}
\end{align*}

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Determination of $\beta_1$ and $\beta_2$

Determination of $A_{UT}$ inner and outer

TMC2 $A_{UT}^{outer}$
\[ A^L_{UT} = \frac{A^{\text{outer}}_{UT} \beta_1 + A^{\text{inner}}_{UT} (\beta_2 - 1)}{\beta_1 + \beta_2 - 1} \]
\[ A^T_{UT} = \frac{A^{\text{inner}}_{UT} \beta_2 + A^{\text{outer}}_{UT} (\beta_1 - 1)}{\beta_1 + \beta_2 - 1} \]

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<tr>
<td>[A^{\text{outer}}_{UT}]</td>
<td>0.013115± 0.09659</td>
<td>-0.0231192± 0.09559</td>
<td>0.0851553± 0.0696</td>
<td>-0.139191± 0.1045</td>
</tr>
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<td>[A^{\text{inner}}_{UT}]</td>
<td>-0.105491± 0.125</td>
<td>-0.0519132± 0.1229</td>
<td>-0.0236317± 0.1140</td>
<td>0.00524414± 0.1098</td>
</tr>
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<td>[A^L_{UT}]</td>
<td>0.0848868± 0.1725</td>
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<td>0.146551± 0.12649</td>
<td>-0.215505± 1699</td>
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<td>[A^T_{UT}]</td>
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<td>-0.058034± 0.1504</td>
<td>-0.0475108± 0.1399</td>
<td>0.0386484± 0.137</td>
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Results

TMC1

\[ A_{UT}^{L} \]

\[ A_{UT}^{T} \]

TMC2

\[ A_{UT}^{L} \]

\[ A_{UT}^{T} \]
Comparisons Among TMC1 and TMC2

$A_{UT}^L$, blue: TMC1, red: TMC2

$A_{UT}^T$, blue: TMC1, red: TMC2
Comparisons Among $A_{UT}^L$ and $A_{UT}^T$
general averages

\[ A_{UT} \]

\[ T' \]
Conclusions

We separate the transversal and longitudinal components of Transverse Spin Asymmetry in exclusive $\rho^0$ production, using a method based on the cosine of the decay angle of the $\pi^+$ in the $\rho^0$ center of mass, verifying that all the calculation process is correct. We obtain a result of this measurement as follows:

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