Prescription for Analysis

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Abstract

The goal of this document is to provide detailed directions for the data analysis for E02-013. This experiment is the determination of the electric Sachs form factor of the neutron (G_E^n) from the double polarized asymmetry. The focus of the analysis is to properly determine asymmetry from the reaction $^3\overrightarrow{He}(\vec{e}, e'n)$. This requires an understanding of our polarized target, our electron detector, and our neutron detector. Furthermore, it requires an understanding of the other processes that could be recorded through our detectors.

1 Introduction

The goal of the analysis to extract values for the Sachs form factor, G_E^n. This will be accomplished by first identifying quasi-elastic electron-neutron scattered events, then forming an asymmetry using the beam electron helicity, then extracting the physics asymmetry, and finally measuring G_E^n by using our physics asymmetry and our kinematic factors. Once the quasi-elastic neutron events are determined, the following equations move the analyss from the counts to the correct physics asymmetry.

$$A_{exp} = \frac{N_+ - N_-}{N_+ + N_-} \tag{1}$$

$$A_{exp} = P_e \cdot P_n \cdot D_{N_2} \cdot D_{background} \cdot A_{phys} \tag{2}$$

Where $N_{+(-)}$ is the number of neutron events with the beam helicity positive(negative), P_e is the beam polarization, P_n is the target polarization, D_{N_2} is a dilution factor due to nitrogen in the cell, $D_{background}$ is the dilution due to background (including proton/neutron conversion), and A_{phys} is used to extract G_E^n.

This next four sections of this introduction will outline how these variables are determined. The final section of the introduction will outline how G_E^n is extracted from A_{phys}. The overall document will follow this structure.

1.1 Electron Beam

The reaction is started off by the CEBAF electron beam. We need to know the polarization degree, direction, energy, and position of the beam. The polarization degree and helicity of the electron beam are used to extract the physics asymmetry from the experimental asymmetry. The helicity and position are recorded for every event. The polarization was measured using Mott, Møller, and Compton polarimeters. The energy was obtained by the ARC measurement of beam deflection through a known magnetic field. The current was measured by the beam current monitors (bcm), and this information is used to correct for false asymmetries due to helicity correlated current asymmetries. Halos associated with the beam are particularly important for this experiment, due to the significant difference in density between the gas target and the thick glass walls containing the gas. Use of the Compton polarimeter controls the overall size of this halo. However, the beam must be rastered to prevent damage to the glass cell. This rastering may enhance effects due to a beam halo, even if the inherent size of the halo is small.

1.2 Target

For the purposes of analysis, there are several parameters that are required from the target. The primary parameter is the degree of polarization of the target. Like the beam helicity and polarization, the target polarization is a multiplicitive factor relating the experimental asymmetry to the physics asymmetry. Second, the analysis requires precise knowledge of the direction of polarization. The ratio of form factors enters into the equation of the asymmetry weighted by the direction of polarization. This was measured by a new compass system developed for this experiment. Energizing the large dipole spectrometer used in the electron arm did effect the direction of the magnetic field. This effect was significant, but was taken into account.

Electron scattering from a variety of targets – hydrogen, carbon, beryllium oxide, and nitrogen – provide information on the electron and hadron optics, the particle identification efficiency and target dilution factors (*e.g.* dilution from nitrogen and from the glass walls of the cell). Additional background can arise from the passage of particles through the materials used in the construction of the target (*e.g.* the glass of the target cell, the ceramic of the target ladder, and the metal of the holding field box). These were carefully measured and will be used as the inputs into a Monte Carlo simulation of the background.

The electron beam is deflected slightly by the magnetic fields used to create the uniform holding field. This deflection can be taken into account quite easily by a thorough mapping of the magnetic field.

1.3 Electron Arm

The electron arm provides tracking information as well as particle identification and timing. The relevant parameters for determining events in the reaction $^3\overrightarrow{He}(\vec{e}, e'n)$ are the momentum of the electron, the angles with respect to the beam-line, and the vertex position along the target. The likelihood that a particle is an electron or some other particle can be determined *via* the preshower and shower calorimeter. Timing information extracted from the electron arm allows us to determine the correct electron beam bunch, which is required for proper neutron arm time of flight analysis.

1.4 Neutron Arm

The final piece of equipment required to measure the exclusive reaction is the neutron detector, a large time-of-flight spectrometer. In addition to time-of-flight information, this detector determines the in-plane and out-of-plane scattered angles. Measuring the proper exclusive reaction requires particle identification of the scattered hadron. Veto counters detect if an event has electrical charge. This is one part of determining if the captured hadron left the target as a proton or an neutron. The characteristics of the more refined particle identification are obtained from measurements on targets with different proton to neutron ratios, Monte Carlo simulations, comparisions with test run (so-called N20, taken after experiment E01-015) data, and production run data.

1.5 Analysis

The raw data gathered from the systems above are combined to produce the variables that we need to perform the analysis. First, quasi-eleastic neutron events must be identified. This requires knowing the direction and magnitude of $\vec{q}$, as well as Q^2 and W. The selection of quasi-free hadrons requires selecting events with small missing parallel and perpendicular momenta. Once the events are selected, the value of G_E^n is extracted from the asymmetry[1]:

$$\begin{aligned} A_{phys} &= -\Lambda \cdot \frac{2\sqrt{\tau(\tau+1)}\tan(\theta/2)\sin\theta^*\cos\phi^*}{\Lambda^2+(\tau+2\tau(1+\tau)\tan^2(\theta/2))} \\ &\quad -\frac{2\tau\sqrt{1+\tau+(1+\tau)^2\tan^2(\theta/2)}\tan(\theta/2)\cos\theta^*}{\Lambda^2+(\tau+2\tau(1+\tau)\tan^2(\theta/2))} \end{aligned} \tag{3}$$

Where $\Lambda = G_E^n/G_M^n$, $\tau = Q^2/4m_N$, θ is the electron scattering angle, θ^* and ϕ^* are the out-of-plane and in-plane scattering angles with respect to the target polarization. Therefore, we must properly understand the scattered electron angle, and the neutron angle with respect to the polarization angle.

In addition to these variables, which describe an ideal, background-free picture, we must account for the background. Data were taken with a variety of targets in an attempt to measure this background. Production data can also be used to to approximate the background. In addition, Monte Carlo methods are employed to approximate, and effectively separate, this background from our data.

[1]This expresssion is for the asymmetry in the plane wave impulse approximation, corrections due to final state interactions and finite momentum will be applied