Eurasian Journal of Physics and Functional Materials

2019, 3(2), 151-154

New nuclear structure data beyond ^{132}Sn

R. Lozeva

Universite Paris-Saclay, Paris, France

E-mail: radomira.lozeva@csnsm.in2p3.fr

DOI: **10.29317/ejpfm.2019030206**
Received: 24.05.2019 - after revision

Nuclear structure studies beyond ^{132}Sn on the shell evolution, the competition or coexistence of single-particle and collective structures and the GT strength are performed using prompt and decay spectroscopy. Here, we present an overview of our recent data from such experiments on neutron-induced fission products in the mass chain A=136 using the EXILL and Lohengrin spectrometers at the ILL in the framework of other studies we have recently performed in the region around ^{132}Sn.

Keywords: prompt spectroscopy; decay spectroscopy; neutron-rich nuclei.

Introduction

One of the most interesting regions of the nuclear chart as the one around the doubly-magic ^{132}Sn, attracts a lot of experimental and theoretical attention. Close to the r-process path, and to the $A = 130$ peak, where experimental data are insufficient for the theoretical description [1, 2], one observes domination of single-particle excitations in excited isomeric states around [3] and close beyond ^{132}Sn [4]. On the other hand, the evolution of shapes below ^{132}Sn [5], is expected to develop collectivity beyond ^{132}Sn [6] only few particles away in the Sn chain with seniority mixing [7], deformation in Te [8] to octupole shapes [2]. However, no experimental data on such collective mode excitations is available below Xe [9, 10]. The intriguing orbital evolution beyond ^{132}Sn was recently discussed in the framework of isomer and decay investigations [11, 12]. Several works report on the neutron orbital evolution such as between the low-lying $\nu f_{7/2}$ and $p_{3/2}$ and $h_{9/2}$ and on the proton side the low-lying $\pi g_{9/2}$ and $d_{5/2}$ [4, 6, 11, 13-15]. As a consequence of this evolution beyond ^{132}Sn, certain $T_{1/2}$ [16], multiple β-delayed neutron emissions [17] and the opening of GT trength in the β-decay is expected [18], with experimental evidences found in the I isotopes from $A = 136$ [19] to $A = 140$ [12].

Experimental techniques and results

We performed several experimental studies in the region beyond ^{132}Sn [3, 4, 9, 11, 12]. Relevant to the above context are the experiments, performed on thermal-neutron induced fission products at the PF1B and PN1 lines of the ILL research reactor with collimated neutron flux of about 10^8 n/s/cm^2. Detailed prompt spectroscopy was possible as fission can populate rather high spins of the resulting fragments. In a subsequent experiment, in addition, we measured the β-decay of some of these products, first separated by the Lohengrin spectrometer and then implanted in a tape station, adapted to the lifetime of the nuclei of interest. As beyond ^{132}Sn, the probability for β-delayed neutron emission is rather high [17], we were able to detect also these channels using specific experimental setup including five user neutron detectors. The data analysis from the neutron tagging investigation will be reported in a forthcoming article. Here, we give a brief overview of the results without necessity for neutron tagging such as from the $A = 136$ chain from our decay work, compared to the prompt measurement and extending our experimental spectra beyond our recent work [19]. The prompt measurements of $A = 136$ were done within EXILL [20], using ^{235}U and ^{241}Pu targets and $\gamma\gamma\gamma$ coincidences recorded by Clover HpGe detectors. These data complement the above findings, especially at high spin and yrast excitations. The observed non-yrast excitations could be compared to our β-decay measurements, where we used only ^{235}U production target. The population of prompt, predominantly yrast with some non-yrast states, was seen in the first case, while mostly non-yrast low-spin excitations were populated and observed in the β-decay case.

Results on the $A = 136$ chain are recently published in [19], with yrast and non-yrast schemes from prompt fission and decay of fission products. It is interesting to underline, that the data from complementary studies, e.g. different fission targets or β-decay data are consistent with each other and are used for coherent extension of the yrast and non-yrast level schemes. Furthermore, both the non-yrast low-spin states from decay of fission products and direct β-decay data were used for energies detected up to 3.5 MeV. In an additional β-decay data set, an energy range between 3.5 and 6 MeV was also covered. Therefore, it was possible to detect γ-rays to up to about 6.5 MeV for the $A = 136$ chain, composed of I and Xe. The known Q_β value of ^{136}Te β-decay is 5.120(14) MeV, while the for ^{136}I decay it is 6.884(14) MeV [21].

It is visible in the spectrum shown in Figure 1, that several transition candidates exist beyond the earlier data threshold of 3.5 MeV and these can be assigned to decay transitions in ^{136}I and ^{136}Xe from respectively ^{136}Te and ^{136}I β-decay. ^{136}Xe can be considered as stable with negative Q_β value, resulting in no electron

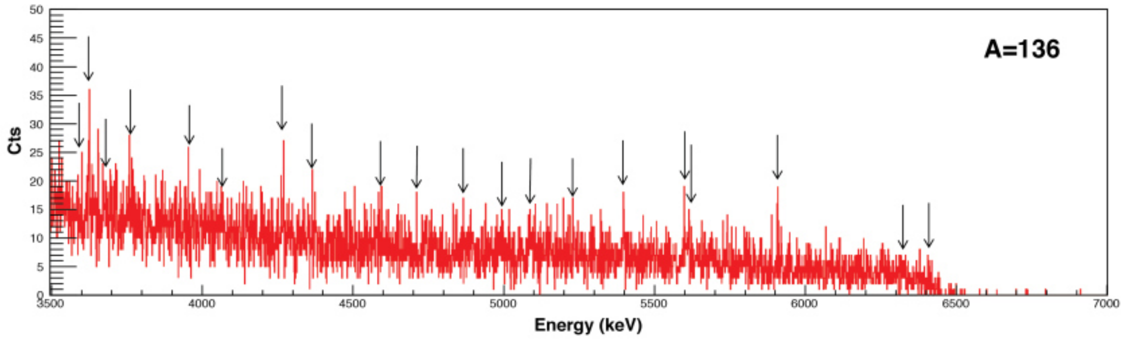

Figure 1. Decay spectrum for A=136 above 3.5 MeV.

or positron emission energetically possible. From the sharp end-point energy detected here, it is reasonable to assume that only these β-decays take place and that no strong neutron channel is present, consistent with the low Pn reported for the ^{136}Te decay [17]. Any contribution form e.g. other fission product arriving at implantaiton point was investigated and considered negligible.

Discussion

The new results in the $A = 136$ chain from our recent measurements trigger several discussions. The position of the proton $\pi g_{7/2}$ and $\pi d_{5/2}$ orbitals at the beginning of the $\nu g_{7/2}$ shell (N>82) could be investigated [19], especially in the context of our recent work also at its end, where at N=89 a crossing between the two orbitals was proposed [11]. The new results at $N = 83$ are consistent with large energy spacings between states invoilving certain orbitals (e.g. $\pi g_{7/2}$-$d_{5/2}$ or $\nu f_{7/2}$-$i_{13/2}$) inferred from shell-model calculations presented in [19]. This, on one side is consistent with the proximity to semi-magic $N = 82$ chain [21] and on the other, reasonably in conjunction with the proposed orbital evolution toward the increase of N [11]. One has to note that this is very valuable as, a fast drop of the $\pi d_{5/2}$ at $N = 83$ was proposed earlier to explain data in ^{136}I [22], inconsistent with our data [19]. Furthermore, from the high excitation energy above 2.5 MeV and large spacings between states containing neutron $\nu i_{13/2}$ orbital, one can conclude that the placement of this orbital is also rather high in energy (see Figure 3 and Figure 13 in [19]), consistent with slowly developing collectivity close to ^{132}Sn e.g. with the increase of both Z and N. In the decay data, we have also identified some GT strength for $A = 136$ and compared it to the GT strength for $A = 140$ [12] iodine nuclei, based on the strong occupation of the $\nu h_{9/2}$ orbital and transitions of type $\nu h_{9/2} \rightarrow \pi h_{11/2}$ for which we used also β-decay data from ^{136}Te$\rightarrow$ ^{136}I$\rightarrow$ ^{136}Xe. These give rise to several 1+ states in ^{136}I and 2-states in ^{136}Xe, populated with GT transitions [19]. One cannot exclude the existence of other such states in ^{136}I, extended to higher excitation energy above 3.5 MeV, though they may have more mixed configurations analyzing the shell-model results in [19].

References

[1] T. Kratz et al., Astrophys. J. **662** (2007) 39.
[2] Moller et al., At. Dat. Nucl. Dat. Tabl. **109** (2016) 1.
[3] R. Lozeva et al., Phys.Rev. C **77** (2008) 064313.
[4] R. Lozeva et al., Phys.Rev. C **92** (2015) 029901.
[5] T. Togashi et al., Phys. Rev. Lett. **121** (2018) 062501.
[6] H. Naidja et al., Phys. Rev. C **96** (2017) 034312.
[7] Naidja et al., JPCS **580** (2015) 012030.
[8] W. Urban et al., Phys. Rev. C **93** (2016) 034326.
[9] S. Ilieva et al., Phys.Rev. C **94** (2016) 034302.
[10] B. Bucher et al., Phys. Rev. Lett. **116** (2016) 112503.
[11] R. Lozeva et al., Phys. Rev. C **93** (2016) 014316.
[12] B. Moon et al., Phys.Rev. C **96** (2017) 014325.
[13] L. Coraggio et al., Phys. Rev. C **87** (2013) 034309.
[14] A. Covello et al., JPCS **267** (2011) 012019.
[15] S. Sarkar et al., JPCS **267** (2011) 012040.
[16] Y.F. Niu et al., Phys. Lett. B **780** (2018) 325.
[17] R. Caballero-Folch et al., Phys. Rev. C **98** (2018) 034310.
[18] I. Borzov et al., Phys. Rev. C **71** (2005) 965801.
[19] R. Lozeva et al., PRC **98** (2018) 024323.
[20] M. Jentschel et al., J. Instr. **12** (2017) 11003.
[21] https://www.nndc.bnl.gov/
[22] W. Urban et al., Eur. Phys. J. A **27** (2006) 257.