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

Nora Estrada

September 19, 2006

Abstract

This report presents the measurement of the Transverse Target Spin Asymmetry (A_{UT}) in exclusive electro production for the process $\gamma p^{\uparrow} \rightarrow \rho_0 p$, Using hydrogen data from the 2005 run of HERMES, using the method of separation based in the information of the decay angle of the π^+ in the ρ^0 center-of-mass system.

.

Contents

1 Introduction **3**

2 Data and Kinematic Cuts **3**

2.1 Data Selection . . . 3

2.2 Kinematic Cuts . . . 3

3 Methodology **4**

3.1 ρ^0 Reconstruction . . . 4

3.2 Method Description . . . 5

3.3 Determination Of β_1 And β_2 . . . 7

3.4 Determination Of A_{UT}^{inner} And A_{UT}^{outer} . . . 7

3.5 ϕ And ϕ_s Angles Verification . . . 9

4 Results **9**

5 Conclusions **11**

6 Acknowledgments **12**

1 Introduction

The measurement of the Transverse Target Spin Asymmetry (TTSA) A_{UT} in the exclusive production of longitudinally polarized ρ^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 $\gamma^\star p^\uparrow \rightarrow \rho^0 p$, separated over ρ^0_L and ρ^0_T, using the latest data produced by HERMES.

2 Data and Kinematic Cuts

2.1 Data Selection

For this analysis we used two sets of data with different methods for the transverse magnet correction (TMC1 and TMC2) containing event information from the 2005 running period of the HERMES experiment using hydrogen polarized gas target in the 27.5 GeV electron ring at DESY. The HERMES detector is described in detail in Ref. [1]. For the data selection the following basic characteristics:

- More than two were required trajectories coming from the target region $-18 < Z < 18$.
- at least the scattered electron and two oppositely-charged hadrons, we assume that the two detected hadrons are pions. More information about the data selection can be found in Ref. [2].
- We also checked that the tracks were not kaons from a ϕ meson.

  The relevant 4-momenta are: k (k') for the incident (scattered) electron, $q \equiv k - k'$ of the photon, P of the struck nucleon, P_{h^+}, P_{h^-} of the detected hadrons, the momentum of the ρ^0 candidate $V = P_{h^+} + P_{h^-}$ and $P_y = P + q - V$ of the undetected final state.

2.2 Kinematic Cuts

For the data selection criteria we apply different cuts to select events with properly working detector components and reasonable target polarization (official burst list was used with DQ pattern 401ffffd")(*Data quality cuts*).

Also for this analysis the following kinematic cuts were applied:

- Exclusivity: $\Delta E < 0.6$, where $\Delta E = (P_y^2 - \frac{\mu^2}{2M})$, M is the proton mass.
- $Q^2 > 1$, $y <$, where $Q = (t - t')^2$.

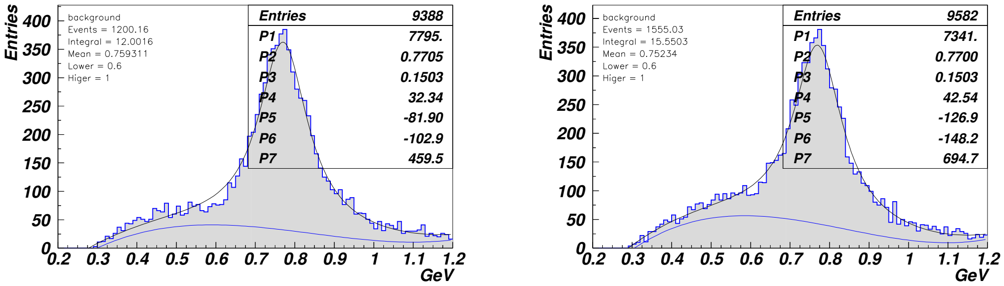

Figure 1: $\pi^+\pi^-$ invariant mass fit for TMC1 (left) and TMC2 (right).

- Diffractivity $t = (q - V^2)$, $t' = t - t_0$.

The total statistic in each version of data was divided in t' bins containing each set approximately the same amount of events.

The following t' bins were used:

- $0.0 < -t' < 0.45$
- $0.45 < -t' < 0.11$
- $0.11 < -t' < 0.21$
- $0.21 < -t' < 0.4$

The events were also divided in order to apply the separation method, according to cosine of the decay angle of the π^+ in ρ^0 center of mass ($\cos\theta$).

- $|\cos\theta| < 0.5$ rad. Inner bin
- $|\cos\theta| > 0.5$ rad. outer bins

3 Methodology

3.1 ρ^0 Reconstruction

As a first step we reconstruct the ρ^0 to verify that the peak of our data sample is at the correct value of mass for the ρ^0.

Also we made a fit of $\pi^+\pi_-$ invariant mass histogram with a Breit-Wigner distribution with the mean fixed at 775 MeV, and *Gamma* fixed at 150 according to PDG, this jobs are plotted in figure 1.

3.2 Method Description

The used method [3] uses the decay angle θ of the π^+ to get information about the longitudinal polarization of the ρ^0 meson.

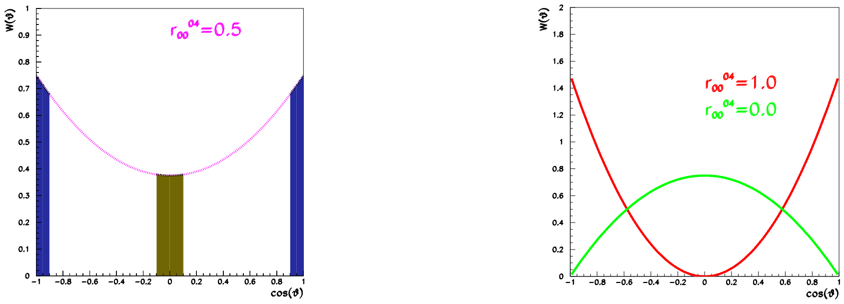

Figure 2: Left: $W(\theta)$ distribution with $r_{00}^{04} = 0.5$. Right: $W(\theta)$ distribution with $r_{00}^{04} = 0$(transversal ρ^0) and $r_{00}^{04} = 1$ (longitudinal ρ^0)

We used the $\cos\theta$ and it's distribution [3]:

$$W(\theta) = \frac{3}{4}(1.0 - r_{00}^{04} + (3.0\dot{r}_{00}^{04} - 1)\cos^2(\theta)) \tag{1}$$

Is a function not only of $\cos\theta$, but of longitudinal polarization(r_{00}^{04}) of the ρ^0.

In figure 2 we show the $W(\theta)$ distribution for different helicities of the ρ^0. The right part shows a combination of equal amounts of longitudinally and transversely polarized ρ^0 mesons, the left part shows the $W(\theta)$ distribution separated for longitudinally and transversely polarized ρ^0 mesons. In principle, with unlimited statistics, when we determine the asymmetry A_{UT} for events with $\cos(\theta) = 0$, we have selected the process $\gamma^\star p^\uparrow \to \rho_T^0 p$. For events satisfying $|\cos(\theta)| = 1$, the process $\gamma^\star p^\uparrow \to \rho_L^0 p$ is selected.

In reality, the longitudinal polarization of ρ^0 varies between 0.33 and 0.53 depending on the Q^2 at HERMES kinematics. Assuming that r_{00}^{04} is the same for a polarized target as for an unpolarized target we use the previous results of HERMES [4] to calculate the corresponding values of r_{00}^{04} for each t' (average) value.

This was done first by adjusting the data we have from this previous measurements with a straight line as shown in figure 3, then from this very simple equation obtained, we calculated the values according with our own data. We obtained the following results:

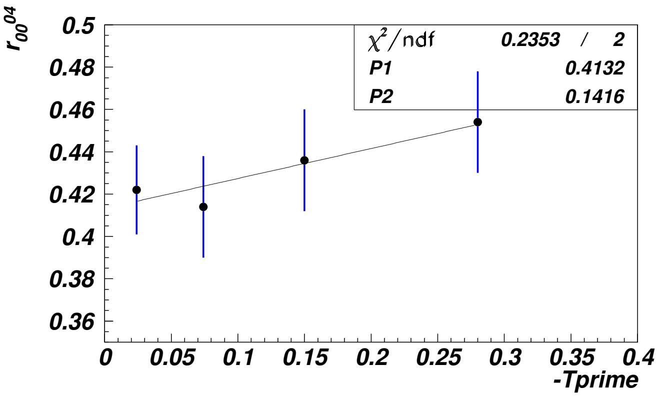

Figure 3: Fit of r_{00}^{04} versus t' to a straight line

TMC1				
	Bin 1	Bin 2	Bin 3	Bin 4
t'	0.02141	0.07620	0.1581	0.2898
r_{00}^{04}	0.41623	0.42399	0.43558	0.45423
TMC2				
	Bin 1	Bin 2	Bin 3	Bin 4
t'	0.02063	0.07515	0.1560	0.2867
r_{00}^{04}	0.41612	0.42384	0.43528	0.453796

We separate data according to the $W(\theta)$ distribution in two bins, $|\cos(\theta)| < 0.5$ and $|\cos(\theta)| > 0.5$ calling the ρ^0 with $|\cos(\theta)| < 0.5$ inner (ρ^0_{inner}) and the ρ^0 with $|\cos(\theta)| > 0.5$ outer (ρ^0_{outer}).

The asymmetries A_{UT}^{inner} and A_{UT}^{outer} in the inner and outer bins of $|\cos(\theta)|$ are related to the pure A_{UT}^{L} (Transverse) and A_{UT}^{T} (Longitudinal) by the relations:

$$A_{UT}^{inner} = \beta_1 A_{UT}^{T} + (1-\beta_1) A_{UT}^{L} \tag{2}$$

$$A_{UT}^{outer} = \beta_2 A_{UT}^{L} + (1-\beta_2) A_{UT}^{T} \tag{3}$$

where β_1 is the fraction of transversely polarized ρ^0 in the inner bin and β_2 is the fraction of longitudinally polarized ρ^0 in the outer bins. We can solve the previous equations into equations for A_{UT}^{L} and A_{UT}^{T}:

$$A_{UT}^{L} = \frac{A_{UT}^{outer}\beta_1 + A_{UT}^{inner}(\beta_2 - 1)}{\beta_1 + \beta_2 - 1} \tag{4}$$

$$A_{UT}^{T} = \frac{A_{UT}^{inner}\beta_2 + A_{UT}^{outer}(\beta_1 - 1)}{\beta_1 + \beta_2 - 1} \tag{5}$$

3.3 Determination Of β_1 And β_2

The two constants β_1 and β_2 were calculated using the following integrals:

$$\beta_1 = \frac{\int_{-0.5}^{0.5} (1-X)W(\theta)^T d\theta}{\int_{-0.5}^{0.5} (XW(\theta)^L + (1-X)W(\theta)^T)d\theta} \tag{6}$$

$$\beta_2 = \frac{\int_{-1}^{-0.5} XW(\theta)^L d\theta}{\int_{-1}^{-0.5} (XW(\theta)^L + (1-X)W(\theta)^T)d\theta} \tag{7}$$

Where $X = r_{00}^{04}$ for the corresponding t'. We obtained the following results:

TMC1				
	Bin 1	Bin 2	Bin 3	Bin 4
t'	0.02141	0.07620	0.1581	0.2898
β_1	0.88524	0.88196	0.87695	0.86856
β_2	0.66626	0.67331	0.68362	0.69973
TMC2				
	Bin 1	Bin 2	Bin 3	Bin 4
t'	0.02063	0.07515	0.1560	0.2867
β_1	0.88528	0.88202	0.87708	0.86876
β_2	0.66616	0.67317	0.68336	0.69936

3.4 Determination Of A_{UT}^{inner} And A_{UT}^{outer}

The Transverse Target Spin Asymmetry is defined as follows:

$$A_{UT} = \frac{\sigma^{\uparrow\Uparrow} - \sigma^{\uparrow\Downarrow}}{\sigma^{\ uparrow\Uparrow} + \sigma^{\uparrow\Downarrow}} \tag{8}$$

This was easily calculated using PAW[1] as a tool extracting the information from the Ntuples and following the steps:

- The ϕ angle and the ϕ_s (Sievers) angle and we calculate de difference among these two in every event.

  The angles were calculated as follows [5]:

$$\phi = signum(q \times k \cdot P_h) \cdot \arccos\left(\frac{q \times k \cdot q \times P_h}{|q \times k| \cdot |q \times P_h|}\right)$$

$$\phi_s = signum(q \times k \cdot S_T) \cdot \arccos\left(\frac{q \times k \cdot q \times S_T}{|q \times k| \cdot |q \times S_T|}\right)$$

[1]Physics Analisys Workstation

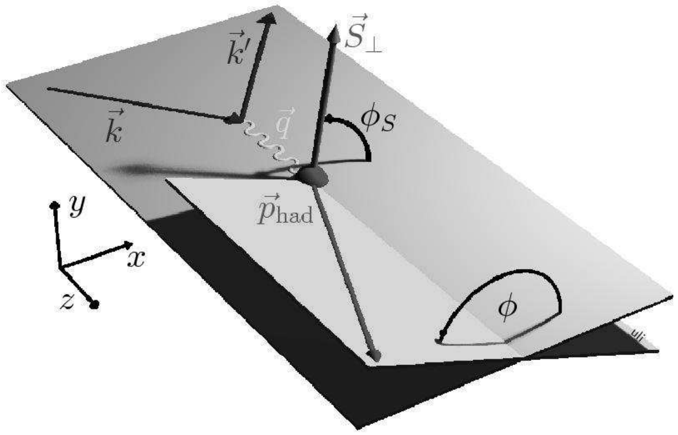

Figure 4: Definition of azimuthal angles

Where S_T is the target polarization vector, always defined parallel to the transverse holding field of the target (0,-1,0), in the HERMES coordinated system. the other kinematic variables are also shown in figure 4).

- With this difference we fill two different histograms, one for the events for which the spin of the target in the experiment was UP (H1), and the other for the case when the spin was DOWN (H2).
- Using the histograms we calculate the TTSA $\frac{H1-H2}{H1+H2}$ for the inner and outer bins.

From this calculations we get the following results:

TMC1				
	Bin 1	Bin 2	Bin 3	Bin 4
A_{UT}^{outer}	0.013115± 0.09659	-0.0231192±0.09559	0.0851553±0 .0696	-0.139191±0.1045
A_{UT}^{inner}	-0.105491±0.125	-0.0519132±0.1229	-0.0236317±0. 1140	0.00524414±0.1098
TMC2				
	Bin 1	Bin 2	Bin 3	Bin 4
A_{UT}^{outer}	0.102504±0.09669	0.0821026±0.0929	0.0128155±0.0 946	-0.0881018±0.1027
A_{UT}^{inner}	-0.0279112±0.1188	0.0516653±0.1236	-0.161044±0. 120	0.0839373±0.1096

3.5 ϕ And ϕ_s Angles Verification

In order to be sure about the results, we perform our own calculations of ϕ and ϕ_s angles and we compare this with the information of the angles contained in the Ntuples.

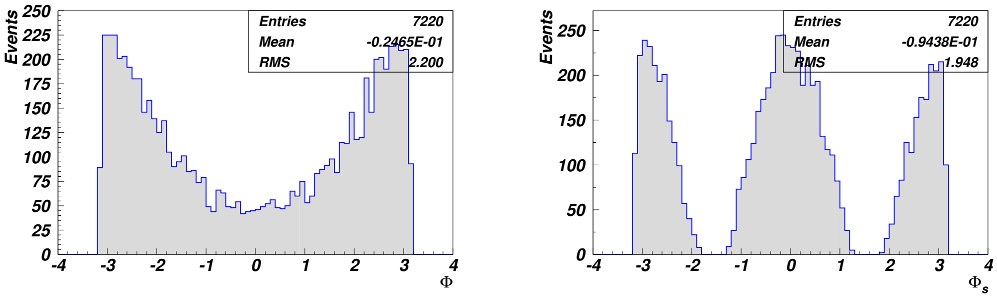

Figure 5: Histograms showing the distributions for the ϕ and ϕ_s coming from data in HERMES acceptance.

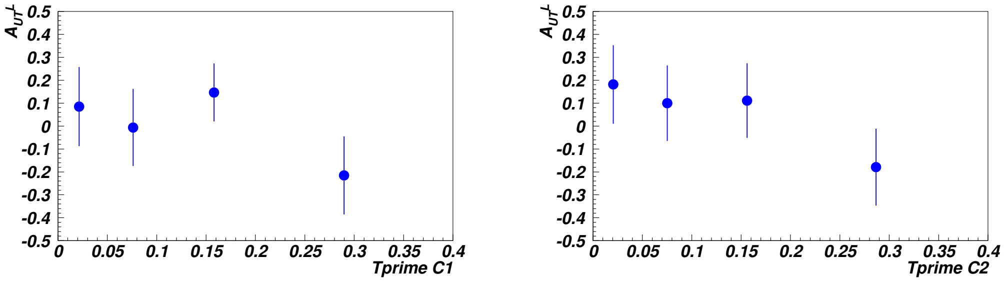

Figure 6: Results of the A_{UT}^L for the two versions of data, TMC1 (left) and TMC2 (right)

4 Results

We perform the calculations for A_{UT}^L and A_{UT}^T for each one of the t' bins obtaining the following results:

TMC1				
	Bin 1	Bin 2	Bin 3	Bin 4
A_{UT}^L	0.0848868±0.1725	-0.00617872±0.168	0.146551±0.126 49	-0.215505±1699
A_{UT}^T	-0.130171±0.1523	-0.058034±0.1504	-0.0475108±0.13 99	0.0386484±0.137
TMC2				
	Bin 1	Bin 2	Bin 3	Bin 4
A_{UT}^L	0.181454±0.171	0.10002±0.164	0.111041±0.1628	-0 .179139± 0.1675
A_{UT}^T	-0.0550403±0.1449	0.0451979±0.1512	-0.199175±0.14 79	0.123677±0.137

In figure 6 we show A_{UT}^L for each bin in both versions of data, in figure 7 we show A_{UT}^T for each bin in both versions of data. In figure 9, we show the total A_{UT}^L and A_{UT}^T averages calculated for each version, in the plot we shift artificially the t' averages for visual effect.

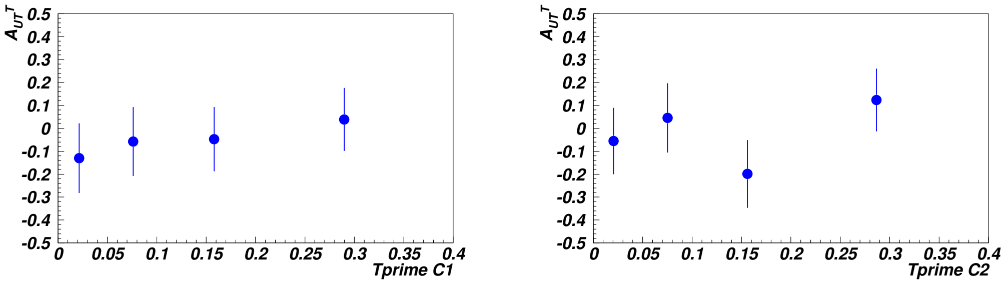

Figure 7: Results of the A_{UT}^{T} for the two versions of data, TMC1 (left) and TMC2 (right)

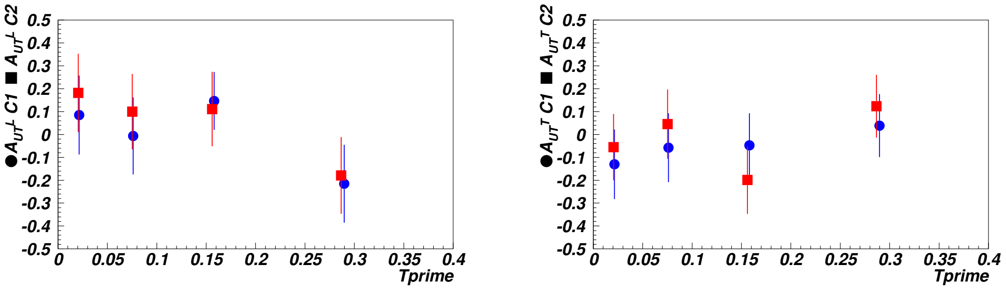

Figure 8: Comparison among the two versions of data of A_{UT}^{L} (left) and A_{UT}^{T} (right).

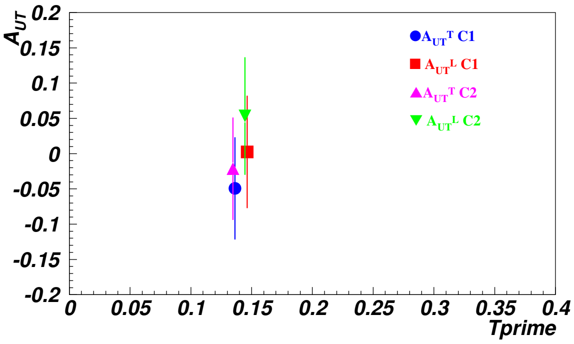

Figure 9: Total averages of A_{UT}^{L} and A_{UT}^{T} for both version of data

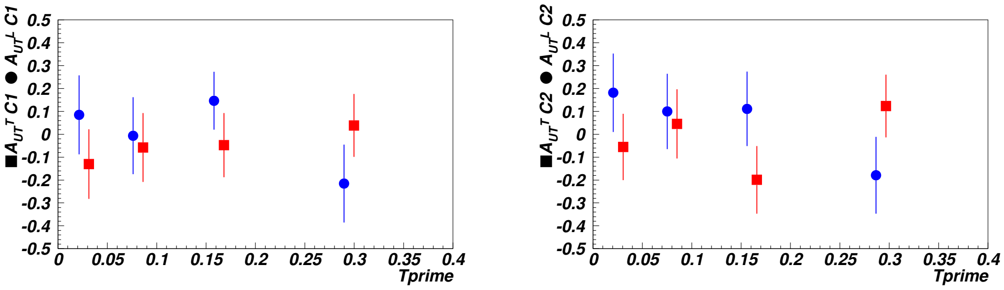

Figure 10: Comparision of A_{UT}^{L} and A_{UT}^{T} among data from the same version TMC1 (left), TMC2 (right).

5 Conclusions

We made comparisons among the information obtained from our analysis:

Because this is the first time this extractions are done, we cannot compare our results with previous analyzes but a different behavior was expected between A_{UT}^{L} and A_{UT}^{T} . We can conclude from figure 8 that the result from the two versions are in agreement. All errors are statistical.

6 Acknowledgments

I would like to thank DESY and the Summer Students Program for giving me the opportunity to work in such a stimulating environment. To the HERMES collaboration for working into a friendly and enthusiastic atmosphere and in a special way, to my supervisors Avetik Hairapetyan and Wouter Deconinck for all the support, infinite patience and encouragement.

References

[1] K. Ackerstaff *et.al.*, Nucl. Insr. Meth.**A417**, 230 (1998)

[2] K. Ackerstaff *et.al.*, Phys. Rev.Lett**82**, 3025 (1999)

Prospects for Measuring the Transverse Target Spin Asymmetry in DVCS and ρ^0 Production at HERMES, F. Ellinghaus, W.-D. Nowak, A.V. Vinnikov, Z. Ye.,04-008 HERMES Internal Report

[3] A. Airapetian, W. Deconinck, W. Lorenzon, *Measurement of Transverse Target Spin Asymmetry in Exclusive Electroproduction of rho0 Mesons in the Processes:*$\gamma^\star p^\uparrow \to \rho^0 p$ HERMES Internal Report 05-004.

[4] HERMES Collaboration *Spin Density Matrix Elements In Exclusive Difractive ρ^0 Production On Proton And Deuteron At Intermediate Energies*, Draft version v5.4 (2006)

[5] U. Elschenbroich, M, Diefenthaler, *Single-spin azimuthal Asymmetries in Semi-inclusive Deep-inelastic Scattering on a Transversely Polarised Hydrogen Target*, HERMES Internal Report.