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# Prompt and delayed gamma-ray spectroscopy of neutron-rich Au isotopes populated from multi-nucleon transfer reaction

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The investigation of neutron-rich nuclei situated below $^{208}$Pb is anticipated to unveil a spectrum of phenomena, from shape evolution to the existence of exotic shapes and co-existence, which manifest from nuclear interaction. Additionally, nuclides' vicinity to the N=126 shell closure is linked to understanding the r-process path towards actinides. Although its importance is well recognized, only limited knowledge of the excited states is available, restricting comprehensive understanding. Despite the acknowledged importance of this realm, our understanding remains restricted primarily due to challenges in the production of such isotopes. Furthermore, the available excited states of known isotopes are limited to decay spectroscopy.

To address these limitations, a novel experiment was performed at GANIL aimed at exploring isotopes of interest via multi-nucleon transfer reactions between a 7 MeV/u $^{136}$Xe beam and a $^{198}$Pt target. The large acceptance VAMOS++ magnetic spectrometer and AGATA Ge tracking array were used to measure excited states of nuclides of interest. Several new experimental techniques were implemented. First, a new second arm ToF spectrometer was installed, which is composed of a 1.2 m long vacuum chamber and large area multi-wire proportional counter to measure the velocity vector of the target-like fragments. Second, a four EXOGAM clover HPGe array was installed at the end of the second arm to measure the delayed gamma rays from the excited states. Finally, a new method to determine particle identification was developed using a machine learning algorithm, where energy and charge states are determined using supervised machine learning, and atomic numbers are determined by the unsupervised learning method.

Among the plethora of populated isotopes, particular attention was devoted to the nuclear structure of odd-mass Au isotopes. The structure of Au isotopes has the longest chain of odd-mass isotopes with excited state information; showcasing proton-hole states with nearly constant energies across varying neutron numbers, but the neutron-rich part of information is limited near the stable isotope $^{197}$Au. The preliminary results of several neutron-rich Au isotopes, such as their level structure, will be presented.

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