Towards Superheavies: Spectroscopy of $94<Z<98$, $150<N<154$ Nuclei*

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The structure of nuclei that lie at the edges of stability in the nuclear landscape hold the most discovery potential for new physics. While nuclei along the proton and neutron drip-lines reveal stellar nucleosynthesis pathways, very heavy high-Z nuclei, whose fragility stems from enhanced Coulomb repulsion, lead us towards superheavy physics. The island of superheavy nuclei predicted to lie at the next doubly-magic proton and neutron shell-gap is a topic of intense interest in contemporary nuclear structure research. While steady, albeit slow, progress is being made towards synthesizing superheavy elements, their picobarn production cross-sections via fusion preclude the possibility of studying excitations built on them for some time to come. The heaviest nuclei where such spectroscopy is possible is near Z ~100, where the nuclei exhibit surprisingly robust fission barriers up to high angular momenta [1]. These studies provide critical input for constraining theoretical models that attempt to describe the physics of superheavy nuclei, which include single-particle energies, shell-gaps and pairing. While $Z \geq 100$ nuclei can be produced and studied via fusion-evaporation reactions, we have concentrated on $Z < 100$ nuclei, where inelastic and transfer reactions are possible, as these are the heaviest long-lived radioactive nuclei which can be used as targets. Compared to fusion reactions leading to $Z \geq 100$, inelastic and transfer reactions with $Z < 100$ nuclei have comparatively higher cross-sections, and can populate more neutron-rich nuclei. We have focused on studying the highest neutron orbitals with $150 \leq N \leq 154$.

In a series of recent experiments, we have populated high angular momentum states in a range of nuclei: $^{244\text{-}246}$Pu (Z=94), $^{245\text{-}250}$Cm (Z=96) and $^{248\text{-}251}$Cf (Z=98). Beams of ^{208}Pb and ^{209}Bi from the ATLAS accelerator facility at Argonne were used to bombard backed radioactive targets of ^{244}Pu, ^{248}Cm and ^{249,251}Cf. The gamma rays were detected by the Gammasphere array. The radioactive targets pose experimental and analysis challenges that require the full power of the Gammasphere array, both in solid angle and granularity, to extract spectroscopic information. Rotational excitations were populated typically to angular momenta $I > 20\hbar$. Multiple band structures have been identified and quasiparticle alignments mapped [2,3]. Odd-A band structures help identify specific orbital configurations. Comparison of rotational alignments in collective bands built on different configurations in isotones and isotopes allow competing alignment contributions from neutrons and protons to be disentangled using blocking arguments, and reveal contributions from higher-multipole shapes [2]. Since both neutron and proton pairing are extremely weak in these very heavy nuclei, tracking rotational alignments in these nuclei allow a rare look at how pairing can diminish and re-emerge in these fragile systems [3]. There is also tantalizing evidence that deformed valence orbitals here may have their origin above the N =184 spherical shell gap. The most recent results and analysis [4] will be presented and discussed within the context of the emerging physics.

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