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OBSERVATION OF A NEW $(25/2^+)$ ISOMER IN ^{121}Sb*

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The beam pulse structure of the HIL cyclotron and thick target γ–γ coincidence measurements in the in-beam and off-beam modes have been used to search for isomers in the $A \approx 120$ mass region using heavy-ion reactions. The half-life of the 2721 keV, $(25/2^+)$ level in ^{121}Sb was determined in the off-beam mode to be 167 ± 19 μs. Two deexcitation sequences of this isomer are proposed. The isomeric state is considered to be of 3-quasiparticle nature $\pi(d_{5/2})\nu(h^2_{11/2})_{10^+}$.

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1. Introduction

The neutron shell $N = 50$–82 contains the positive parity $s_{1/2}$, $d_{3/2}$, $d_{5/2}$ and $g_{7/2}$, and the unique parity high-j $h_{11/2}$ orbitals. It is well known [1] that nuclei near $Z = 50$ closed proton shell exhibit both collective and noncollective features. The $2h$–$3p$ rotational high-spin structures are found in the low mass $^{109-119}$Sb isotopes, while they are not observed in the heavier masses since the excitation energies of the deformed structures show minimum at the middle of the $N = 50$–82 shell [2]. Yrast decays of high-spin states of $^{121-127}$Sb nuclei would thus proceed via levels originating from coupling of one proton to the Sn core excitations, which presumably arise from broken neutron pairs. Such observation is of special interest for testing effective n–p interactions in the shell model calculations. The aim of the present work was

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to study $A \sim 120$ mass region, where the existence of unknown high-spin isomers was expected, using ^{10}B + ^{120,122}Sn reactions. The ^{121}Sb nucleus has previously been studied in the fusion evaporation reaction [3] and also as fission fragment in reactions induced by heavy ions [2], where the existence of $25/2^+$ isomer was predicted from comparison with neighbouring odd-A Sb isotopes. In this paper we report a successful attempt to measure the life-time of this isomer.

2. Experimental method

The OSIRIS-II array consisting of 12 Compton suppressed HPGe detectors has been employed in the present experiment. The HPGe detectors were arranged in two rings parallel to the beam line; in the first one at angles $\Theta = \pm 38°$, $87°$, $90°$, $\pm 142°$ and in the second one at $\Theta = 25°$, $\pm 63°$, $\pm 117°$, $155°$ with respect to the beam axis. The 48-elements sum-energy and γ-ray multiplicity filter made of BGO crystals was also used in the present experiment. The optimal beam-target combination was obtained for reaction ^{10}B + ^{120}Sn with beam energy of 55 MeV and target thickness of 43 mg/cm^2. Energy and efficiency calibrations were obtained using ^{152}Eu

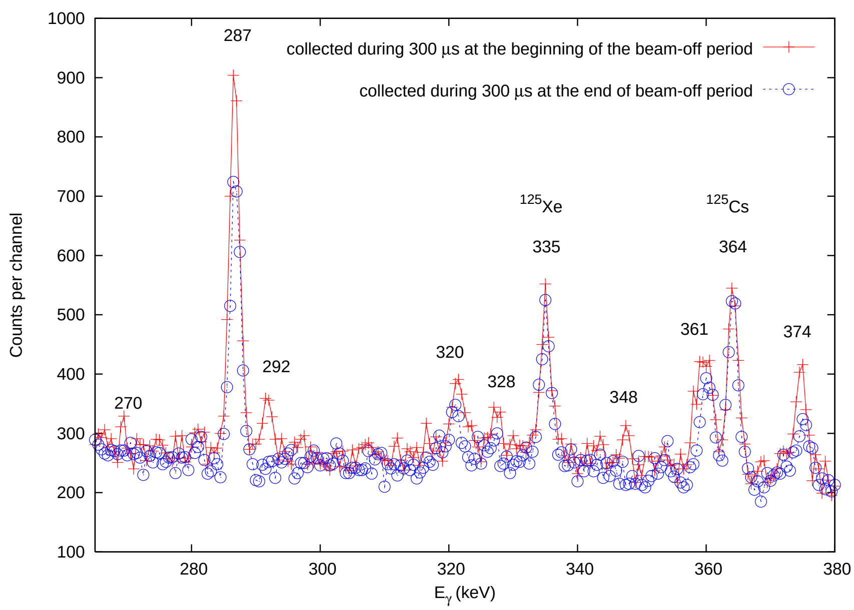

Fig. 1. An example of two spectra collected during 300 μs at the begining and at the end of beam-off period. One can see a decay of γ-rays of energy 287 and 292 keV which belong to band-I and 321, 328 348, 361 and 375 keV, which belong to band-II of ^{121}Sb nucleus.

and ^{60}Co radioactive sources. Using the unique beam pulse structure of the HIL cyclotron one could measure the γ–γ coincidence spectra in the in-beam (adjustable 1–3 ms) and off-beam (3–8 ms break in the beam duration) time intervals. The Fig. 1 shows an example of spectra measured in beam-off period. Background subtracted time spectra for γ-lines in branch I and branch II (see level scheme) have been made and sums of them are shown in Figs. 3 and 4. Evidently some of the lines are complex with long-lived components which may deexcite long-living isomers or belong to daughter nuclei. Half-lives for both branches have been obtained by fitting exponential plus constant functions to experimental time spectra.

3. New isomer in ^{121}Sb

A new $(25/2^+)$ isomeric state at 2721 keV in ^{121}Sb has been populated via the ^{10}B + ^{120}Sn reaction. Isotopic identification of the isomer was performed by examining X–γ coincidences and the isomer-delayed γ-rays measured in off-beam mode. The level scheme deduced from present experiment is shown in Fig. 2 and the results are in agreement with those of Ref. [2]. This new isomer decays by 287 keV, most probably (basing on lower limits for empirical $T_{1/2}$ values [4]), E3 transition to 2434 keV, $(19/2^-)$ state, which then decays via previously known 292, 715 and 392 keV γ-lines, that can be seen in off-beam delayed spectrum. Except branch (I) (Figs. 2 and 3), another delayed branch (II) of similar intensity, namely the sequence of 320, 361, 348, 328

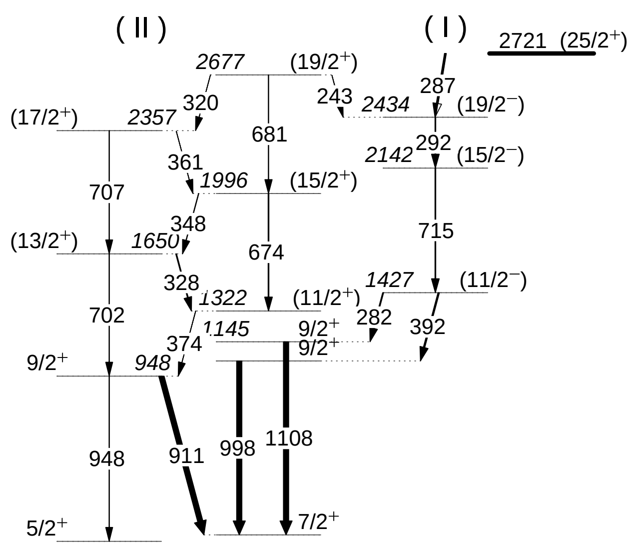

Fig. 2. Level scheme of ^{121}Sb obtained in the ^{10}B + ^{120}Sn reaction at 55 MeV beam energy. Two branches of the $25/2^+$ isomer decay are marked (I) and (II).

and 374 keV transitions was also observed in the off-beam spectrum (Fig. 4). In the both branches one can observe short-lived component (ascribed to investigated here isomer) as well as long-lived contribution due to a presence of some unresolved lines.

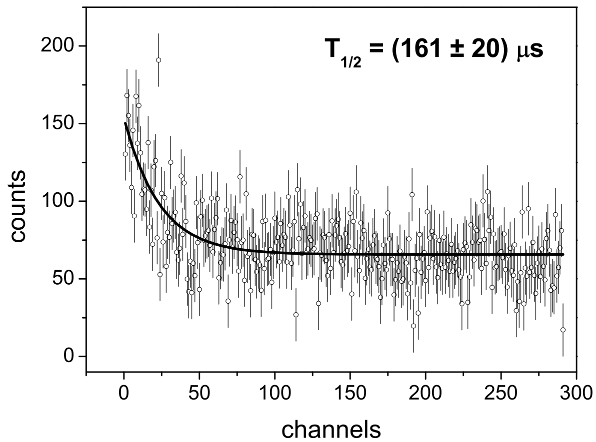

Fig. 3. Sum of the time spectra of 287, 292 and 715 keV γ-rays in the branch (I): $(25/2^+) \rightarrow (19/2^-) \rightarrow (15/2^-) \rightarrow (11/2^-) \rightarrow 9/2^+$.

The half-life observed in branch (I) ($T_{1/2} = 161 \pm 20\mu$s) (Fig. 3) is close to that observed in branch (II) ($T_{1/2} = 203 \pm 50\mu$s)(Fig. 4) suggesting the existence of one isomeric state with the half-life of to $167{\pm}19\mu$s, calculated as a weighted average of the values obtained for the two decay branches. It also suggests the presence of unobserved, highly converted low energy ~44 keV transition connecting the 2721 keV, $(25/2^+)$ state in branch (I) and 2677 keV, $(19/2^+)$ state in branch (II). The M3 multipolarity of this transition follows from the selection rules. However, the M3 multipolarity is in contradiction with the empirical rule for spin and parity assignment [4] which states that transition cannot be M3 if partial half-life $T_{1/2}(\gamma)$ for γ-emission is less than $0.1 \times T^{\rm sp}_{1/2}(M3)$, where $T^{\rm sp}_{1/2}(M3)$ stands for Weisskopf estimation for M3 transition. In our case $T_{1/2}(\gamma) = (1 + \alpha_{\rm tot}(M3)) \times T_{1/2}(\text{branch (I)}) \sim 0.7$ s is less than $0.1 \times T^{\rm sp}_{1/2}(\text{M3}) \sim 3.3 \times 10^4$ s. Therefore, one can rule out a M3 character of the 44 keV transition. Assumption that $\sim$ 44 keV is an E2 transition leads to the conclusion that 2721 keV state is $23/2^+$, which is however, in variance with the systematics of $25/2^+$ states in the odd-A light Sb isotopes (Fig. 5). Instead of 44 keV transition one can consider a cascade of two low energy γ-rays with the resultant energy of 44 keV. In such case this isomer would persist as a $(25/2^+)$.

Another possibility is the existence of two isomeric states showing similar half-lives. Evolution of the high-spin positive-parity states in odd-A $^{115-121}$Sb isotopes, and of 10^+ states of the corresponding $^{A-1}$Sn cores [2] is in agreement with the proposed $\pi(d_{5/2})\nu(h^2_{11/2})_{10^+}$ configuration for $25/2^+$ isomeris state. A further investigation of the isomeric states in the mass region $A \sim 120$ including ^{121}Sb nucleus will be continued.

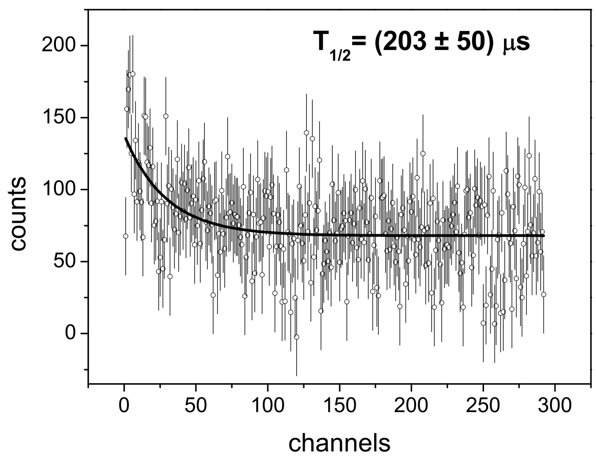

Fig. 4. Sum of the time spectra of 320, 361, 346, 328 and 374 keV γ-rays in the branch (II): $(25/2^+)\rightarrow(19/2^+)\rightarrow(17/2^+)\rightarrow(15/2^+)\rightarrow(13/2^+)\rightarrow(11/2^+)\rightarrow 9/2^+$.

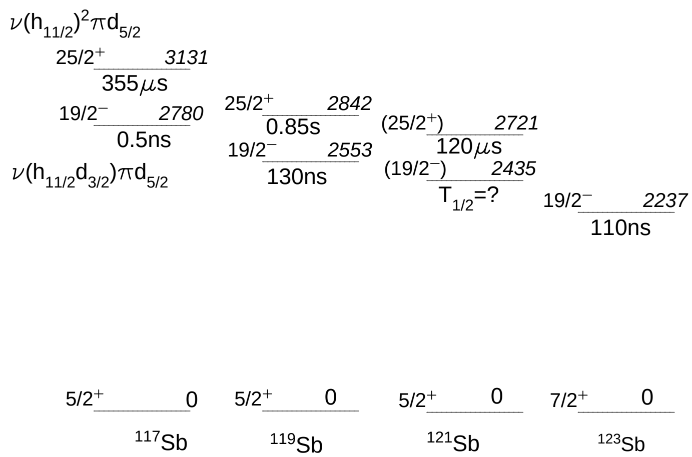

Fig. 5. Systematics of the $25/2^+$ and $19/2^-$ isomeric states in the odd-A light isotopes.

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