Spectroscopy of neutron-rich Sb isotopes using AGATA, VAMOS++ and EXOGAM

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Introduction

^{132}Sn is one of the rare neutron-rich unstable nuclei, with classical doubly magic shell closures, that is experimentally accessible with the recent developments in accelerators and detectors. The study of the excited states and the transition probabilities in nuclei in its vicinity, with few particles or/and holes added to the inert core, are crucial for understanding the shell model theory and the relevant *pp*, *pn* and *nn* interactions in this mass A $\sim$ 130 region. Additionally, in this mass-region, there are presence of many seniority isomers in the range of ns to μs. When the lifetime of the isomer is of the order of μs's, an additional challenge appears in correlating the γ-ray transition feeding and depopulating these isomers. Therefore, these nuclei are often known either from their isomer decay or from their prompt γ spectroscopy. In the present work, the prompt-delayed spectroscopy of neutron-rich Sb isotopes have been carried out by utilising the unique combination of AGATA, VAMOS++ and EXOGAM detectors [1].

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Experimental Details and Results

The neutron-rich $^{122-131}$Sb fission fragments were populated using the inverse kinematics reaction, ^{9}Be(^{238}U, f) at 6.2 MeV/u. The experimental setup included the AGATA array, VAMOS++ spectrometer and the EXOGAM detectors. The prompt γ rays, emitted by the excited fission fragments, were detected using the AGATA γ-ray tracking array. The VAMOS++ spectrometer was used for the unambiguous identification of the neutron-rich fission fragments on an event by event basis. The delayed γ rays were detected by the EXOGAM detectors, placed at the focal plane of VAMOS++. More details regarding the experimental setup are given in Ref. [2]. This setup enabled the correlation of the prompt and delayed γ rays in the time range of 100 ns - 200 μs.

A systematic analysis of the prompt and delayed transitions for all the neutron-rich $^{122-131}$Sb isotopes have been carried out. The already known isomers in the odd-A $^{123-131}$Sb isotopes have been confirmed in the present analysis. In addition, several new prompt and delayed transitions for these isotopes have been identified. New isomers, prompt and delayed γ rays have been identified in the even-A

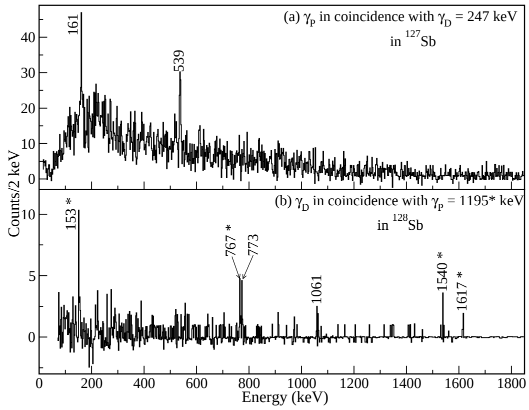

FIG. 1: (a) The prompt γ-ray spectrum (γ_P) in coincidence with already known delayed 247 keV γ-ray (γ_D) in ^{127}Sb. (b) The γ_D in coincidence with newly identified 1195 keV prompt γ-ray in ^{128}Sb. The newly observed delayed transitions have been marked with an asterisk.

$^{122-130}$Sb isotopes. An example of the prompt γ-ray spectrum (γ_P) with gate on an already known delayed 247 keV transition in ^{127}Sb and the delayed spectrum (γ_D) with gate on the newly identified prompt 1195 keV transition in ^{128}Sb have been shown in Fig. 1(a) and (b), respectively.

Shell model calculations using the restricted model space, consisting of neutron $d_{3/2}$, $s_{1/2}$, $h_{1/2}$ and proton $p_{1/2}$, $g_{9/2}$, and $g_{7/2}$ orbitals have been carried out using the interaction used in Ref. [3]. The interaction has been improved so as to have a better agreement for the binding energies, excitation energies and the transition probabilities. Also, a systematic comparison of the isomers in Sb have been carried out with the corresponding isomers in $^{121-130}$Sn isotopes, showing that the isomers in Sb dominantly arise due to a $\pi g_{7/2}$ particle coupled to the corresponding neutron configurations in the Sn isotopes. Though the energies of the excited states in the Sb isotopes seem to follow the seniority scheme, the transition probabilities do not. This could be probably due to the breaking of the neutron pairs in the $h_{11/2}$ orbital arising due to the $\pi g_{7/2}$-$\nu h_{11/2}$ interaction.

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References

[1] S. Biswas, *et al.*, Manuscript in preparation.

[2] Y. H. Kim, *et al.*, Eur. Phys. J. **24**, 39 (2017).

[3] M. Rejmund, *et al.*, Phys. Lett. B **753**, 86 (2016).