Evaluation of the $\pi^+ n$ and $\pi^0 p$ electroproduction cross section from the data measured with the CLAS detector

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Abstract

The measurements of exclusive $\pi^+ n$ and $\pi^0 p$ electroproduction with the CLAS detector in Hall B at Jlab provided the dominant part of the world data on observables of these channels [1] stored in the CLAS Physics Data Base [2]. The data on exclusive $N\pi$ and $\pi^+\pi^- p$ electroproduction are the major source of the information on nucleon resonance N^* electroexcitation amplitudes. They offer insight into the nucleon and N^* structure and strong QCD dynamics which underlie the nucleon resonance generation from quarks and gluons [1, 3, 4, 5, 6]. The approach for evaluation of the unpolarized, transverse-transverse, longitudinal-transverse exclusive structure functions will be presented in the talk. The estimates of these $N\pi$ electroproduction observables have become available from the measured with the CLAS detector differential cross-sections for the first time. They cover a broad kinematics area of the invariant masses of the final hadron system of $W < 1.7\ GeV$ and the photon virtuality range of $Q^2 < 5.0\ GeV^2$. The estimated $N\pi$ exclusive structure functions are of particular importance in the studies of the N^* structure.

Objective

- Evaluation of exclusive structure functions $\frac{d\sigma_u}{d\Omega}(W, Q^2, \cos\vartheta, \varphi)$, $\frac{d\sigma_{tt}}{d\Omega}(W, Q^2, \cos\vartheta, \varphi)$, $\frac{d\sigma_{lt}}{d\Omega}(W, Q^2, \cos\vartheta, \varphi)$ for $\pi^+ n$, $\pi^0 p$ electroproduction channels at W less than 1.7 GeV, Q^2 less than 5 GeV^2

Cross sections and structure functions

The structure functions were obtained by fitting the CLAS experimental data $\frac{d\sigma}{d\Omega}(W, Q^2, \cos\vartheta, \varphi)$ differential cross sections as a function of the angle φ between electron scattering and the reaction planes:

$$\frac{d\sigma}{d\Omega}(W, Q^2, \cos\vartheta, \varphi) = \frac{d\sigma_u}{d\Omega}(W, Q^2, \cos\vartheta) + \frac{d\sigma_{tt}}{d\Omega}(W, Q^2, \cos\vartheta)\cos 2\varphi + \frac{d\sigma_{lt}}{d\Omega}(W, Q^2, \cos\vartheta)\cos\varphi \quad (1)$$

where $\frac{d\sigma_u}{d\Omega}, \frac{d\sigma_{tt}}{d\Omega}, \frac{d\sigma_{lt}}{d\Omega}$ stand for: unpolarized, transverse-transverse, and longitudinal-transverse structure functions respectively;

ϑ is the CM frame pion emission angle;

W and Q^2 are the invariant mass of the final hadrons and photon virtuality.

Data selection

- The data points with relative uncertainties > 0.7 were excluded.
- The data in each bin of (W, Q^2, $\cos\vartheta$) were fitted according to equation (1). The data points which deviated from fit >±1.5 sigma were excluded.
- $(W, Q^2, \cos\vartheta)$ bins with less than 4 data points were excluded.

The methods for extraction of the exclusive structure functions

- Method 0: The data cover the full φ range $[0, 2\pi]$. The data fit according to equation (1).
- Method 1: The data are available in $\Delta\varphi$ range $[\varphi_{min}, \varphi_{max}]$

$$\frac{d\sigma_u}{d\Omega}_{method\,1} = \frac{1}{\phi_{max} - \phi_{min}}\left[\int_{\varphi_{min}}^{\varphi_{max}} \frac{d\sigma}{d\Omega_{exp}} d\varphi - \frac{d\sigma_{tt}}{d\Omega}\int_{\varphi_{min}}^{\varphi_{max}} \cos 2\varphi d\varphi - \frac{d\sigma_{lt}}{d\Omega}\int_{\varphi_{min}}^{\varphi_{max}} \cos\varphi d\varphi\right]$$

$\frac{d\sigma}{d\Omega_{exp}}$ stands for the experimental data.

$\frac{d\sigma_{tt}}{d\Omega}, \frac{d\sigma_{lt}}{d\Omega}$ are determined from the data fit according to equation (1).

- Method 2:

$$\frac{d\sigma_u}{d\Omega}_{method\,2} = \frac{1}{2\pi}\left[\int_{\varphi_{min}}^{\varphi_{max}} \frac{d\sigma}{d\Omega_{exp}} d\varphi + \int_{0}^{\varphi_{min}} \frac{d\sigma}{d\Omega_{proj}} d\varphi + \int_{\varphi_{max}}^{2\pi} \frac{d\sigma}{d\Omega_{proj}} d\varphi\right]$$

$\frac{d\sigma}{d\Omega_{proj}}$ are taken from the equation (1).

- Methods 3 and 4: There are one (method 3) or two (method 4) gaps in the φ-dependence of the experimental data

$$\frac{d\sigma_u}{d\Omega}_{method\,3,4} = \frac{1}{\sum_i \Delta\varphi_i}\sum_i\left[\int_{\varphi_{min\,i}}^{\varphi_{max\,i}} \frac{d\sigma}{d\Omega_{exp}} d\varphi - \frac{d\sigma_{tt}}{d\Omega}\int_{\varphi_{min\,i}}^{\varphi_{max\,i}} \cos 2\varphi d\varphi - \frac{d\sigma_{lt}}{d\Omega}\int_{\varphi_{min\,i}}^{\varphi_{max\,i}} \cos\varphi d\varphi\right]$$

Unpolarized structure functions from different methods

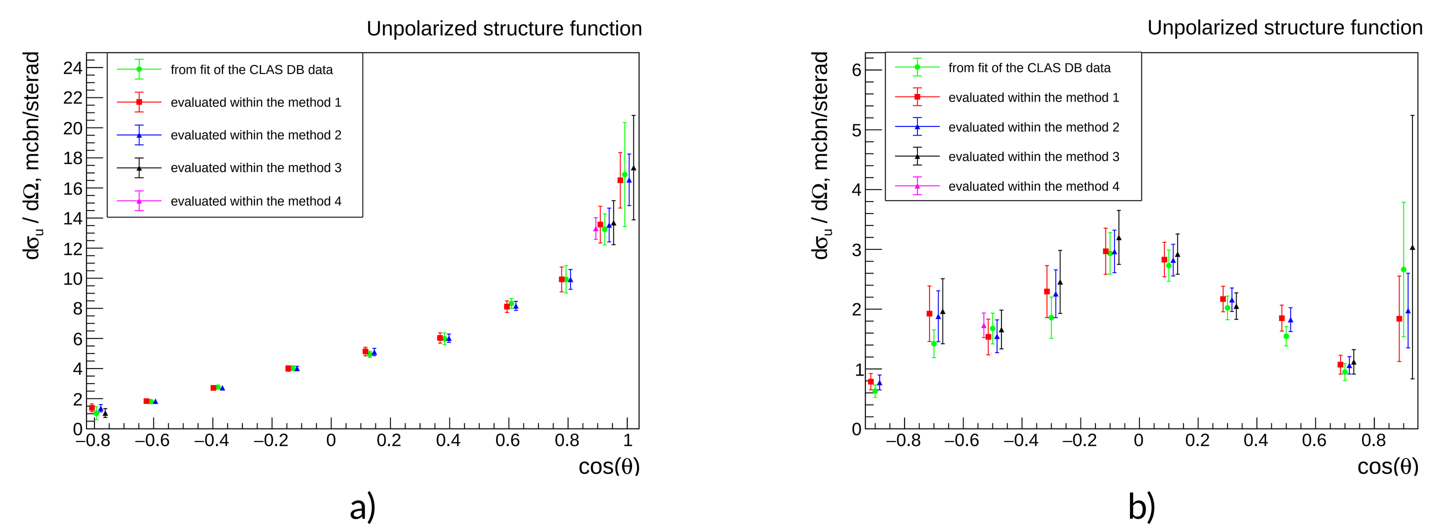

Figure 1:a) $\pi^+ n$, $W = 1.31\ GeV$, $Q^2 = 0.3\ GeV^2$ b) $\pi^0 p$, $W = 1.4\ GeV$, $Q^2 = 0.65\ GeV^2$

Separation between transverse and longitudinal structure functions

The transverse $\frac{d\sigma_t}{d\Omega}$ and longitudinal $\frac{d\sigma_l}{d\Omega}$ structure functions were obtained from unpolorized $\frac{d\sigma_u}{d\Omega}$ structure function by employing the experimental results on the ratio $R = \frac{d\sigma_l}{d\Omega}/\frac{d\sigma_t}{d\Omega}$ [7]

$$\frac{d\sigma_u}{d\Omega} = \frac{d\sigma_t}{d\Omega} + \varepsilon\frac{d\sigma_l}{d\Omega}, \qquad \varepsilon = \left(1 + 2\frac{\nu^2 + Q^2}{Q^2}\tan^2\frac{\theta}{2}\right)^{-1}$$

$$\nu = E_{beam} - E' = \frac{W^2 + Q^2 - M_p^2}{2M_p} \qquad \sin^2\frac{\theta}{2} = \frac{Q^2}{4E_{beam}(E_{beam} - \nu)}$$

ε is polarisation of a virtual photon

E', θ are the energy and the angle of scattered electron in lab frame.

$$\frac{d\sigma_t}{d\Omega} = \frac{\frac{d\sigma_u}{d\Omega}}{1 + \varepsilon R} \qquad \frac{d\sigma_l}{d\Omega} = \frac{R\frac{d\sigma_u}{d\Omega}}{1 + \varepsilon R}$$

The structure functions for $\pi^+ n$ exclusive channel

The results were obtained within the method 0 in a case of full coverage over φ range. In a case of a partial φ coverage the method 1, 3, 4 were used.

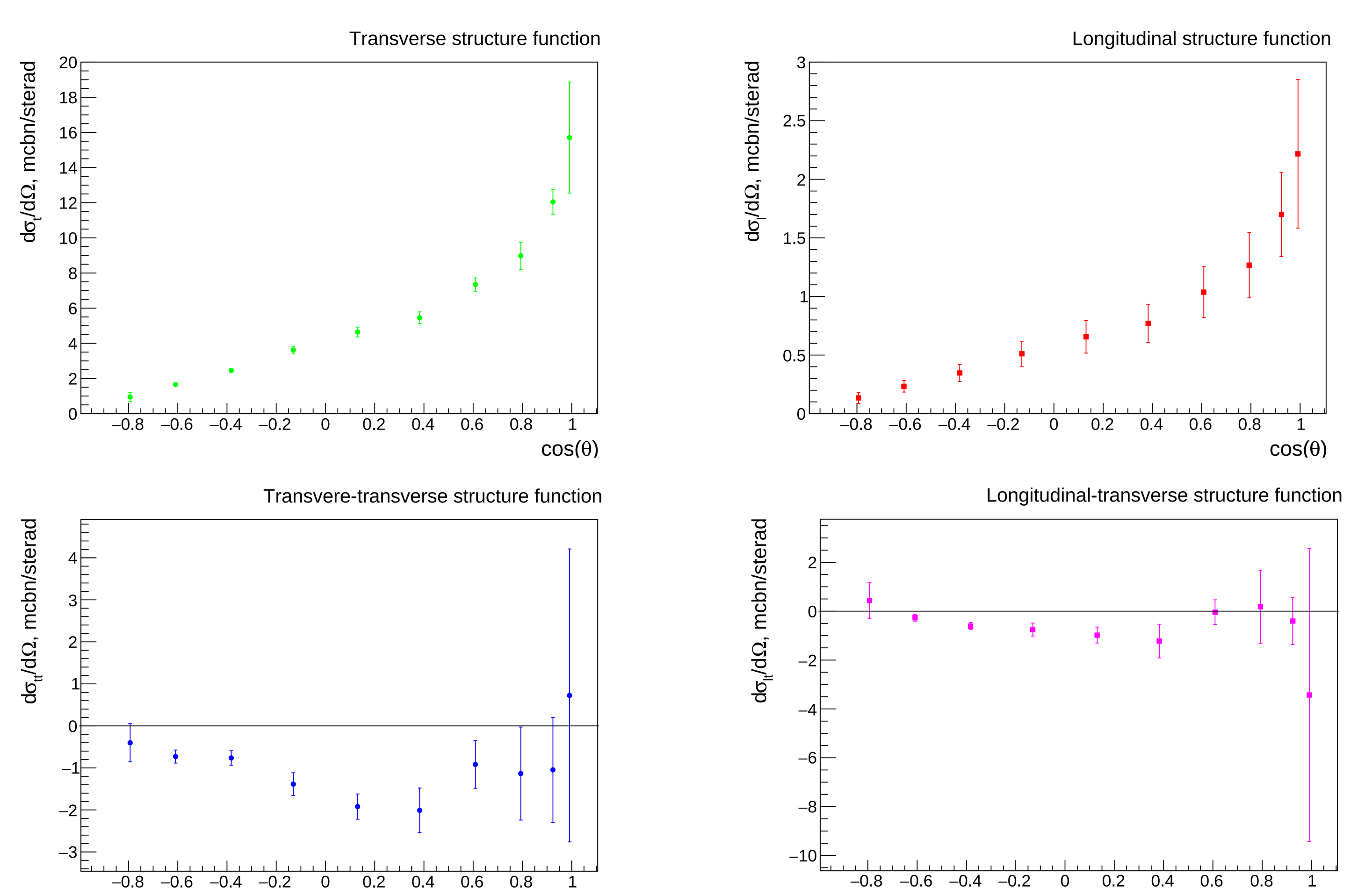

Figure 2:$\pi^+ n$, $W = 1.31\ GeV$, $Q^2 = 0.3\ GeV^2$

The structure functions for $\pi^0 p$ exclusive channel

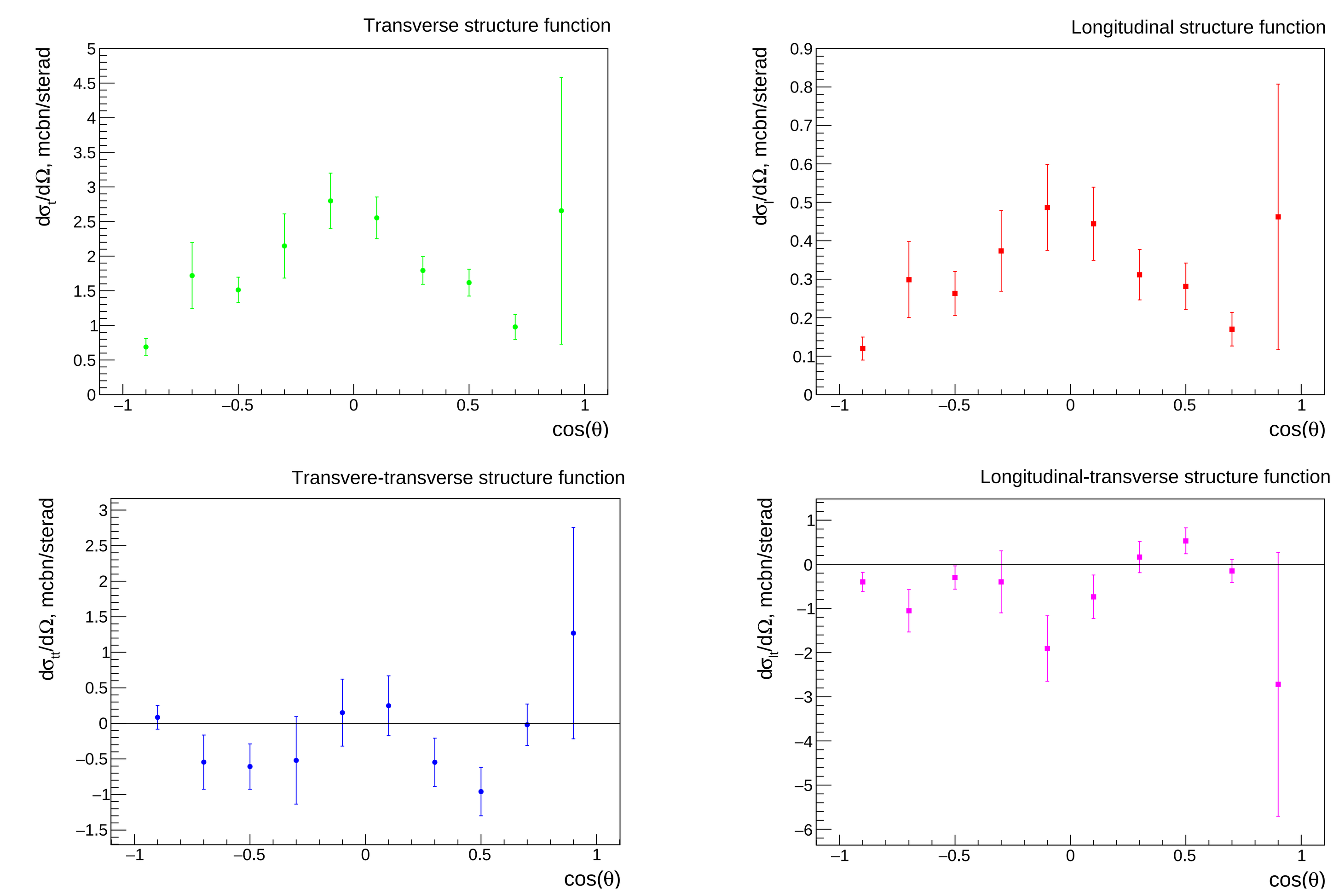

Figure 3:$\pi^0 p$, $W = 1.4\ GeV$, $Q^2 = 0.65\ GeV^2$

Conclusions and outlook

- Exclusive structure functions $\frac{d\sigma_t}{d\Omega}, \frac{d\sigma_l}{d\Omega}, \frac{d\sigma_{tt}}{d\Omega}, \frac{d\sigma_{lt}}{d\Omega}$ have become available from the CLAS $\pi^+ n$, $\pi^0 p$ electroproduction channels of experimental data at W ∈ [1.1, 1.7] GeV, $Q^2 \in [0.25, 5]$ GeV^2 for the first time.
- Evaluation of two-fold differential $\pi^+ n$, $\pi^0 p$ virtual photon cross sections in the aforementioned kinematic area is in progress.

References

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