RIKEN Accel. Prog. Rep. 48 (2015)

# $1p_{3/2}$ Proton-Hole State in $^{132}$Sn and Shell Structure Along N=82[†]

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The nucleus $^{132}$Sn is of particular interest for nuclear structure investigations since it is the only heavy neutron-rich doubly-magic nucleus far away from the valley of stability which is accessible for experimental studies. While $^{132}$Sn as well as the neighboring Sn ($Z$=50) and Sb ($Z$=51) isotopes have been studied in detail in the past, the experimental information for nuclei in the region below $^{132}$Sn is scarce. Important knowledge, e.g. with respect to the energies of the proton single-hole states in $^{132}$Sn, is still missing.

In an experiment performed in December 2012 as part of the EURICA campaign at the Radioactive-Isotope Beam Factory (RIBF), the neutron-rich nuclei $^{131,132}$Cd were produced by the in-flight fission of a $^{238}$U beam and implanted into the active stopper WAS3ABi. The $\gamma$ rays emitted following the $\beta$ decay of $^{131}$Cd and after $\beta$-delayed neutron emission of $^{132}$Cd were detected with the EURICA array comprising 84 germanium crystals. A single $\gamma$ ray with an energy of 988 keV was observed in the decays of both $^{131}$Cd and $^{132}$Cd. It was placed to populate the known $(1/2^-)$ $\beta$-decaying isomer in $^{131}$In at an excitation energy of $E_x = 365(8)$ keV thus defining a second excited state at 1353 keV. This newly identified state is preliminary assigned to have spin and parity of $3/2^-$ and to correspond to the previously unknown $1p_{3/2}$ proton single-hole state with respect to the $^{132}$Sn core. A full account of the arguments which lead to this assignment is presented in Ref. [2)].

Using the newly established $1p_{3/2}$ proton single-hole energy, shell-model calculations have been performed to calculate the energies of the first excited $2^+$ states and the proton gaps $\Delta_{2p}$ [defined here as $\Delta_{2p} = M(Z+2,N) + M(Z-2,N) - 2M(Z,N)$, with $M(Z,N)$ the mass of a nucleus with Z protons and N neutrons] for the $N$=82 isotones below $^{132}$Sn as shown in Fig. 1. For comparison, Fig. 1 also shows the results of similar SM calculations performed for the $N$=50 isotones below $^{100}$Sn, in that case in comparison with available experimental information. While for the $N$=50 isotonic chain typical signatures of sub-shell closures are observed at $Z$=38 and 40[3,4)], they disappear for the $N$=82 isotones below $^{132}$Sn. The disappearance of the proton sub-shell closures has its origin in the small energy gap between the $1p_{1/2}$ and the next single-particle orbital (SPO), independent of the character of the latter. Figs. 1 c) and d) show the reappearance of the sub-shell gap when increasing the energy separation between the $1p_{1/2}$ orbit and the next SPO.

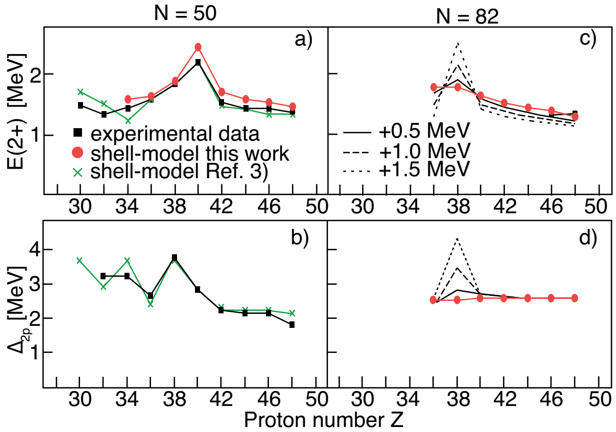

Fig. 1. a) and c): Energies of the first excited $2^+$ states, E($2^+$), and b) and d): proton gaps, $\Delta_{2p}$, in the even $N$=50 and $N$=82 isotones, respectively. The black lines (solid, dashed, and dotted) in c) and d) show the results of SM calculations assuming an increase of the $1p$ splitting by 0.5, 1.0, and 1.5 MeV, respectively.

Without the existence of pronounced proton sub-shell closures the $N$=82 isotones $^{120}$Sr and $^{122}$Zr should behave as mid-shell nuclei and consequently enhanced cross-shell excitations are expected to lead to a reduction of the $N$=82 shell gap in that region. Such a reduction would have a significant impact on $r$-process calculations and it is therefore concluded that preference should be given to mass models which indeed predict a reduction of the $N$=82 gap, such as the HFB24[5)] approach.

References

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[†] Condensed from the article in Phys. Rev. Lett., Vol. 112, 132501 (2014)

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