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# High Precision Separation of Polarized Structure Functions in Electroproduction of the Δ Roper Resonances

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We plan to make a precise measurement of the $p(\vec{e},e'\vec{p})\pi^0$ reaction at the Δ and Roper resonances. The measurements will be made in Hall A and will utilize the proton focal plane polarimeter in addition to the standard complement of detectors. Six individual response functions: $R'^{l}_{LT}, R'^{t}_{LT}, R^{n}_{LT}, R_{LT}, R'^{l}_{TT}$ and $R'^{t}_{TT}$ will be separated. In addition, we will determine the combination $2\varepsilon R_L^n + R_T^n - \varepsilon R_{TT}^n$ and $2\varepsilon R_L + R_T - \varepsilon R_{TT}$. This high precision determination of absolute response functions will complement the more extensive studies planned for CLAS.

The important question of "deformation" in the nucleon and Δ wavefunctions is particularly well suited for polarization studies. The deformation (non-S-state components of the wavefunctions) results from one gluon exchange and leads to non-zero coulomb and electric quadrupole amplitudes in the $N \to \Delta$ transition. Three of the LT-type response functions are highly sensitive to the presence of a resonant quadrupole ($S_{1+}$) amplitude in the $N \to \Delta$ transition. The inherent redundancy in these observables will allow the $S_{1+}$ contribution to be isolated from the several other amplitudes present in each response function. The other LT-type response, $R_{LT}^n$, along with $2\varepsilon R_L^n + R_T^n = \varepsilon R_{TT}^n$, will characterize the influence of other (resonant and non-resonant ) amplitudes since they, like the "fifth" response function $R'_{LT}$ identically vanish for an isolated resonance. Knowledge of the two TT'-type response functions will allow the dominant $|M_{1+}|^2$ term to be accurately determined and, by isolating it, we will then have a measure of the remaining transverse strength, most of which is expected to come from the resonant $E_{1+}$ multipole.

We will also explore the next excited state of the proton: the $P_{11}(1440)$ Roper resonance. This is treated in the simple symmetric quark model as a radial excitation of one quark to a 2s state: $(1s)^2(2s)^1$, keeping the spin-flavour wavefunction the same as that of the proton. In this view, the transition, considered as a "breathing mode" of the proton, is expected to have a sizable longitudinal component and, experimentally, a large C0 component should be present along with the only other allowed multipole, the M1. This Coulomb monopole excitation is, in bag models, related to the compressibility of the bag and hence the vacuum pressure. Determination of the longitudinal strength has, therefore, significant implications for models of nucleon structure and understanding of the confinement mechanism. Recent theoretical developments have indicated the possible description of the Roper resonance as a hybrid state composed of three quarks and a gluon. In this case, the radial wavefunctions are orthogonal. The identity of the radial wavefunctions implies that, to lowest relativistic order, the matrix elements of the charge operator vanish so that the transition is of purely magnetic dipole character.

The polarization observables for the Roper can cleanly distinguish between the various possibilities. These include: no Roper at all, a Roper with zero longitudinal coupling as predicted if the Roper is a hybrid (3 quarks + 1 gluon) baryon and more conventional quark models where the Roper is a radial excitation and may have a large longitudinal coupling. Knowledge of several polarization observables is necessary since they exhibit different sensitivities to the physics input.