Study of the Effect of Cuts and Resolution on the Proton to Neutron Density Ratio in ^{3}He

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January 9, 2008

Abstract

A major source of uncertainty in the final result for experiment 02-013 is the conversion of neutrons to protons (and *vice versa*). The rate of conversion can be calculated from the data. However, applying this to scattering from a ^{3}He nucleus is not straightforward. This document examines the results of recent theoretical calculations of the proton and neutron densities as detector resolution and appropriate cuts are applied.

1 Introduction

Experiment 02-013 is a measurement of the electric form factor of the neutron (G_E^n) using the double polarized asymmetry of the exclusive reaction ^{3}He(e,e′n). The proper identification of protons and neutrons is essential the accurate measurement of this asymmetry. The design of this experiment is built around this identification.

However, it is sometimes the case that particles detected as protons(neutrons) were not protons(neutrons) when they scattered from the ^{3}He nucleus. Conversion of the particles can occur when they pass through any material, including the glass wall of the target cell, the iron of the magnetic box, the lead shielding before the veto detectors, or any other material.

It is possible to calculate the approximate conversion factor from the data taken on various targets: nitrogen, carbon and BeO. However, this calculation is based on the assumption that the ratio of protons to neutrons in the nucleus is 2:1. This assumption is not true for low momenta.

2 Calculation

A calculation of the proton and neutron density for a range of momenta was provided to the experiment (Fig 1). A plot of the integrated densities (Fig. 2) makes it clear that at low momenta, the ratio of protons to neutrons is not 2:1. Looking at the ratio of the integrated densities (Fig. 3), it is only when the

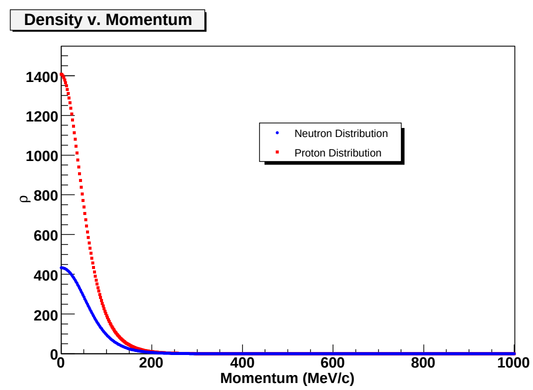

Figure 1: **Nucleon Density.** Proton and neutron densities in the ^{3}He nucleus as a function of momentum.

momentum is greater than 2.5 fm^{-1} (483 MeV/c)that the ratio comes within a percent of 2:1.

3 Effect of Cuts

In the physical experiment, we added cuts on different components of the momentum. These cuts were added so that the neutron can be treated as quasi-free in the nucleus and so that proton polarization and small non-nucleonic admixtures in the wave function are suppressed [1]. The effect of such cuts can be seen by plotting the ratio of the densities as a function of missing parallel momentum – with the various cuts applied to the missing perpendicular momentum (Fig. 4). The cuts used for kinematic 4 in our experiment were:

$$|p_{\|}| < 250 \mathrm{MeV}/c$$

$$p_{\perp} < 150 \mathrm{MeV}/c$$

This corresponds to a p:n ratio of approximately 2.25:1. Such a ratio significantly changes the resulting p/n leakage dilution factor and may affect the final result on the measurement of $\mathrm{G_E^n}$ by more than 5%.

4 Effect of Resolution

The deviation from a p:n ratio of 2:1 seen in Section 3 is for the case of an infinitely precise spectrometer. In the case of a real spectrometer, the resolution of that spectrometer must be included.

This is accomplished by generating a random, uniform distribution of momentum vectors. The limits to the momenta are based on the calculations of

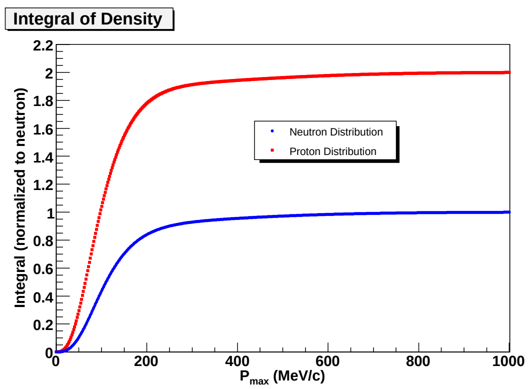

Figure 2: **Integral of Density.** Density of proton and neutron densities in ^{3}He as a function of momentum.

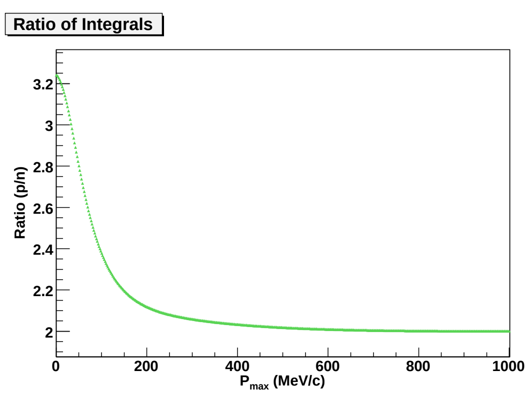

Figure 3: **Ratio of Integrals.** Ratio of proton and neutron density integrals, it approaches 2 as the momentum increases.

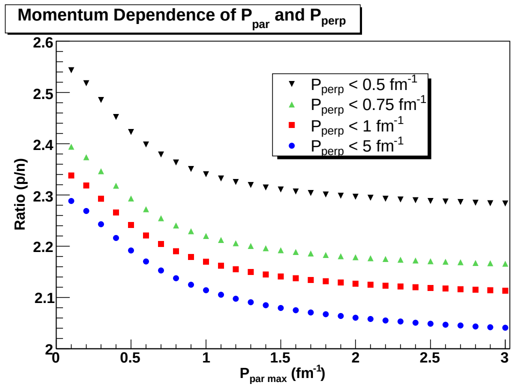

Figure 4: **Density Ratio with Cuts.** The ratio of proton to neutron integrated densities with cuts on perpendicular momentum, as a function of parallel momentum.

neutron density (Fig 1). For each of these vectors, the neutron and proton densities are calculated. Then, the effect of the spectrometer resolution is added by first generating a gaussian distribution whose width is determined by the spectrometer resolution ($\sigma_{random} \equiv \sigma_{spectrometer}$). A member of the random distribution is added to each of the initial vector components to generate a "final" or "observed" vector. Finally, cuts are applied to these observed vectors and the densities are summed to generate the ratio of p/n for the appropriate cuts. The figures in this document are based on 40,000 random vectors.

In Figure 5, the ratio of proton to neutrons is ploted with a resolution for $\text{p}_\perp$ of 0.1fm^{-1} and 0.43fm^{-1} for $\text{p}_\parallel$. A cut has been placed on such that $|p_\parallel| <$ 1.3fm^{-1}. The resulting ratio has been plotted against $p_\perp$. In our experiement, a cut is place so that $p_\perp < 0.75$fm^{-1}. This corresponds to a p/n ratio of 2.139.

5 Conclusion

The p/n ratio in ^{3}He is an essential element to a precise measurement of the double polarized asymmetry. This ratio changes as both spectrometer resolution and experimental cuts are applied. It is now possible to calculate the p/n ratio for various resolutions and momentum cuts, using simple Monte Carlo techniques.

References

[1] G. Cates, K. McCormick, B. Reitz, and B. Wojtsekhowski, Jefferson lab experiment 02-013 (2002).

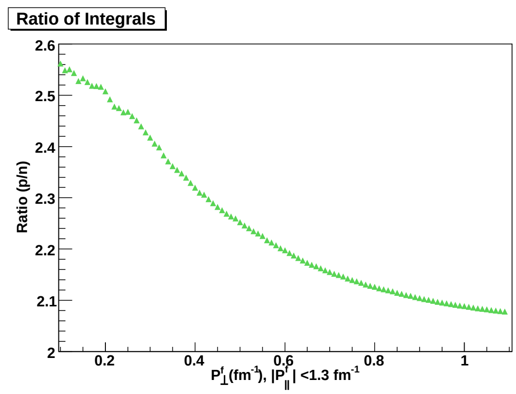

Figure 5: **Density Ratio with Cuts and Resolution.** The p/n ratio for the cuts and resolution found during E02-013 kinematic 4.