Abstract

We propose a precision measurement of $A_\pi$, the electron helicity flip asymmetry, in the reaction $p(e,e'p)\pi^0$ over the $\Delta(1232)$ resonance at $Q^2$ of .3 and .4 $(\text{GeV}/c)^2$. The observable $A_\pi$ is interesting because it is sensitive to the $G_C$ (charge) form factor in the $N\rightarrow \Delta$ transition, and a non-zero value for this form factor would suggest nucleon or $\Delta$ deformation. $A_\pi$ is also of interest because its relatively simple multipole structure may simplify the treatment of Born backgrounds. We show this important out-of-plane measurement is possible due to the large vertical acceptance of the HMS-SOS spectrometer system for $Q^2 \geq .3$ $(\text{GeV}/c)^2$.

1 Introduction

1.1 Physics Motivation

The $\Delta(1232)$ resonance has a very special place in $N^*$ physics. It is the least massive baryon resonance, the most strongly excited at low $Q^2$, and it is relatively well separated from other resonances. Its first-order quark structure, three spin-aligned quarks in relative s-states, is well known. Because effects of the $\Delta$ are ubiquitous in intermediate energy nuclear physics, Hamiltonian models exist which incorporate the $\Delta \rightarrow N\pi$ transition and the effects of off-shell pion rescattering. Measurements are simplified by the fact that the $\Delta$ tends to decay into two-body final states: $N + \pi$ (99.4%) or $N + \gamma$ (.6%). For these reasons, the $\Delta(1232)$ is an ideal candidate for modern precision studies of baryon structure which go beyond the first order quark model.

Isgur and collaborators [1] have predicted that both the $N$ and $\Delta$ have small d-wave components due to quark-quark hyperfine interactions. These components would permit a very small E2 amplitude ($E2/M1 \approx .007$) in the $\Delta \rightarrow N\gamma$ transition. (C2 amplitudes were not estimated because only $\Delta \rightarrow N\gamma$ decays were considered.) In a nonrelativistic model with no hyperfine interactions, the quark wave functions for the $N$ and $\Delta$ are L=0 and so cannot be coupled by the L=2 quadrupole operator. The transition is then purely M1 [2]. Complicating this tale is the observation of Bienkowska et al. [3] that the use of relativistic wave functions yields $E2/M1 = .002$ even in the absense of tensor forces. Isgur et al. also mention a number of apparent successes of the quark-quark hyperfine interaction, and propose the search for E2 admixtures as a way to rule out an alternative explanation in terms of spin-orbit effects.

There is also evidence from bag models of non-strange baryons that at least some baryons may be deformed. Vioillier et al. [4] found that the one-gluon exchange interaction caused the $\Delta$ bag to become deformed as much as 30%. Meanwhile, minimum energy was obtained for the nucleon bag when it was given zero deformation. Murphy and Bhaduri [5] have investigated deformation as a means of improving the description of higher mass resonances such as the $N(1440)$ and the $N(1710)$, while maintaining the successes of the spherical model of Isgur and Karl. [6]

Many researchers believe that possible deformation of the nucleon and $\Delta$ is a question of fundamental importance. There are other pieces of circumstantial evidence which suggest