First Determination of the $^{27}$Al Parity-Violating and Parity-Conserving Asymmetries
2016-2017 JSA Fellowship Report
Kurtis D. Bartlett
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1 Introduction

At the time of my proposal for the 2016-2017 JSA Graduate Fellowship, the final analysis of the QWeak collaboration’s measurement of the proton’s weak charge was coming to completion. Upon receiving the fellowship award I had started to shift my focus towards the ancillary analyses of the parity-violating and parity-conserving $^{27}$Al asymmetries. As one of the last remaining graduate students working in the QWeak collaboration these analyses have become the focus of my dissertation research. Presented here are preliminary results and statuses of these ancillary asymmetry analyses that will be included in my forthcoming dissertation.

2 Background

QWeak’s original motivation behind taking this $^{27}$Al data was for it to be used to help make an important background correction for the proton’s weak charge measurement. However, in 2014 C.J. Horowitz published a paper[1] indicating the possibility of using this data to extract the radius of $^{27}$Al neutron distribution, which would be a useful test of theory. Provided the pure elastic scattering $^{27}$Al parity-violating asymmetry could be extracted from this data.

For these ancillary measurements the collaboration used a thicker $^{27}$Al alloy target. This target was purpose built to be made of the same material as that of the aluminum cell used to contain the liquid hydrogen in the main target. As this target is an aluminum alloy other chemical elements are present. To extract out either the pure parity-violating or parity-conserving asymmetries these non aluminum elements have to be corrected for.

In addition, corrections are needed for non-elastic scattering processes, such as quasi-elastic, inelastic, discrete exited state scattering. Most of these corrections are determined within our Monte Carlo simulation, which allows us to interpret the physics of the measured data set. A large amount of my time, while
supported by the fellowship, was spent on the integration of data from previous experiments and theoretical models into our simulation with the purpose of background correction determination. These simulation determined corrections were then used to extract the pure $^{27}$Al asymmetries.

3 Results

Presented here is a preliminary determination of the elastic parity-violating $^{27}$Al asymmetry. Most known corrections have been applied with the exception of a few small experimental ones. My upcoming dissertation will contain the final value with all known corrections.

At a beam energy of 1.16 GeV and mean scattering angle of 8°, the QWeak collaboration has measured the parity-violating $^{27}$Al asymmetry to be $A_{pv} = 1.924 \pm 0.180$ ppm (parts-per-million). The uncertainty broken down into statistical and systematic pieces are 0.090 ppm and 0.156 ppm, respectively. That total uncertainty corresponds to a 9.4% relative measurement of the asymmetry. The measurement agrees within its uncertainty with C.J. Horowitz’s 2014 theoretical prediction[1]. To see how this visually compares, see Figure 1. The uncertainty on this measurement is presently dominated by the systematic uncertainty, which comes about from the inelastic scattering background correction. Future theoretical calculations might be able to reduce the uncertainty in this inelastic correction.

Using this extracted asymmetry the radius of the $^{27}$Al neutron distribution can be determined using a collection of theoretical models in a method similar to that used by the PREX collaboration[2]. The correlation between the parity-violating asymmetry ($A_{pv}$) and the radius of the neutron distribution ($R_n$) was determined from a collection of ten relativistic mean field models[3]. The correlation for this set of models is the following: $A_{pv} = -1.6555R_n + 6.9347$. Using the extracted $^{27}$Al asymmetry as input, the following radius is determined to be $R_n = 3.027 \pm 0.127$ fm.

This is the first determination of the $^{27}$Al neutron distribution radius from a parity-violating asymmetry measurement. Note that this is a preliminary value and the asymmetry analysis is still missing a few small corrections which will change this value once they are included. Look forward to an upcoming publication with the finalized values.

The analysis of the parity-conserving $^{27}$Al asymmetry is still ongoing. A preliminary result is not yet ready to show. Look to my forthcoming dissertation for more information.

4 Presentations

While under the financial support of the JSA Graduate Fellowship I was able to present these preliminary results in both in contributed talk and poster presentation form at conferences both locally and national. An itemized list of these
Figure 1: Preliminary comparison of the $Q_{Weak}$ parity-violating $^{27}$Al asymmetry with theory curves from C.J. Horowitz[1].

presentation engagements are listed below:

- "The $Q_{Weak}$ Experiment Measuring The Weak Charge of the Proton" (Contributed Talk), Jefferson Lab Hall A/C Users Meeting, June 23, 2016, Newport News VA.

- "$Q_{Weak}$: First Measurement of the Parity-Violating Aluminum Asymmetry" (Contributed Talk), Frontiers and Careers in Nuclear and Particle Physics, August 5, 2016, Durham NH.

- "Elastic Beam-Normal Single-Spin Asymmetries in $Q_{Weak}$: $^{27}$Al and $^{12}$C" (Poster), Gordon Research Conference on Photonuclear Reactions, August 7-12, 2016, Holderness NH.


5 Acknowledgements

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Figure 2: Preliminary correlation between $A_{pv}$ and $R_n$ using ten relativistic mean field models[3]. $Q_{Weak}$'s measured $^{27}$Al asymmetry is plotted in black.

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References