SELECTIVE POPULATION AND DECAY OF NEUTRON UNBOUND STATES IN $^{13}$Be

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RESEARCH ABSTRACT

Atomic nuclei with an overabundance of neutrons relative to the number of protons are known to exhibit different structural properties than their more stable counterparts. For example, the "shells" in which the neutrons arrange themselves are known to change far from stability, resulting from a relative shift of the discrete energy states that are available to the valence particles. The exotic neutron-rich $^{13}$Be provides an excellent opportunity to explore the effects of neutron excess on shell behavior since it has one more neutron than an established closed shell at neutron number $N=8$. The ultimate goal of this research is to understand the decay process by which $^{13}$Be integrates into a neutron and a $^{14}$Be nucleus, to identify and measure the energy states of $^{13}$Be and infer the energy levels occupied by its valence neutrons, and to compare the measured results to contemporary shell model calculations. In November, 2010, an experiment was conducted at the National Superconducting Cyclotron Lab at Michigan State University that produced $^{13}$Be and recorded events associated with its disintegration. The work accomplished this summer has focused on calibrations of the various detector systems used to record and track the $^{13}$Be nuclei that result from the decay of $^{13}$Be. These included position and energy-sensitive calibrations that are necessary to track the trajectories and measure the energies of the $^{13}$Be nuclei. Such calibrations are essential to the proper identification of $^{13}$Be, which eventually will lead to inferences about the structure of $^{13}$Be just prior to its disintegration.

THE NEUTRON DRIp LINE

The Neutron Drip Line is the jagged line on the chart of nuclides that marks the boundary between neutron bound and neutron unbound isotopes. Unbound isotopes have a binding energy of 0 for at least one of their constituent neutrons, meaning the outermost valence neutrons spontaneously fall off the nucleus until the nucleus becomes neutron bound. Unbound neutron decay by neutron emission mediated by the strong nuclear force. Theoretically there are numerous nuclei near the Neutron Drip Line (and the Proton Drip Line) that have not been studied. Because the area of known nuclei is so small compared with the entire nuclear landscape, the rules formed to describe the behavior of nuclei in the known region do not necessarily hold up for nuclei in general. The purpose of this research is to study and understand the territory beyond the Neutron Drip Line.

WHY $^{13}$Be?

$^{13}$Be is neutron unbound and lies just beyond the Neutron Drip Line. In fact, it is surrounded on three sides by neutron-bound isotopes yet decays 18 orders of magnitude faster than any of them. Furthermore, it is just one neutron away from a closed shell ($^{13}$Be has 4N). Thus, $^{13}$Be affords an excellent opportunity to study nuclear shells far from stability.

EXPERIMENTAL SETUP

Detector Calibrations

Work this summer has focused on calibrations of the detector systems. Below are a few examples of those calibration procedures.

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*Members: Augsburg College, Central Michigan University, Concordia College, Gettysburg College, Hope College, Indiana University-South Bend, Michigan State University, Ohio Wesleyan University, Rhodes College, Widener College, Westminster College