Gamma decay of unbound neutron-hole states in ^{133}Sn[†]

V. Vaquero,[*1] A. Jungclaus,[*1] P. Doornenbal,[*2] K. Wimmer,[*2,*3] A. Gargano,[*4] J. A. Tostevin,[*5] S. Chen,[*2,*6] E. Nácher,[*1] E. Sahin,[*7] Y. Shiga,[*8] D. Steppenbeck,[*2] R. Taniuchi,[*2,*3] Z. Y. Xu,[*9] and the NP1306-RIBF98R1 collaboration

The region around the doubly magic nucleus ^{132}Sn ($N = 82$ and $Z = 50$) is of particular interest for nuclear structure investigations. Nuclei with a few nucleons outside this closed-shell core provide direct information about the evolution of nucleon-nucleon correlations, quadrupole collectivity and single-particle energies. In this context, the low-lying states in the neutron-rich nucleus ^{133}Sn, which consists of a single neutron coupled to the doubly-magic nucleus ^{132}Sn, provide information about the position of the neutron single-particle orbitals belonging to the $N = 82$–126 major shell. Neutron single-particle energies of 854, 1367, 1561, and 2002 keV for the $2p_{3/2}$, $2p_{1/2}$, $0h_{9/2}$ and $1f_{5/2}$ orbitals, respectively, relative to the $1f_{7/2}$ orbital, have been established combining the information from both β decay and (d, p) neutron-transfer experiments.[1,2] The neutron single-hole states in ^{133}Sn are expected to have excitation energies above $S_n = 2.402(4)$ MeV and to decay via neutron emission mediated by the strong interaction.

In an experiment performed in April 2015 at the RI Beam Factory (RIBF), excited states in the nucleus ^{133}Sn were investigated by in-beam γ-ray spectroscopy. These states in ^{133}Sn were populated knocking out a neutron from a slightly heavier nucleus, ^{134}Sn, at relativistic energies. The exotic nuclei to be investigated were produced by the in-flight fission of a 345 MeV/nucleon ^{238}U beam with an average intensity of 15 pnA, impinging on a 4-mm thick Be target. In the BigRIPS in-flight separator, the $B\rho$-ΔE-$B\rho$ method was used in order to select and identify a secondary beam of ^{134}Sn. The identified ^{134}Sn ions then impinged with a kinetic energy of 165 MeV/nucleon on a 3-mm thick C target. The γ radiation emitted in the decay of excited states was detected using the γ-ray spectrometer DALI2 which was installed surrounding the secondary target. Reaction products from the secondary target were identified using the ZeroDegree spectrometer.[3)]

Figure 1 shows the Doppler-corrected γ-ray spectrum measured in coincidence with ^{134}Sn ions detected in BigRIPS and ^{133}Sn nuclei detected in the ZD spectrometer. Besides the known γ rays emitted in the decay of the single-particle states (transitions at 513, 854, 1561, and 2002 keV), clearly additional γ strength is observed above the neutron separation energy, reaching up to about 5.5 MeV. These excited states are interpreted as neutron-hole states that are populated following the knock-out of a neutron from the closed $N = 50$–82 shell of the ^{134}Sn projectile ion. These neutron-hole states are expected to decay via neutron emission because they are situated far above the neutron separation energy. However, the ability of γ-ray emission to compete with neutron decay is explained taking into account the structure of the initial and final states and the resultant wave-function overlap. Our study raises the question whether, due to nuclear structure effects, the γ-ray emission may play a much more significant role than generally assumed in the decay of highly excited states populated following β decay in the region southeast of ^{132}Sn.

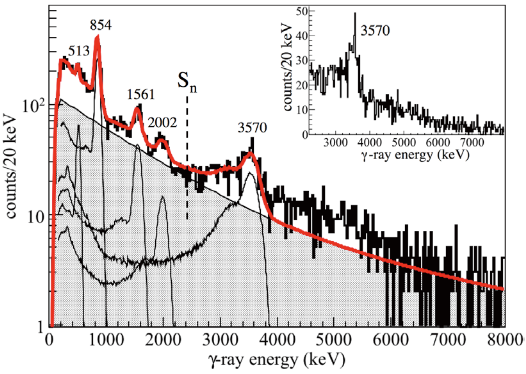

Fig. 1. Doppler-corrected γ-ray spectrum (for γ-ray multiplicity $M_\gamma = 1$ after add back) of ^{133}Sn populated via one-neutron knockout from ^{134}Sn. The response function fit to the experimental spectrum is shown by the thick red line while the individual components are shown as thin black lines. The background is indicated as the gray area. The inset shows the high-energy region of the spectrum on a linear scale.

† Condensed from the article in Phys. Rev. Lett. **118**, 202502 (2017)

*1 Instituto de Estructura de la Materia, CSIC
*2 RIKEN Nishina Center
*3 Department of Physics, University of Tokyo
*4 Istituto Nazionale di Fisica Nucleare
*5 Department of Physics, University of Surrey
*6 State Key Laboratory of Nuclear Physics and Technology, Peking University
*7 Department of Physics, University of Oslo
*8 Department of Physics, Rikkyo University
*9 Department of Physics, University of Hong Kong

References

1) P. Hoff *et al.*, Phys. Rev. Lett. **77**, 1020 (1996).
2) K. L. Jones *et al.*, Nature (London) **465**, 454 (2010); Phys. Rev. C **84**, 034601 (2011).
3) N. Fukuda *et al.*, Nucl. Instrum. Methods Phys. Res. B **317**, 323 (2013).