Neutron intruder states and collectivity beyond $N = 50$ towards ^{78}Ni

L. Plagnol,[*1] F. Flavigny,[*1] for the RIBF196 and HiCARI collaborations

Recent spectroscopy studies in the vicinity of ^{78}Ni[1,2) hint to the presence of low-lying deformed configurations. These intruder configurations are predicted to originate from the multiparticle-multihole excitations[3)] of nucleons above the $N = 50$ and $Z = 28$ shell gaps becoming competitive in energy owing to neutron-proton correlations enhancing quadrupole collectivity. The quantification of collective effects above $N = 50$ is crucial since it directly impacts binding energies, drip-line limits,[4)] and consequently r-process nucleosynthesis calculations. Because these states involve many-particle excitations, their theoretical description is very challenging: thus, identifying them experimentally is of prime interest to constrain models.

We report here on the analysis status of the RIBF196 experiment to identify and characterize 2p-1h intruder states above $N = 50$ in ^{83}Ge and ^{81}Zn for the first time using a neutron knockout reaction from $N = 52$ isotopes. This selective reaction enables neutron removal from the $g_{9/2}$ orbital populating preferentially $9/2^+$ states with a significant intruder $\nu(g_{9/2})^{-1}(s_{1/2}d_{5/2})^{+2}$ configuration. Simultaneously, low-lying states in ^{82}Zn were populated using proton removal from ^{83}Ga, and their lifetimes will be extracted using line-shape analysis to better characterize the onset of deformation developing in Zn above $N = 50$.[5)]

To attain these scientific objectives, a secondary cocktail beam containing ^{84}Ge, ^{83}Ga, and ^{82}Zn was produced and purified in the BigRIPS spectrometer to induce knockout reactions on a secondary 6-mm thick Be target. De-excitation γ-rays of the reaction products ^{83}Ge, ^{82}Zn, and ^{81}Zn were detected using the HiCARI germanium array[6)] surrounding the secondary reaction target. Event-by-event particle identification for beam nuclei and reaction products was achieved in the BigRIPS and ZeroDegree spectrometers by reconstructing their atomic number (Z) and their mass-to-charge ratio (A/Q) using the TOF-$B\rho$-ΔE method combined with a two-fold $B\rho$ method.

We performed higher-order optical corrections of the A/Q values to compensate for remaining dependencies on spectrometer variables such as as positions and angles at the focal planes. This additional correction is equivalent to a higher-order determination of optical transfer matrices and improves the identification. It was performed using a multi-dimensional fitting procedure, considering cross-terms. An optically corrected particle identification diagram (PID) is shown in Fig. 1.

The A/Q resolution achieved through this optical correction procedure is of 7.10^{-2}% calculated on the identification of ^{84}Ge in BigRIPS with an amelioration of approximately 14% compared with the uncorrected

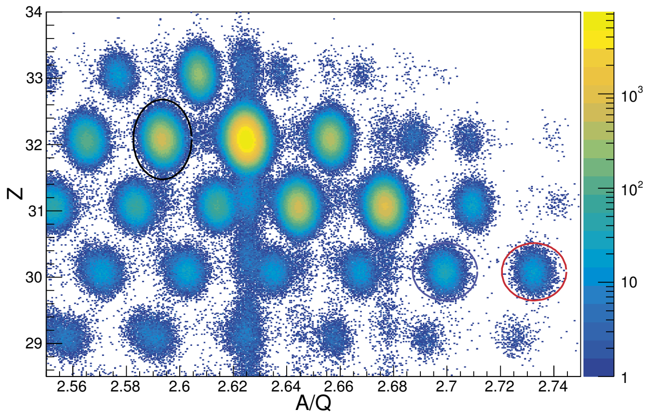

Fig. 1. Particle identification of the reaction products in the ZeroDegree spectrometer. The black, red, and purple ellipsoids indicate ^{83}Ge, ^{82}Zn, and ^{81}Zn, respectively: see text for details.

A/Q resolution, and 9.10^{-2}% on ^{83}Ge in ZeroDegree spectrometer with an amelioration of more than 50%. In addition, we cleaned the PID by removing unwanted events such as delta rays in PPAC detectors, pileup events in plastic detectors and ionisation chambers, and change in charge states. The most impacting selection is the pileup events removal cutting away approximately 10% of events on the total PID.

The HiCARI detectors have been aligned in time, calibrated in energy (38 crystals and 376 segments) using sources of ^{60}Co, ^{152}Eu, and ^{133}Ba, and the array efficiency was determined (2.9% at 1 MeV with a 0.5 mm Pb shield). The non-linearities of the ADCs were quantified from the residuals of the energy calibrated spectra and exhibit a saw-tooth pattern with variations up to 2–3 keV.[7)] Their impact on Doppler corrected spectra will be quantified using simulations. Finally, a preliminary Doppler-corrected gamma spectrum has been produced using photogrammetry positions of the clusters and a fixed velocity at the target, but we aim at improving this result using event-by-event Doppler correction using the measured velocity distributions in the BigRIPS and ZeroDegree spectrometers.

References
1) R. Taniuchi *et al.*, Nature **569**, 53 (2019).
2) X. F. Yang *et al.*, Phys. Rev. Lett. **116**, 219901 (2016).
3) K. Heyde, J. L. Wood, Rev. Mod. Phys. **83**, 1467 (2011).
4) J. Erler *et al.*, Nature **486**, 509 (2012).
5) C. Shand *et al.*, Phys. Lett. B **773**, 492 (2017).
6) K. Wimmer *et al.*, RIKEN Accel. Prog. Rep. **54**, S27 (2020).
7) K. Dolde *et al.*, Nucl. Instrum. Methods Phys. Res. A **848**, 127 (2017).

*1 LPC Caen, CNRS/IN2P3