GADGET II: Search for Novel αα Decay Using ^{220}Rn

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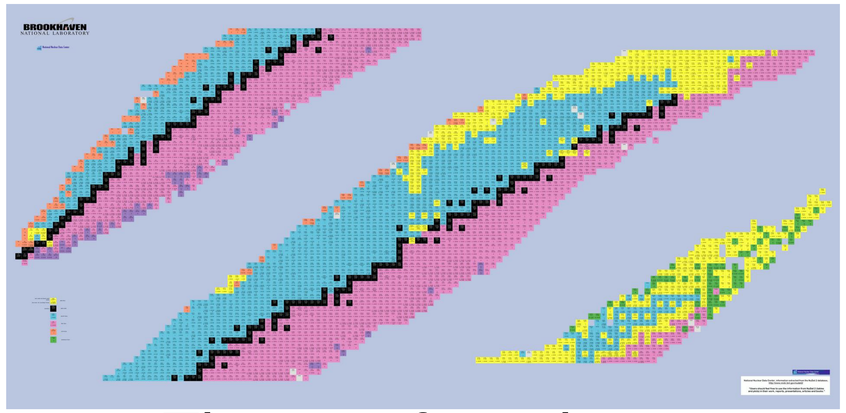
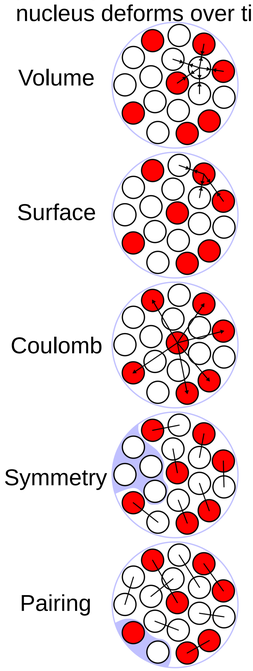
Introduction

Since the first observation of radioactivity by Becquerel in the late 19th century, there has been emphasis placed on measuring how nuclei decay to get a better understanding of the strong nuclear force. Since then, many more exotic decays have been observed. We would like to explore cluster decays such as back-to-back αα-decays, as there have been large discrepancies in recent theoretical calculations.

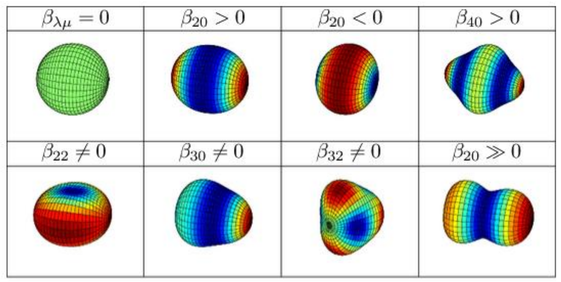


Theory of αα-decay

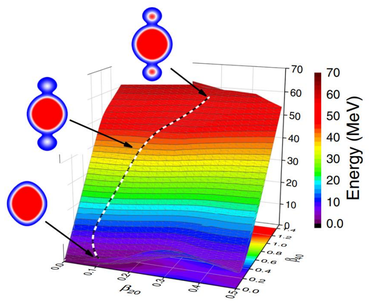
Heavy nuclei typically decay via alpha decay or spontaneous fission. We can predict properties of how a nucleus will decay by considering how that particular nucleus deforms over time, eventually leading to an emission of a particle.



MGLDM uses a rotational and proximity energy term instead of symmetry and pairing



Bing-Nan Lu et al. "Multi-dimensional potential energy surfaces…". In: Journal of Physics: Conference Series 492 (Apr. 2013).



F. Mercier et al. "Microscopic Description of 2α Decay in 212Po and 224Ra Isotopes". In: Phys. Rev. Lett. 127 (1 July 2021), p. 012501.

Predictions from recent theory papers for the branching ratio of αα in ^{220}Rn range from $10^{-2.07}$ (Denisov et. al.) to $10^{-6.4}$ (Zhao et. al.) to ~10^{-20} (Santhosh et. al.)

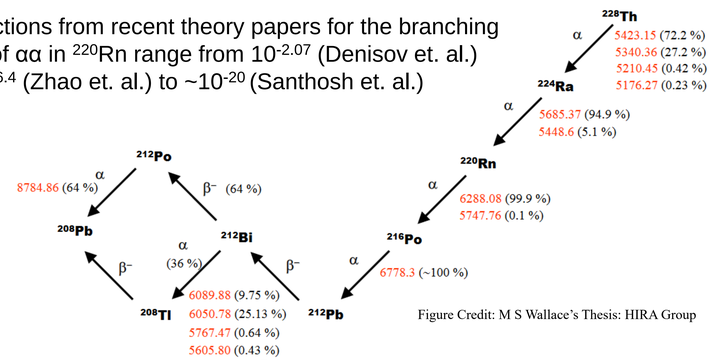


Figure Credit: M S Wallace's Thesis: HIRA Group

Upgrades to our TPC

The Gaseous Detector with GErmanium Tagging (GADGET II) TPC is designed to measure decays of species in a rare isotope beam experiment. A few adjustments have to be made to operate at higher pressures during our experiment. Dimensions of the active volume are length of 40 cm and diameter of 10 cm.

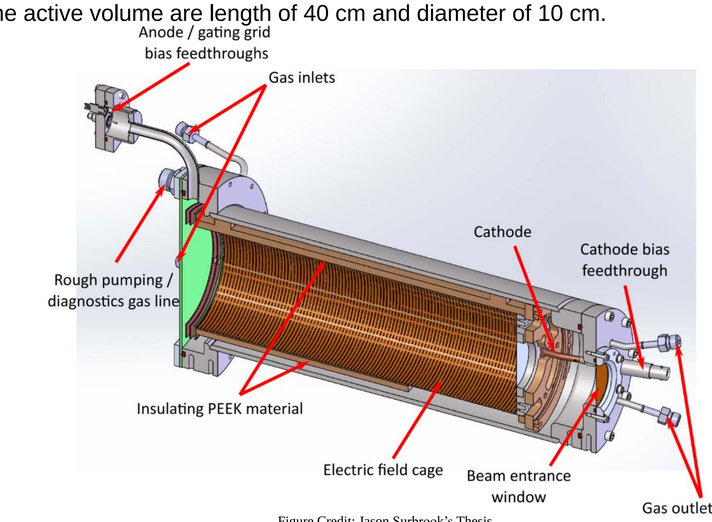
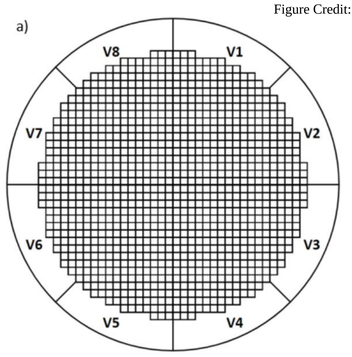
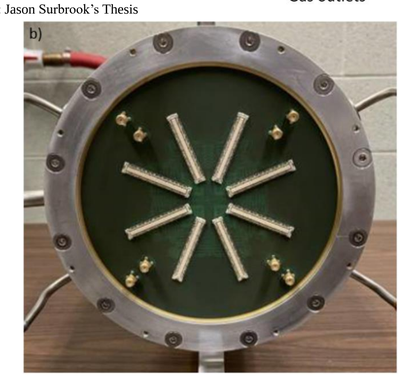


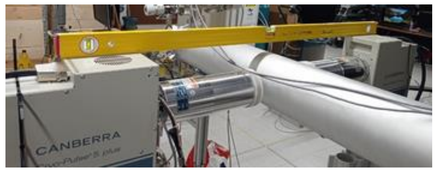
Figure Credit: Jason Surbrook's Thesis





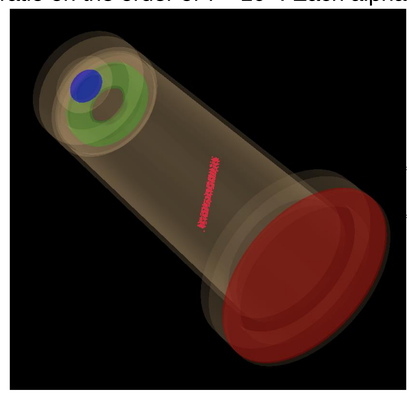
Resistive MICROMEGAS are used to protect electronics. They serve as the anode and end cap of the TPC, with a total of 1016 2.2 mm pads.

We are interested in integrating our 2 high volume HPGe detectors to measure alpha decays to excited states in ^{216}Po and ^{212}Pb. These particular isotopes have little information on their alpha decays due to Radon being a noble gas.

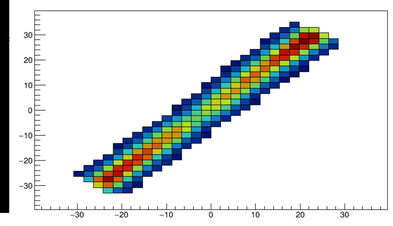


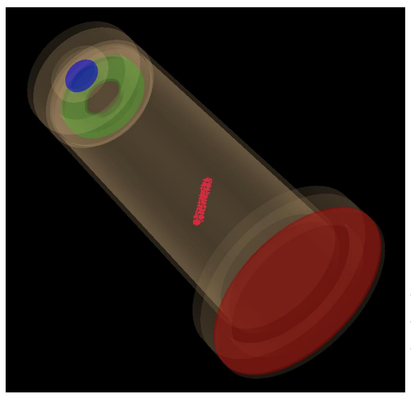
Simulations

Due to the nature of the proposed experiment, it is crucial to simulate how our detector functions under different conditions. Given our constraints, it is still possible to run the experiment over the course of a few weeks and constrain the branching ratio on the order of 7 * 10^{-8}. Each alpha has an energy of 6.656 MeV.

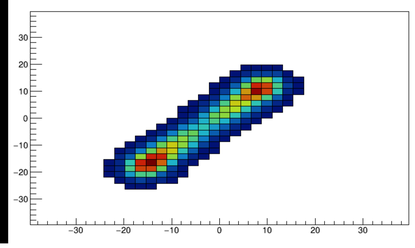


Simulation of double alpha decay event at an operating pressure of 800 torr





Simulation of double alpha decay event at an operating pressure of 2000 torr



Future Work

After completion of the double alpha decay search, we will return to running beam experiments at FRIB. GADGET II typically runs on the FRIB beamline, integrated with HPGe detector arrays (such as SeGA or FDSi). Our proposal to measure the NiCu cycle reaction rates was accepted earlier this year.

FRIB Facility for Rare Isotope Beams
U.S. Department of Energy Office of Science
Michigan State University

Theory Papers: F. Mercier et al. Phys. Rev. Lett. 127 (1 July 2021), p. 012501.
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J. Zhao et al. Phys. Rev. C 107 (3 Mar. 2023), p. 034311.

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