Diffractive Slope Extraction of Exclusive $\rho_L^0$ and $\rho_T^0$ at HERMES

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Motivation

- Observing $\rho^0$ electroproduction ($ep \rightarrow e'p'\rho^0$) through decay channel $\rho^0 \rightarrow \pi^+\pi^-$.  
- $\rho^0$ meson shrinks at higher values of $Q^2$.  
  - Effect known as shrinkage and is a precondition for color transparency, or the ability to scatter off small targets with reduction of color interaction.
- Transverse size of $\rho^0$ reflected in cross-sectional slope parameter $b$.  
- $b$ fairly well understood.  
- Very little known about dependence on helicity of $\rho^0$.  

$Q^2$ is the absolute value of the magnitude of the four-momentum of the virtual photon involved in the $ep$ collision.

$-t'$ is the momentum transfer above the minimum required for the reaction to take place.

$\epsilon$ is the virtual photon polarization parameter.
\[ \phi \] is the angle between the scattering plane and the production plane.

\[ \phi_S \] is the angle between the scattering plane and the target polarization.

\[ \varphi \] and \[ \vartheta \] spherical angles between the forward direction of \( \pi^+ \) and forward direction of \( \rho^0 \) in the \( \rho^0 \) rest frame.
World data with old HERMES results from M. Tytgat, “Diffractive Production of $\rho^0$ and $\omega$ Vector Mesons at HERMES”, PhD. thesis, University Gent, Belgium (2001).

Agreement with other experiments very good.


Going one step further in the analysis: $L$–$T$ separation.
Theoretical curve of $Y_{L/T}$ from Kopeliovich et al. (B.Z. Kopeliovich, J. Nemchik, and Ivan Schmidt, hep-ph/0703118)

\[ b_{L/T}(Q^2) \propto b_N + \text{const} \frac{Y_{L/T}^2}{Q^2 + m_V^2} \]

- $b_N$ contribution from nucleon
- $Y_{L/T}$ relates the size of the $q\bar{q}$ pair to $Q^2$

Several specific values computed in the paper

- $b_T - b_L = 0.7 \text{ GeV}^{-2}$ at $Q^2 = 0.7 \text{ GeV}^2$
- $b_T - b_L = 0.4 \text{ GeV}^{-2}$ at $Q^2 = 5 \text{ GeV}^2$

- Coulomb wave function has $b_T - b_L = 0$ at low $Q^2$.
- Oscillator wave function has $b_T - b_L = 0$ at high $Q^2$.
- Legend has ZEUS and H1 points, but none on graph
  - No results from any experiment as of yet.
- HERMES kinematics range: $0.5 \text{ GeV}^2 < Q^2 < 7.0 \text{ GeV}^2$
Comparison of theories

- Exact values disputed, but in general $|b_L - b_T| \approx 1 \text{ GeV}^{-2}$.
- Dispute over $b_L \leftrightarrow b_T$.
- Shrinkage seen for both $b_{L/T}$. 
Sample histogram of $b$ extraction ($b$ is p1).

- Black curve is full fit.
- Red curve is signal.
- Green curve is background.

$b$ for unpolarized $\rho^0$: $\frac{d\sigma}{d(-t')} = Ae^{-b(-t')}$. 
Use M. Diehl formalism (arXiv:0704.1565v2) for base angular distributions: cross section parameterized by $W_{XY}(\phi)$

- $W_{XY}(\phi, \varphi, \vartheta) = \frac{3}{4\pi} [\cos^2(\vartheta) W_{XY}^{LL}(\phi) + \sqrt{2} \cos(\vartheta) \sin(\vartheta) W_{XY}^{LT}(\phi, \varphi) + \sin^2(\vartheta) W_{XY}^{TT}(\phi, \varphi)]$

- $X, Y = U, L$
- Additional dependencies for $X, Y = T$ on $\phi$

- $W_{UU}^{LL}(\phi) = (u_{00}^{00} + \epsilon u_{00}^{00}) - 2\cos(\phi) \sqrt{\epsilon(1 + \epsilon)} \text{Re}(u_{00}^{00}) - \cos(2\phi) \epsilon u_{00}^{00}$

- $W_{UU}^{LT}(\phi, \varphi) = \cos(\phi + \varphi) \sqrt{\epsilon(1 + \epsilon)} \text{Re}(u_{00}^{0+} - u_{00}^{-0}) - \cos(\varphi) \text{Re}(u_{00}^{0+} - u_{00}^{-0} + 2\epsilon u_{00}^{0+}) + \cos(2\phi + \varphi) \epsilon \text{Re}(u_{00}^{0+}) - \cos(\phi - \varphi) \sqrt{\epsilon(1 + \epsilon)} \text{Re}(u_{00}^{0-} - u_{00}^{+0}) + \cos(2\phi - \varphi) \epsilon \text{Re}(u_{00}^{+0})$

- $W_{UU}^{TT}(\phi, \varphi) = \frac{1}{2} (u_{00}^{++} + u_{00}^{--} + 2\epsilon u_{00}^{++}) + \frac{1}{2} \cos(2\phi + 2\varphi) \epsilon u_{00}^{++} - \cos(\phi) \sqrt{\epsilon(1 + \epsilon)} \text{Re}(u_{00}^{++} + u_{00}^{--}) + \cos(\phi + 2\varphi) \sqrt{\epsilon(1 + \epsilon)} \text{Re}(u_{00}^{++} - u_{00}^{--}) - \cos(2\phi) \epsilon \text{Re}(u_{00}^{++}) + \cos(\phi - 2\varphi) \sqrt{\epsilon(1 + \epsilon)} \text{Re}(u_{00}^{+0}) + \frac{1}{2} \cos(2\phi - 2\varphi) \epsilon u_{00}^{+0}$

- etc.

- $u_{AB}^{CD}$ are SDME's where $A, B, C, D = +, -, 0$
We chose to modify angular distributions by $e^{-b_{L/T}(-t')}$ in appropriate places.

\[ W_{XY}(-t', \phi, \varphi, \vartheta) = \frac{3}{4\pi} \left[ e^{-b_L(-t')} \cos^2(\vartheta) W_{XY}^{LL}(\phi) + e^{-b_{\text{interference}}(-t')} \sqrt{2} \cos(\vartheta) \sin(\vartheta) W_{XY}^{LT}(\phi, \varphi) + e^{-b_T(-t')} \sin^2(\vartheta) W_{XY}^{TT}(\phi, \varphi) \right] \]

- $b_{\text{interference}}$ chosen to be $\frac{b_L + b_T}{2}$

A WORD OF CAUTION: Simply using the $\vartheta$ angular distributions is not sufficient to correctly characterize the distributions in order to extract $b_{L/T}$.

\[ \frac{d\sigma}{d(-t')d(\cos(\vartheta))} = A_L \cos^2(\vartheta) e^{-b_L(-t')} + A_T \sin^2(\vartheta) e^{-b_T(-t')} \]

- $A_{L/T}$ proportionality constants.
Results have not been released yet.

Current status:
- All data sets prepared for extraction.
- Monte Carlos generated to test extraction procedure.
- Systematic studies chosen.
- Working on fitting programs.
  - Maximum Likelihood fit method in Minuit.