1 Monte Carlo Model of Deep Exclusive π^- Production From The Neutron

One of the primary goals of this proposed measurement is to extend our knowledge of the σ_L, σ_T, σ_{LT} and σ_{TT} to larger values of Q^2, $-t$ and W. Initial Monte Carlo studies require a model for experimentally unexplored region of kinematics. The electroproduction of charged pion is best described by the VR model [1]. A brief description of VR model is given in section 1.2. The scattering cross section for $n(ee'\pi^-)p$ in one-photon exchange is given by equation 1:

$$\frac{d^5\sigma}{dE' d\Omega_{e'} d\Omega_\pi} = \Gamma_V \frac{d^2\sigma}{d\Omega_\pi}. \tag{1}$$

The virtual photon flux factor Γ_V in equation 1 is defined as:

$$\Gamma_v = \frac{\alpha}{2\pi^2}\frac{E'}{E}\frac{K}{Q^2}\frac{1}{1-\epsilon}, \tag{2}$$

where α is the fine structure constant, K is the energy of real photon equal to the photon energy required to create a system with invariant mass equal to W and ϵ is the polarization of the virtual photon.

$$K = (W^2 - M_p^2)/(2M_p) \tag{3}$$

$$\epsilon = \left(1 + \frac{2|\mathbf{q}|^2}{Q^2}\tan^2\frac{\theta_e}{2}\right)^{-1}, \tag{4}$$

where θ_e is the scattering angle of scattered electron. The two-fold differential cross section $\frac{d^2\sigma}{d\Omega_\pi}$ in the lab frame can be expressed in terms of the invariant cross section in center of mass frame of photon and proton:

$$\frac{d^2\sigma}{d\Omega_\pi} = J\frac{d^2\sigma}{dtd\phi}, \tag{5}$$

where J is the Jacobian of transformation of coordinates from lab Ω_π to t and ϕ (CM). The invariant cross section of equation 5 can be expressed in four terms. Two terms correspond to the polarization states of the virtual photon (L and T) and two states correspond to the interference of polarization states (LT and TT),

$$2\pi\frac{d^2\sigma}{dtd\phi} = \epsilon\frac{d\sigma_{\rm L}}{dt} + \frac{d\sigma_{\rm T}}{dt} + \sqrt{2\epsilon(\epsilon+1)}\frac{d\sigma_{\rm LT}}{dt}\cos\phi + \epsilon\frac{d\sigma_{\rm TT}}{dt}\cos 2\phi \tag{6}$$

1.1 Data Constraints

Precise L/T separated experimental data of exclusive electroproduction of π^- on ^{2}H are available up to $Q^2 = 2.57$ GeV^2, $-t = 0.350$ GeV^2 and $W = 2.168$ GeV [2]. Precise L/T separated experimental data of exclusive electroproduction of π^+ on ^{1}H are available up to $Q^2 = 2.703$ GeV^2, $-t = 0.365$ GeV^2 and $W = 2.127$ GeV [3]. In [4] and [5], separated σ_L and σ_T are measured up to $Q^2 = 4.703$ GeV^2 and $W = 2.2$ GeV. CLAS experiment E99-105 measured the unseparated cross section at Q^2 up to 4.35 GeV^2 and $-t$ up to 4.5 GeV^2 [6]. The HERMES collaboration measured the unseparated cross section for $Q^2 = 3.44$ GeV^2 and 5.4 GeV^2 [7] at $W = 4$ GeV.

1.2 Model for Higher Q^2 Kinematics

The electroproduction of charged pion is best described by the VR model [1]. The VR model is a Regge model with a parametrization of deep inelastic scattering amplitude to improve the description of σ_T. The description of σ_L is constrained by a fit to our F_π data from Jlab[3]. In figure 1 we plotted the last six data points of table v of [2], our parametrization and VR model points for exactly same values of Q^2, $-t$ and W. It shows the comparison of the same points of $\sigma_{L,T,LT,TT}$ vs. Q^2.

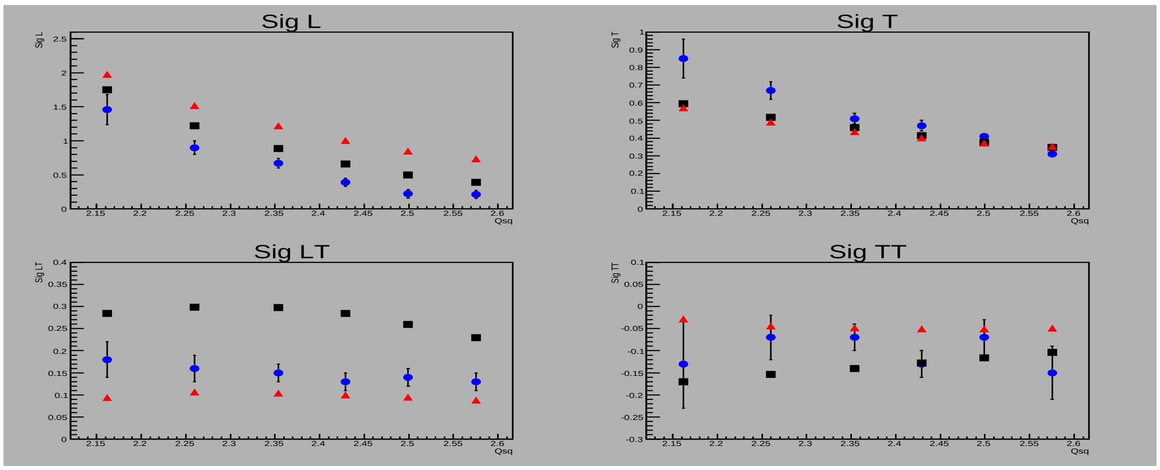

Figure 1: A comparison of last six points of table v of [2], VR model and our parametrization values vs. Q^2 of π^- electroproduction. Experimental data is shown in blue circles, VR model is shown in red triangles and our parametrization is shown in black boxes. In each graph value of $-t$ is decreasing left to right from maximum value 0.35 GeV^2 to 0.15 GeV^2. Value of W also decreases left to rigth from 2.2978 GeV to 2.1688 GeV.

1.3 Parametrization of σ_L, σ_T, σ_{LT}, & σ_{TT}

For exclusive DVMP in SoLID the kinematic region of interest for parametrization of $\sigma_{L,T,LT,TT}$ is Q^2 from 4.5 GeV to 7.5 GeV, $-t$ from 0 GeV^2 to 1.0 GeV^2 and we set $W = 3.0$ GeV. After the parametrization of $\sigma_{L,T,LT,TT}$ for $-t$ and Q^2, we used the same W dependence given by [3] which is $(W^2 - M^2)^{-2}$ where M is the proton mass. Our parametrization of all four cross sections is given in equations 7 to 10:

$$\sigma_L = \exp\left(P_1(Q^2) + |t| * P_1'(Q^2)\right) + \exp\left(P_2(Q^2) + |t| * P_2'(Q^2)\right) \tag{7}$$

$$\sigma_T = \frac{\exp\left(P_1(Q^2) + |t| * P_1'(Q^2)\right)}{P_1(|t|)} \tag{8}$$

$$\sigma_{LT} = P_5(t(Q^2)) \tag{9}$$

$$\sigma_{TT} = P_5(t(Q^2)), \tag{10}$$

where the parameters P_i are polynomial functions of ith order. Each coefficient (P_i) of fifth order equations 9 and 10 is a further second order polynomial of Q^2. Deep exclusive π^- events are generated using a C++ code. The quality of parametrization is checked by plotting the parametrization functions of $\sigma_{L,T,LT,TT}$ versus the VR model as shown in figure 2.

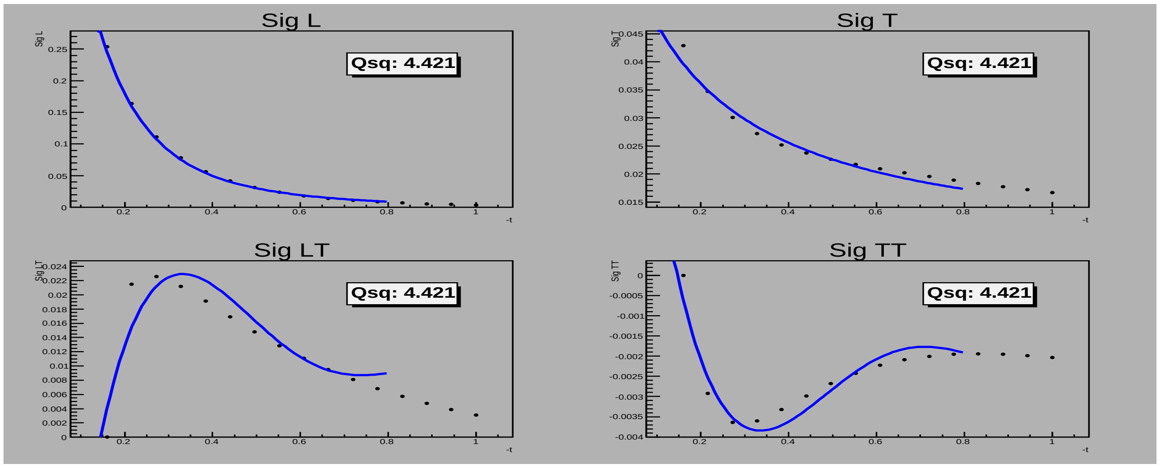

Figure 2: A comparison of parametrized $\sigma_{L,T,LT,TT}$ and VR model values at $Q^2 = 4.421$ GeV^2 and $W = 3.0$ GeV. Black points are VR model values and blue line is parametrized $\sigma_{L,T,LT,TT}$ given by equations 7 to 10.

Figure 2 shows the comparison of parametrization of $\sigma_{L,T,LT,TT}$ and VR model points. The blue line is the parametrization curve and black points are the VR model points.

1.4 Single Spin Asymmetry (SSA) $\mathbf{A_L^{\perp}}$

It is shown in [8] that the generalized parton distribution ($\tilde{E}$) can be probed by measuring the single spin asymmetry(SSA). The SSA is defined in equation 11, where β is the angle between the transversely polarized target vector and the reaction plane, and $\sigma_L^{\pi^-}$ is the exclusive π^- cross section for longitudinal virtual photons. We parametrized the single spin asymmetry using the model of [8] at $x = 0.1$ and $x = 0.3$. Parametrization of SSA is shown in Figure 3 and equation 12 is the parameterized function of single spin asymmetry.

$$\mathbf{A_L^{\perp}} = \frac{\int_{\mathbf{0}}^{\pi} \mathbf{d}\beta \frac{\mathbf{d}\sigma_{\mathbf{L}}^{\pi^-}}{\mathbf{d}\beta} - \int_{\pi}^{\mathbf{2}\pi} \mathbf{d}\beta \frac{\mathbf{d}\sigma_{\mathbf{L}}^{\pi^-}}{\mathbf{d}\beta}}{\int_{\mathbf{0}}^{\mathbf{2}\pi} \mathbf{d}\beta \frac{\mathbf{d}\sigma_{\mathbf{L}}^{\pi^-}}{\mathbf{d}\beta}} \tag{11}$$

$$\mathbf{A_L^{\perp}} = \begin{cases} A_0 \left[1 - \exp^{[-\lambda \times (t - t_{min})]}\right] & \text{if } t \geq t_{min}, \\ 0 & \text{if } t < t_{min}. \end{cases} \tag{12}$$

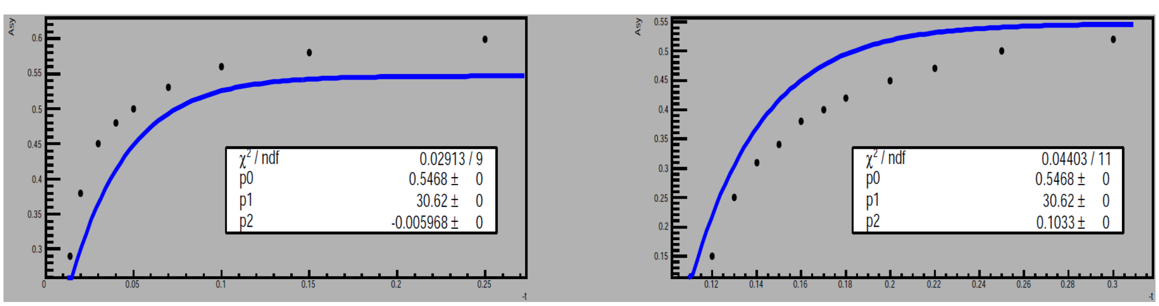

Figure 3: Parametrization of single spin asymmetry $\mathbf{A_L^{\perp}}$ vs. $-t$ at $Q^2 = 10$ GeV^2 in left graph $x = 0.1$ and in right graph $x = 0.3$ where the points are from the model defined in [8] and blue line is our parametrization function.

References

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