Developing a Rutherford Backscattering Spectrometry Station for TUNL

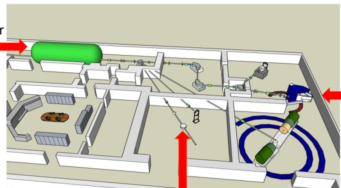
A. Wantz,[1] R. Longland[2]
[1]Indiana Wesleyan University, [2]TUNL

This work is funded by NSF grant PHY-1757783

TUNL

Triangle Universities Nuclear Laboratory (TUNL) is a national laboratory located in Durham, North Carolina on the Duke University campus. Originally founded in 1965 by the University of North Carolina, North Carolina State University and Duke University, TUNL houses three major experimental areas: the High Intensity Gamma Source (HIGS), the Laboratory for Experimental Nuclear Astrophysics (LENA), and the Tandem Accelerator Laboratory.

Tandem Accelerator



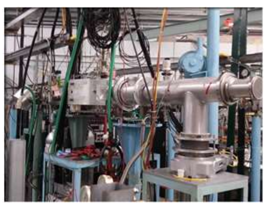
Shown here is the Tandem Accelerator Laboratory, in which the 52 degree "RBS" beam line sits

Enge Spectrograph

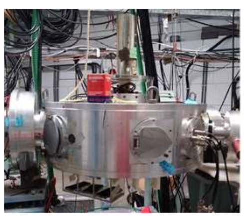
RBS Chamber

Rutherford Backscattering Spectrometry (RBS)

RBS is a technique used to analyze the targets that are used in other experiments. The dimensions of the target, particularly the number of target nuclei, must be known in order to find the cross-section for the reaction.



Shown above is the RBS beamline. The chamber and some of the vacuum equipment is visible.



Outside view of the RBS chamber

Cross-section/Rutherford Formula

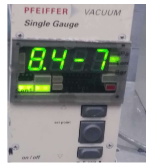
Much of nuclear physics focuses on finding the probability of a given reaction occurring, the cross section for the reaction. The main data points that we collected were these experimental differential cross-sections, given by:

$$\frac{d\sigma}{d\Omega} = \frac{A * N_R}{N_T * N_B * \Omega}$$

$$\frac{d\sigma}{d\Omega} = \left(\frac{Z_1 Z_2 e^2}{4E_0}\right)^2 \frac{1}{\left(\sin\left(\frac{\theta}{2}\right)\right)^4}$$

The equation above is the Rutherford formula, which was used to make the theoretical curve to which the experimental cross-sections were compared.

Preparing the Chamber



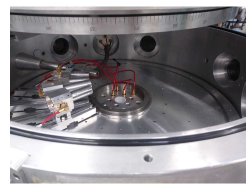
Shown above is the vacuum gauge that displayed the improved vacuum in the chamber

By fixing the leaks found with the leak-chaser, the baseline vacuum was improved from $2.5*10^{-5}$ to $7.0*10^{-7}$ torr.

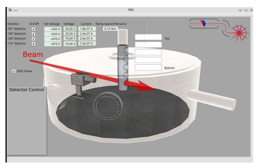
Displayed here is the leak-chaser that was used for the majority of the leak chasing

Detector Installation and Integration

The number of detectors was increased from one to four to obtain a better angular distribution of the scattering. These three additional detectors were integrated into the existing data analysis software (EPICS).



Interior view of the RBS chamber, showing the different angles of the detectors



The GUI for the EPICS software, which controls the detectors

Target Production

Silicon dioxide targets were made by floating a 40 µg carbon foil onto a metal frame and evaporating SiO_2 powder onto the foils.

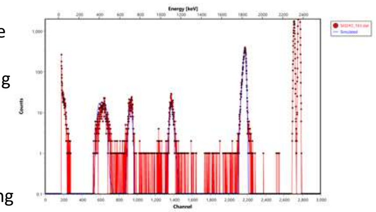
These targets were made to test the improved chamber and were later used for an experiment on the ENGE Spectrograph that looked at the excited states of ^{29}Si.

Data Acquisition

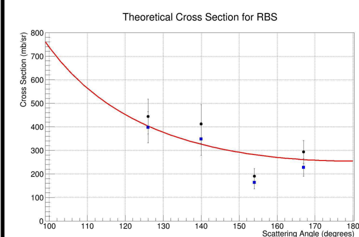
The experiment took place on July 25th, 2018. A 2 MeV ^{4}He beam was incident on a ladder consisting of targets including a gold foil on carbon and the two silicon dioxide targets. Data was collected for roughly 30 minutes per target.

Comparison of Experimental and Theoretical Cross Section

The figure to the right is a sample SIMNRA spectrum. This software was used to analyze the scattering data. The integral of the peaks is the number of reactions (N_R), needed for the cross-section formula. The data is energy calibrated using a target consisting of gold on carbon foil. Once calibrated, the peaks are fit to find the area under the curve.



Displayed above is the SIMNRA spectrum from the 165 degree detector. From left to right, the peaks correspond to carbon, oxygen, silicon, and tantalum.

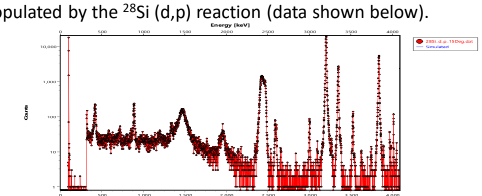


This plot compares the experimental cross-section (blue and black data points) to the theoretical Rutherford cross-section (Red Line).

A ROOT script was used to plot the experimental and theoretical cross-sections. The blue data points are from one SiO_2 target, while the black points are from the other. Overall, the data shows good agreement with theory, successfully demonstrating the ability of the improved RBS chamber.

Significance/Future Work

RBS is rarely performed on its own. Rather, understanding the composition of targets aids in the analysis of more complicated experiments. The silicon dioxide targets that were produced were used for an experiment that observed the ^{29}Si excited states populated by the ^{28}Si (d,p) reaction (data shown below).



Acknowledgements

I would like to thank Duke University and Triangle Universities Nuclear Laboratory for use of their facilities, the NC State nuclear astrophysics research group for their help and encouragement, and Indiana Wesleyan University. Additionally, I would like to thank the US Department of Energy (grant numbers DE-SC0017799 and DE-FG02-97ER41041).