Progress In Research: Influence of Nuclear Deformation on the Survival of Rn, Fr, and Ra Compound Nuclei

Jordan Mildon

Advisor: Charles M. Folden III

Date: November 2, 2022

A number of new super heavy elements (SHEs) have been produced in recent decades. From 1981 to 2004, 11 new elements were synthesized: element 107 (bohrium) to element 116 (livermorium), and element 118 (oganesson). Since then, however, only one new SHE has been synthesized, element 117 (tennessine) in 2009, despite numerous attempts to do so. Attempts have been made as of late to synthesize both element 118 and 119, with no success at present.[1] A lack of understanding of the factors that affect the survival of the compound nucleus is, perhaps, one of the reasons that previous attempts have been unsuccessful at producing elements heavier than 118.[1] SHEs span a large range of quadrupole (β_2) deformations, with some SHEs, especially those away from the region of beta-stability, being predicted to have substantial deformations.[2,3] These deformations increase the level density of states in the compound nucleus. It is well established that the decay path for the compound nucleus favors the mode with the highest level density (Fermi's Golden Rule Number 2), and further, it has been shown that a spherical nucleus increases in deformation as it undergoes fission. The consequence of these observations is an increased level density for the fission decay mode, which results in a lower-than-expected cross section for fusion-fission reactions to form heavy spherical nuclei.[4]

Previous work in the Folden Group focused on the effects of neutron binding energy on the survival probability of the compound nucleus, and the effects of deformation on the compound nucleus during fission (of otherwise near-spherical nuclei).[5] The current work seeks to expand upon that previous work by examining how the highly deformed compound nucleus changes these results. The goal is to create isotopic series by bombarding targets of Gd and Dy with ^{48}Ti and ^{51}V, to elucidate properties which can lead to successful synthesis of SHEs.

I entered graduate school in the Fall of 2022 and have completed almost all of the required coursework. I have completed an initial experiment for my thesis and have another one planned in November 2022. Throughout my first year, most of the work for this project involved characterizing the AGGIE gas-filled separator to be able to perform the experiments required for the later thesis experiments. Characterization of the magnetic field was also completed, and the separator can now be reliably tuned to steer products, based on their magnetic rigidity, for any given reaction. The transmission efficiency has been measured; data was collected during multiple beamtimes and preliminary analysis has been completed.

In terms of thesis experiments, the first experiment was carried out in the Spring of 2022 to examine the cross section for complete fusion of ^{48}Ti on with ^{158,160}Gd targets. Data was collected and a preliminary analysis has been performed (see Figures 1 and 2). During the upcoming experiment in November of 2022, the excitation function for those two targets will be finalized, in addition to completing the ^{157}Gd excitation function.

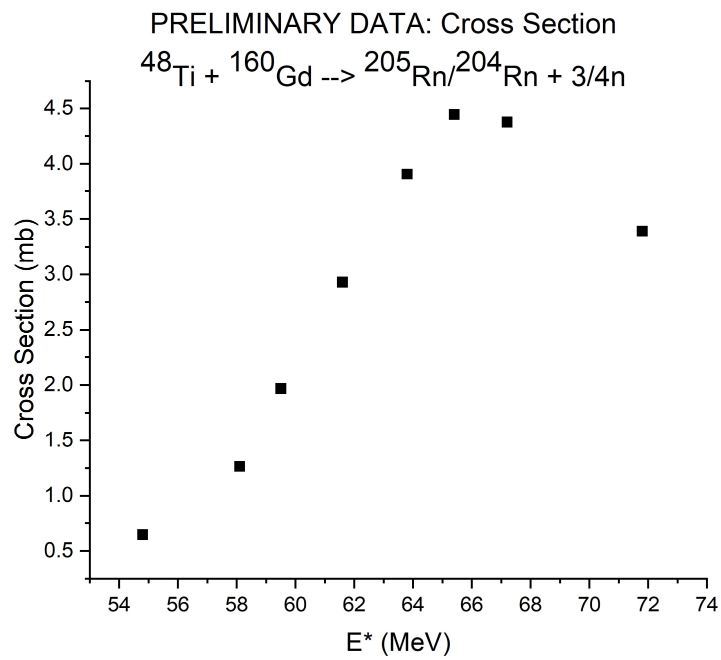

FIG. 1. Preliminary measured ^{48}Ti + ^{160}Gd excitation function.

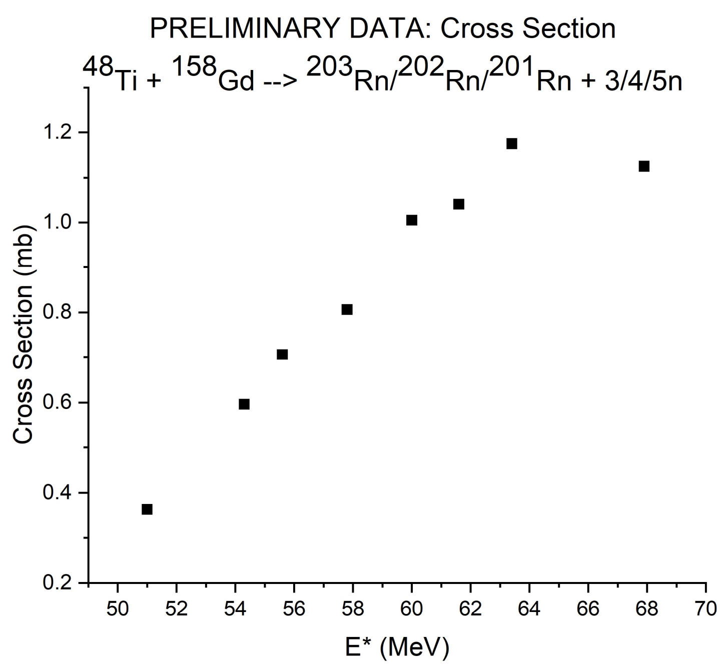

FIG. 2. Preliminary measured ^{48}Ti + ^{158}Gd excitation function.

Future work will consist of finishing the excitation functions for the Gd series and then performing a similar series of measurements for the reactions of ^{48}Ti on Dy and ^{51}V on Gd. This work will proceed in parallel with efforts by the Accelerator Physics group to improve the intensity of medium-mass metallic beams.

References

[1] J. Khuyagbaatar *et al.*, *Search for elements 119 and 120*, Phys Rev C **102**, 064602 (2020). doi:10.1103/PhysRevC.102.064602

[2] P. Moller, J. R. Nix, W. D. Myers, and W. J. Swiatecki, *Nuclear Ground-State Masses and Deformations*, At. Data Nucl. Data Tables **59**, 185 (1995). doi:10.1006/adnd.1995.1002

[3] P. Moller, A. J. Sierk, T. Ichikawa, and H. Sagawa, *Nuclear ground-state masses and deformations: FRDM(2012)*, At. Data Nucl. Data Tables **109**, 1 (2016). doi:10.1016/j.adt.2015.10.002

[4] T. A. Werke, D. A. Mayorov, M. C. Alfonso, M. E. Bennett, M. J. DeVanzo, M. M. Frey, E. E. Tereshatov, and C. M. Folden III, *Hot fusion-evaporation cross sections of ^{45}Sc induced reactions with lanthanide targets*, Phys Rev C **92**, 034613 (2015). doi: 10.1103/PhysRevC.92.034613

[5] T. A. Werke, D. A. Mayorov, M. C. Alfonso, E. E. Tereshatov, and C. M. Folden III, *Hot fusion-evaporation cross sections of ^{44}Ca induced reactions with lanthanide targets*, Phys Rev C **92**, 054617 (2015). doi:10.1103/PhysRevC.92.054617