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The ^{3}H–^{3}He Charge Radii Difference

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Abstract. The upcoming E12-14-009 [1] experiment at Jefferson Lab will determine the ratio of the electric form factors for the A=3 mirror nuclei ^{3}He and ^{3}H. The measurement will use a 1.1 GeV electron beam, a special collimator plate to allow for simultaneous optics measurements, and the low-activity tritium target being prepared for Jefferson Lab. By observing the dependence of the form factor ratio as a function of Q^2 over 0.05–0.09 GeV^2, the dependence of the radii extraction on the shape of the form factors is minimized. As a result, we anticipate the uncertainty of the extracted charge radii difference to be 0.03 fm, a reduction of 70% from the current measurement. Using precise measurements of the ^{3}He charge radius from isotopic shift or μHe measurements [2–4], we can deduce the absolute ^{3}H charge radius. The results will provide a direct comparison to recent calculations of the charge radii.

1 Introduction

The E14009 experiment [1] proposes to measure the ratio of the electric form factors of ^{3}He and ^{3}H over a range of Q^2 from 0.05 to 0.09 GeV^2. From this measurement, the relative charge radii for the A=3 nuclei can be determined. From this relationship, the experiment plans to extract the charge radius difference with an uncertainty of ~15% – a significant reduction from the current 50% uncertainty [5]. The JLab PAC42 approved the experiment for the requested 1.5 days of beam time.

2 Experimental Layout

This experiment will be a single-arm measurement of elastic electron scattering from ^{3}He and ^{3}H. It will utilize one of the high-resolution spectrometers in Hall A positioned at 12.5° and 15.0°. The setup is very similar to previous form factor measurements in Hall A, and the systematics are well-understood.

There are two unique features of the setup for E14009. First, the electron beam will be set to 1.1 GeV (the lowest achievable energy at the upgraded Jefferson Lab accelerator) and the current will be limited to only 5 μA. The energy is necessary to get down to Q^2 of 0.05–0.09 GeV^2. At these momentum transfers, the cross sections and scattering rates are large. The reduced current significantly reduces the effects of deadtimes in the data acquisition.

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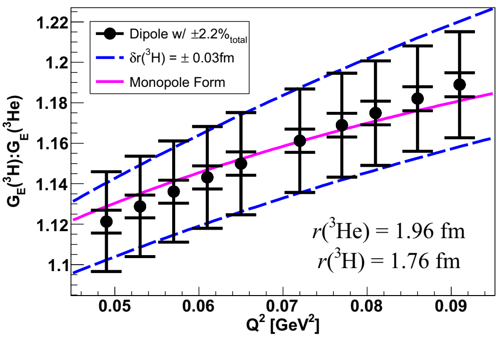

Figure 1. The expected results of the measurement of the charge form factor ratio of ^{3}He and ^{3}H. The ^{3}He radius is fixed to 1.96 fm [5]. The solid line assumes a ^{3}H radius of 1.76 fm with ±0.03 fm used to calculate the dashed lines.

The other unique feature of E14009 is the custom collimator plate to be placed on the spectrometer. This plate consists of a tapered center slot and rows of small holes above and below the slot. This design serves three purposes: (1) the center slot further reduces the event rate in the spectrometer, (2) the tapered design reduces the rate on the low-angle side thereby balancing the rates in each of the five Q^2 bins, and (3) the rows of holes above and below the center slot allow for in situ optics measurements.

3 Expected Sensitivity

The count rates for the elastic electrons are expected to be $\sim 10^5$ counts/hr per Q^2 bin. Data taking for each target will take 1.5 hrs at each HRS angle. As a result, the systematic uncertainties (~ 2%) will dominate the statistical (<0.5%). Within the systematic uncertainty, the largest contribution is expected to come from the relative thickness of the ^{3}H and ^{3}He targets. This uncertainty (~1.5-2.0%) will ultimately be determined using deep inelastic scattering from both targets.

The anticipated results for the experiment are shown in Fig. 1. Assuming a conservative estimate of the uncertainties, the ^{3}He–^{3}H can be determined to ~0.03 fm, a reduction of 70% from the current uncertainty. The model dependence of the radius extraction is constrained by examining the evolution of the form factor ratio over the full range of Q^2.

This measurement will also be able to extract the most precise value of the ^{3}H charge radius by using ^{3}He radii available from isotopic shift measurements [2, 3] and soon from muonic ^{3}He [4]. The proton and neutron matter radii in the A=3 nuclei can be determined from these results (assuming isospin symmetry) which can then be compared to ab initio calculations.

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