Coexisting single-particle and octupole states in ^{133}Sn

G. Simpson,*1 J. Keatings,*2 A. Jungclaus,*3 J. Taprogge,*4 S. Nishimura,*5 P. Doornenbal,*5 G. Lorusso,*5 P. -A. Söderström,*5 T. Sumikama,*5 J. Wu,*5 Z. Y. Xu,*5 T. Isobe,*5 H. Sakurai,*5 and the EURICA RIBF-85 collaboration*5

The experimental study of single valence particle (hole) nuclei provides crucial experimental data for nuclear structure studies. In particular the energies of low-lying levels in these nuclei can provide the effective single-particle (hole) energies used in shell-model calculations.[1)] In experiment RIBF-85,[1,2)], which was part of the EURICA campaign, the single valence neutron nucleus ^{133}Sn was studied following the β- and β-n decay of ^{133,134}In parent nuclei. This has allowed the energies of several single-particle states to be verified and the γ decays of new levels observed. To date all single-particle states in the $N = 82$–126 valence shell have been directly experimentally identified in ^{133}Sn, except the $\nu i_{13/2}$ one.[3–5)] Furthermore the recent report of enhanced quadrupole and octupole strength in ^{132}Sn[6)] allows searches for more complex states to be performed. The co-existence of spherical single-particle and collective states appears to be a ubiquitous feature of the nuclear landscape.

The high Q_β and $Q_{\beta-n}$ values of 14135(60) keV and 11110(270) keV for the β and β-n decays of ^{133,134}In, respectively, make them ideal for studying a wide range of states in ^{133}Sn. The differing spins of the ground states of these nuclei [$(9/2^+)$ and $(4^- - 7^-)$] mean that levels with different spin ranges should be populated.

The experimental γ-ray spectrum obtained following the decay of selected and implanted ^{133}In ions is presented in Fig. 1. Many transitions previously assigned to ^{132}Sn are observed.[7)] A new γ decay of energy 1779 keV is assigned to ^{133}Sn as this transition was observed following both the β decay of ^{133}In and the β-n decay of ^{134}In. The 1561-keV transition, previously reported in several experiments is confirmed.[3–5)] However, no evidence was found for the 513- and 854-keV γ decays of the $\nu p_{3/2}$ and $\nu p_{1/2}$ states from parent ^{133}In nuclei.[4)] This shows that ^{133}In was much more strongly populated in its $\pi g_{9/2}^{-1}$ ground state, than the $\pi p_{1/2}^{-1}$ long-lived isomer. The γ decay of the 854-keV $\nu p_{3/2}$ state was however observed following the β-n decay of ^{134}In.

The 1561-keV transition receives more than one third of the total feeding intensity following the β-n decay of ^{134}In. The weak population of the 1779-keV state in ^{133}Sn following β-n decay means that it may have a positive parity.

*1 LPSC, Grenoble
*2 School of Engineering, University of the West of Scotland
*3 IEM, CSIC Madrid
*4 Departamento de Física Téorica,Universidad Autonoma de Madrid
*5 RIKEN Nishina Center

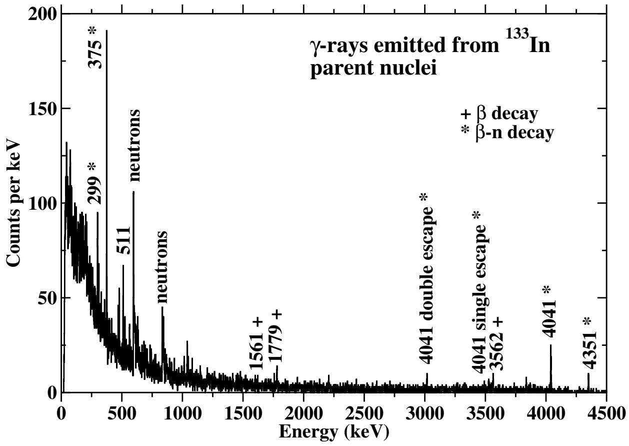

Fig. 1. γ-ray spectrum obtained from the β-decay of ^{133}In in the current work.

Octupole excitations are amongst the first few excited states in ^{132}Sn[7)] and have recently been shown to possess enhanced collectivity.[6)] As the 1779-keV state has not been populated in transfer reaction experiments then its isospin quantum number is probably different to that of the neighboring states[4,5,8)] The 1779-keV state probably has a $\nu f^1_{7/2} \otimes 3^-$ configuration and is lowered in energy due to an attractive proton-neutron interaction.

Following the β decay of ^{133}In the $\log ft$ value for the 1779-keV state was measured to be 6.9(1). This is compatible with either a first-forbidden transition or a hindered allowed Fermi one. Here the hindrance occurs due to $\Delta T \neq 0$ between the initial and final states, which impedes Fermi transitions. This underlines the complex nature of the octupole state, which contains multiple particle-hole excitations.

Evidence of coexisting single-particle and octupole states at an energy of ~1.6 MeV in ^{133}Sn is presented. It is a theoretical challenge to reproduce these states.

References

1) J. Taprogge *et al.*, Phys. Rev. Lett. **112**, 132501 (2014).
2) G. Simpson *et al.*, Phys. Rev. Lett. **113**, 132502 (2014).
3) P. Hoff *et al.*, Phys. Rev. Lett. **77**, 1020 (1996).
4) J. M. Allmond *et al.*, Phys. Rev. Lett. **112**, 172701 (2014).
5) V. Vaquero *et al.*, Phys. Rev. Lett. **118**, 202505 (2017).
6) D. Rosiak *et al.*, Phys. Rev. Lett. **121**, 252501 (2018).
7) B. Fogelberg *et al.*, Phys. Rev. Lett. **73**, 2413 (1994).
8) K. Jones *et al.*, Phys. Rev. C **84**, 034601 (2011).