1 Summaries of Experimental Activities

1.1 E91-011

Investigation of the $N \to \Delta$ Transition via Polarization Observables in Hall A

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We have measured recoil polarization in the $p(\vec{e}, e'\vec{p})\pi^0$ reaction at $Q^2 \approx 1$ $(\text{GeV}/c)^2$ near the Δ resonance, obtaining angular distributions for a total of 16 independent response functions. The past year has been spent trying to resolve inconsistencies between polarizations and response functions extracted using the method of maximum likelihood. The primary problem is that response functions deduced from the ϕ dependence of polarization data do not always agree well enough with response data extracted directly from replaying the raw data. We wrote a new streamlined version of the analysis code in C++, called PALM++, and performed many internal consistency checks. The most important pseudodata test uses the acceptance-rejection algorithm to replace measured values for $(\theta_{fpp}, \phi_{fpp})$ with a simulated distribution based upon a model with known polarization at the target. The reliability of the polarization and response data can then be gauged by analyzing the pseudodata like real data. We found that the extracted responses reproduce acceptance-averaged model responses but that the extracted polarizations sometimes do not. The pattern of problems in the polarization pseudodata is the same as for the real data. The most important problem for polarization appears to be binning with respect to ϕ_π — the most difficulty is encountered for (W, Q^2, x) bins in which scatter plots of the ϕ_π dependence of spin-transport matrix elements are broad. Extracted response functions are more reliable because the ϕ_π dependence is accommodated eventwise without binning. Therefore, we have abandoned binned polarization and are focusing upon completing the analysis of the response data.

Previous versions of the analysis reported 5 bins in W times 2 bins in Q^2. However, the Q^2 dependence is relatively mild while the W dependence across the resonance would benefit from a finer spacing. Therefore, more recent analyses employ 10 bins in W for $Q^2 = 1.0 \pm 0.2$ $(\text{GeV}/c)^2$. Corrections for the differences between central and acceptance-averaged kinematical variables are made according to

$$R(W, Q^2, \bar{x}, \bar{\epsilon}) = R(\overline{W}, \overline{Q^2}, \bar{x}, \bar{\epsilon}) - \frac{\partial R}{\partial W}(\overline{W} - W) - \frac{\partial R}{\partial Q^2}(\overline{Q^2} - Q^2) \qquad (1)$$

where overlines indicate acceptance averaging and where the derivatives are evaluated at central kinematics using a model, such as MAID. The primary effect is to compensate for the x dependence of $\overline{Q^2}$ which, though small, reduces systematic irregularities in the data. This procedure is illustrated in Fig. 1 using pseudodata.

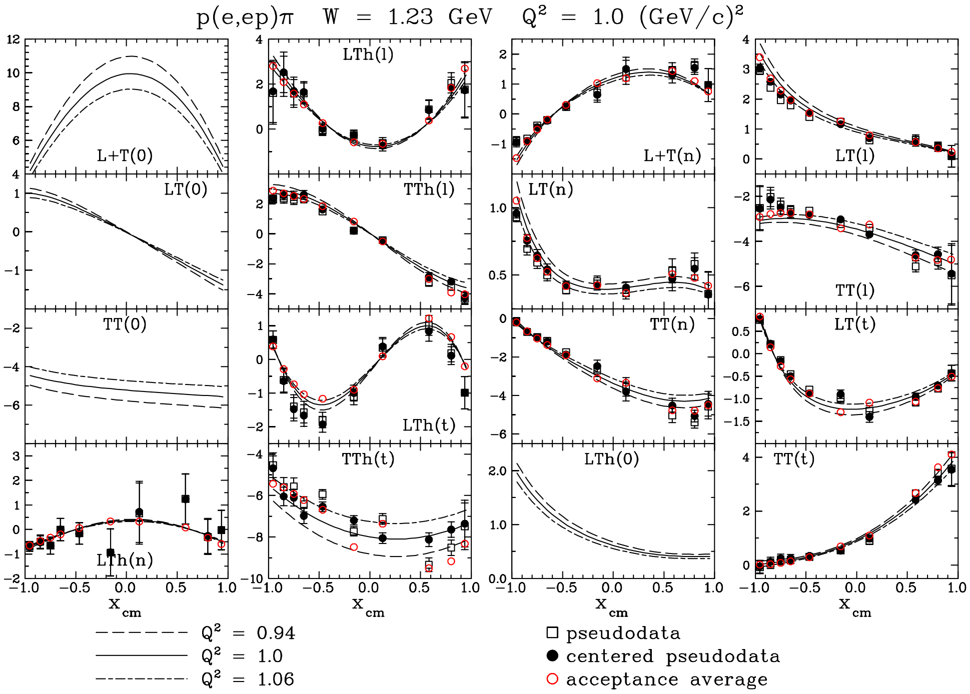

Figure 1: Pseudodata data for response functions at $W = 1.23 \pm 0.01$ GeV and $Q^2 = 1.0 \pm 0.2$ $(\mathrm{GeV}/c)^2$ are compared with the input model (MAID2000) at the central kinematics and neighboring values of Q^2 representative of the x dependence of acceptance averaging. See text for details.

The open squares show raw response functions extracted from pseudodata while open red circles show acceptanced-averaged response functions from MAID2000. The agreement between these data sets, modulo statistical fluctuations, demonstrates the internal consistency of the simulation/analysis program. However, the x dependence of $\overline{Q^2}$ can produce significant systematic deviations from the input model (solid curves) evaluated at central kinematics, especially for $R_{TT}^{\prime t}$. Recognizing that $\overline{Q^2} \approx 0.94$ for $x > 0.5$ or 1.06 $(\mathrm{GeV}/c)^2$ for $x < -0.5$, we observe that the pseudodata for $R_{TT}^{\prime t}$ do cluster around the model curve for the appropriate Q^2. Even the abrupt transition across $x = 0$ is reproduced. The solid circles show that "centered" pseudodata adjusted according to Eq. (1) cluster better around the model curves for central kinematics. Therefore, distortion of multipole amplitudes by the x dependence of $\overline{Q^2}$ should be minimized by fitting centered data.

Response functions for $W = 1.23$ GeV are compared in Fig. 2 with representative models: MAID2003 [1], DMT [2], SAID [3], and Sato-Lee [4]. (Note that this representation removes leading $\sin\theta_{cm}$ dependencies.) The first two columns are governed by real parts of interference products which emphasize resonant amplitudes with relatively little model dependence whereas the last two columns based

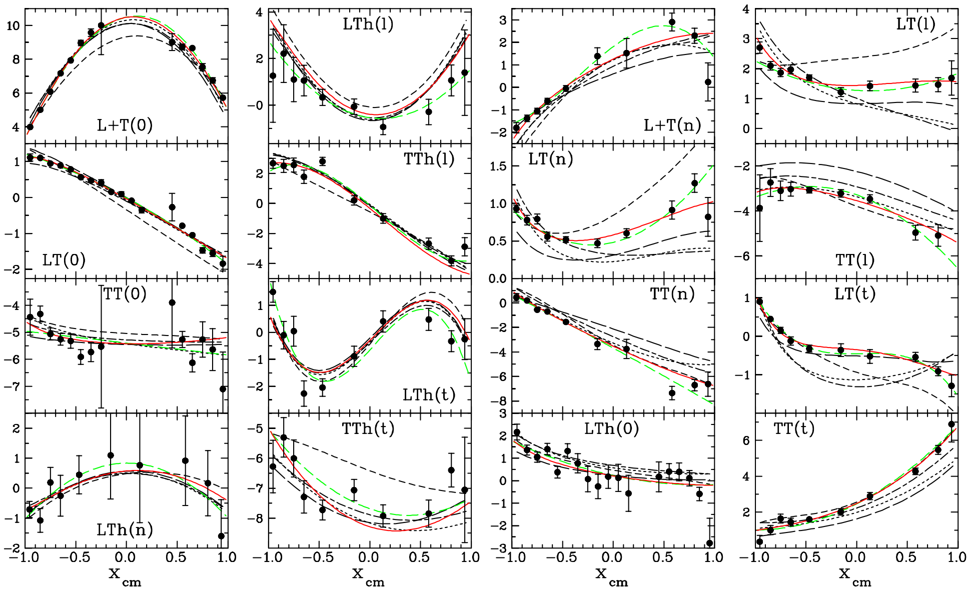

Figure 2: Response functions at $W = 1.23$ are compared with recent models and with fits. The units are μb. The labeling distinguishes L, T, LT, and TT contributions to the unpolarized (0) cross section and to transverse (t), normal (n), or longitudinal (l) components of recoil polarization with an h to indicate helicity dependence, if any. Linear combinations that cannot be resolved without Rosenbluth separation are identified by L+T. Black dash-dotted, dotted, short-dashed, and long-dashed curves represent the MAID, DMT, SAID and SL models, respectively. The green mid-dashed curves show a Legendre fit while the solid red curves show a multipole fit.

upon imaginary parts emphasize nonresonant amplitudes and display much more variation among models. None of the current models provides a uniformly good fit to these data. The solid red curves show a multipole analysis that begins with a baseline model and fits adjustments to selected multipole amplitudes. To minimize bias, we start with Born amplitudes for pseudovector coupling. All s- and p-wave amplitudes plus the real parts of $2-$ amplitudes were fit. Imaginary parts of $2-$ amplitudes are small for all models considered and the data show little sensitivity to variation of $2+$ or higher partial waves. The resulting fit reproduces the data well, with $\chi^2_\nu = 1.5$.

Fitted multipole amplitudes are compared in Figs. 3-4 with representative models. The anomalies at $W = 1.29$ GeV are caused by a couple of data points with inexplicably small error bars that suggest a matrix inversion problem in PALM++; further investigation is needed to resolve that issue. The fitted $1+$ amplitudes show the Δ resonance clearly without coaching. Model variations are relatively small for M_{1+} and S_{1+}, but there is significant variation for E_{1+} with

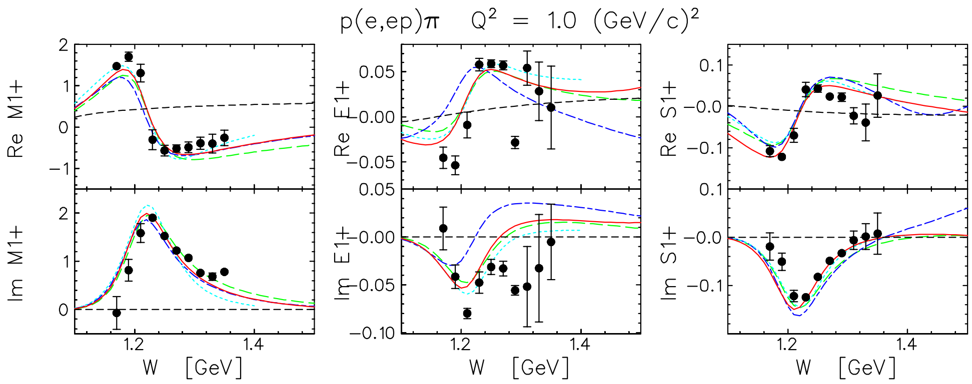

Figure 3: Fitted 1+ multipole amplitudes are compared with MAID2003 (red solid), DMT (green dashed) , SAID (blue dash-dot), and SL (cyan dotted) models. Black short-dashed curves show Born baseline amplitudes.

the fit tending to disfavor SAID. The spread among models is especially large for 1− amplitudes, the partial wave in which the Roper resonance is supposed to live, and the data disfavor SAID rather strongly. Interestingly, the fitted M_{1-} amplitudes are closer to the Born model than to the more sophisticated isobar or dynamical models, but the present precision does not exclude MAID or DMT. Conversely, the slope in ReS_{0+} is similar to SAID and opposite the Born model.

We are now working on final details of the data analysis and on evaluation of systematic errors in response functions and multipole amplitudes. Drafts of a PRL paper on the quadrupole ratios and an archival PRC paper have been prepared and will hopefully be circulated within the Hall A collaboration long before the next progress report is due.

2 References

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[3] R. A. Arndt, W. J. Briscoe, R. L. Workman, and I. I. Strakovsky, gwdac.phys.gwu.edu.

[4] T. Sato and T.-S. H. Lee, Phys. Rev. **C 63**, 055201 (2001).

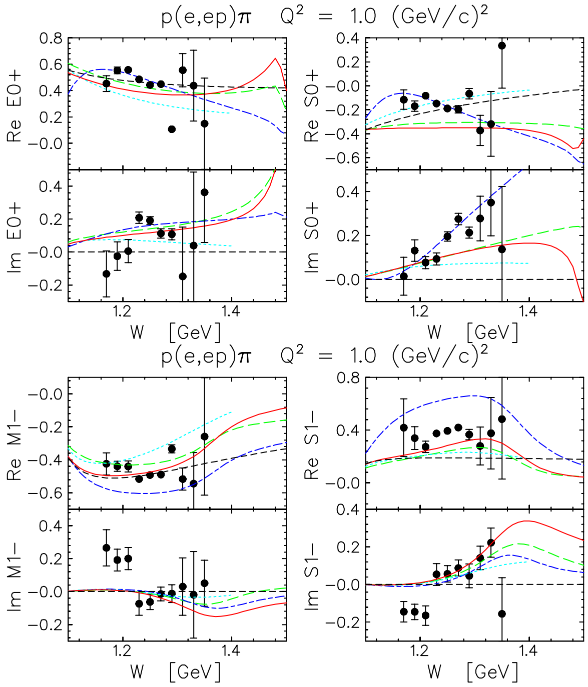

Figure 4: Fitted 0+ and 1− multipole amplitudes are compared with MAID2003 (red solid), DMT (green dashed) , SAID (blue dash-dot), and SL (cyan dotted) models. Black short-dashed curves show Born baseline amplitudes.