Single particle structure of semi-magic $^{129}Ag_{82}$

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The shell structure is one of the fundamental ingredients in the understanding of mesoscopic systems, which includes the atomic nucleus. One crucial question in nuclear physics is how the quantum orbitals evolve as the number of protons and neutrons change. The ordering of the nuclear orbitals can change drastically in neutron-rich nuclei. In extreme cases, traditional magic numbers can disappear and new ones can emerge. Such changes were already observed for light nuclei, and are predicted for middle-mass ones. The evolution of orbitals and shell gap has obvious consequences on the r-process nucleosynthesis, which is responsible for the production of half of the nuclei heavier than iron. The abundances of nuclei with magic neutron numbers are enhanced due to their lower neutron capture probabilities. Thus the $A \sim 130$ r-process abundance peak is the consequence of the $N = 82$ neutron shell closure. The unknown evolution of the shell structure in this region is one of the main sources of nuclear physics uncertainty in r-process calculations. One has to rely on theoretical models whose predictions for regions far off stability diverge significantly.

^{129}Ag is a singly magic $N = 82$ nucleus. With three protons holes below ^{132}Sn it is neutron-rich, and any experimental information to be obtained on its structure is directly applicable for the understanding of the influence of the $N = 82$ nuclei on the r-process path. Using proton knockout from ^{130}Cd single proton states in ^{129}Ag can be populated.

The experiment was performed in November 2020. For an approximate length of 3 days a 345 MeV/nucleon beam of ^{238}U with an average intensity of around 60 particle nA impinged on a 4 mm ^{9}Be target. Fission fragments were separated and identified in flight with the BigRIPS separator centred on ^{130}Cd. Identification was achieved by using the $B\rho$-ΔE-$B\rho$ technique on an individual particle basis. A preliminary BigRIPS particle identification plot is shown in Fig. 1. This secondary radioactive beam impinged on another target of 6 mm ^{9}Be located at F8. The new germanium HiCARI array[1)] was located around this second beryllium target and used to detect the emitted γ rays with high resolution. The reaction products were identified in the ZeroDegree spectrometer, centred on ^{129}Ag, using the same methods as in BigRIPS.

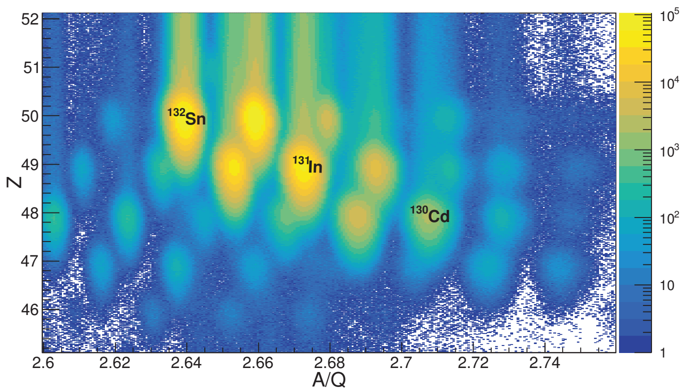

Fig. 1. Particle identification in BigRIPS with $N = 82$ nuclei including ^{130}Cd required for the main expected production channel of ^{129}Ag.

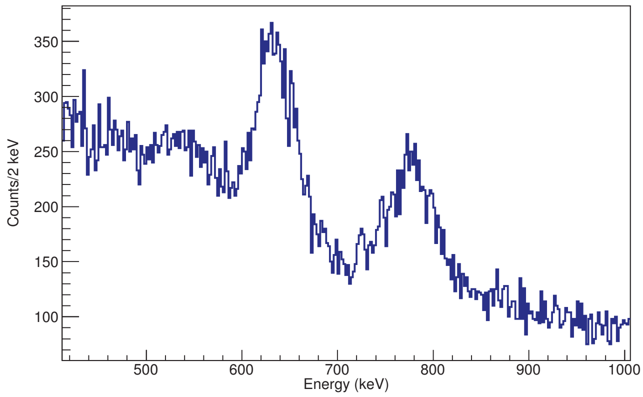

Fig. 2. Doppler corrected γ-ray spectrum of ^{128}Cd as measured by the full HiCARI. Clearly visible are the known[2)] 646 keV 2^+ to 0^+ and 785 keV 4^+ to 2^+ transitions.

The obtained data set is under analysis. As an early indication of the ability of the HiCARI array to achieve in-flight gamma-ray spectroscopy the isotope ^{128}Cd was selected to confirm the array was functioning as intended. ^{128}Cd was selected due to its high yield and its known structure.[2)] A preliminary Doppler corrected γ-ray spectrum of ^{128}Cd populated in one-proton removal from ^{131}In showing the 4^+ and 2^+ gamma rays is presented in Fig. 2. Note that using β values determined for individual particles, as well as updated calibrations, will result in a much better improved energy resolution.

References

1) K. Wimmer *et al.* (HiCARI Collaboration), in this report.
2) A. Scherillo *et al.*, Phys. Rev. C **70**, 054318 (2004).

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