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The E2 $N \rightarrow \Delta$ Transition from Polarized Compton Scattering

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The tensor interaction between the quarks in a proton is predicted to produce a D-wave component in its wave function, which breaks spherical symmetry and results in a static deformation for the proton's first excited state, the Δ resonance at ~ 320 MeV. The Δ is photo-excited mainly by M1 radiation. However, if its wavefunction contains a D-wave component, then the $N \rightarrow \Delta$ transition can also be excited by E2 photons. The magnitude and sign of the E2/M1 mixing ratio in the $N \rightarrow \Delta$ transition are quite sensitive to the internal structure of the proton and have been of great interest in recent years.

The extraction of a small E2 amplitude is complicated by the presence of non-resonant background contributions. Mostly, $N\pi$ decay channels have been studied, where polarization has been used to enhance the E2 signal relative to the backgrounds [1]. A potentially more sensitive channel is elastic (Compton) scattering of polarized photons [2]. Here, most background contributions cancel in the polarization asymmetry. This has not been previously exploited, since such measurements are technically demanding.

The $p(\gamma, \gamma p)$ reaction has been studied using linearly-polarized tagged gamma rays between 210 and 330 MeV from the Laser Electron Gamma Source (LEGS) facility at Brookhaven National Laboratory. In this reaction the chief experimental background comes from the $\gamma p \rightarrow \pi^0 p$ channel, where one high energy photon from π^0 -decay is detected. The cross section for this process is ~ 200 times that expected from Compton scattering. In this measurement, these channels were separated by detecting the photons in a high resolution NaI spectrometer, together with the recoil protons whose trajectories were tracked through wire chambers and whose energies were measured in a plastic scintillator time-of-flight (TOF) array. A typical separation is shown below in the figure (left panel) where the gamma ray energy is plotted against proton TOF. Here, the energy and TOF expected for Compton scattering, as calculated from the tagged beam energy and the proton recoil angles, have been subtracted. The Compton scattering events are clearly resolved.

MASTER

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Preliminary results for the 90° -CM beam asymmetry, from a fraction of the data analyzed to date (March/93), are shown in the right panel as the solid circles. Also shown is the only published datum for this observable (open square) [3]. If only M1 scattering contributed, the 90° asymmetry would simply reduce to the value of $3/7$, indicated by the dashed line. This is clearly not the case. The imaginary part of the Compton scattering amplitude is derivable from π -production via the Optical theorem. There have been many speculations that the real part is negligible, at least near the resonance energy of ~ 320 MeV and possibly over a larger range [4,5]. The calculated asymmetry [2], using the Pfeil, Rollnik and Stankowski (PRS) Compton amplitudes for which dispersion relations were used to derive the real parts [4], is shown as the solid curve in the figure. Recent calculations using purely imaginary amplitudes result in the dashed curve [5]. The real parts are clearly important! At the resonance, the (M1,M1) amplitude completely dominates and the second order contributions come from interferences of various other amplitudes with M1 excitation. The (M1,E2) interference is not the largest of these second order terms. Many others, particularly interference terms of opposite parity, make sizeable contributions to the total cross section. However, these terms are independent of the initial polarization and cancel in the polarization difference (S , the numerator of Σ) leaving E2 interference as the dominant second order contributor to S . This interference results in the reduction of the 320 MeV component to S . This interference results in the reduction of the 320 MeV asymmetry below the dotted '3/7' curve shown in the figure. Extraction of the E2 component requires a further reduction in the experimental errors and is presently underway.

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