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Structure of doubly-even cadmium nuclei studied by β^- decay

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Abstract. We have studied the structure of even-even cadmium isotopes via beta decay of ground and excited isomeric states of parent silver isotopes. Measurements of mass $A = 116$, 118 and 120 cadmium nuclides were carried out at an ion guide isotope separation on-line facility at the University of Jyväskylä. Decay schemes of ^{116m}Ag, ^{118m}Ag, ^{120g}Ag and ^{120m}Ag are considerably extended. Obtained data have enabled extension of available systematics of the three-phonon states to more neutron-rich cadmium nuclei. As a continuation we have conducted an experiment at ISOLDE, CERN to study heavier $A = 122$, 124, and 126 cadmium nuclides, the analysis of the collected data is underway.

PACS. 27.60.+j $90 \leq A \leq 149$ – 23.20.Lv γ transitions and level energies – 21.10.Re Collective levels

1 Introduction

Main features of the cadmium nuclei, which span over a full neutron shell from $N = 50$ to $N = 82$, can be described in the framework of an anharmonic vibrator when the neutron number is few particles or holes away from the closed shells. In addition, around the mid neutron shell so called intruder states can be detected with low excitation energies. These two phenomena can be combined in IBA-1 calculation by performing separate calculation for both normal configuration and intruder configuration with two extra bosons from 2p-2h excitation across the proton shell gap and then finally coupling them by introducing a mixing Hamiltonian [1]. This approach has been used successfully for cadmium nuclei [2].

Microscopic approaches have also been used to describe cadmium nuclei. Because a full shell model calculation is not feasible to derive properties of the whole cadmium chain one must use some kind of truncation of the shell model. One such truncation is developed lately to describe low-lying two-phonon states and electromagnetic transitions from them [3]. This model has been used to derive properties of low-energy vibrational states in even $^{110-120}$Cd nuclei [4] and the work will be continued for the heavier cadmium isotopes. Same group has also calculated, within this same theoretical framework, beta-feeding properties to the low-energy excited states of the $^{116-130}$Cd [5]. However, omission of the intruder states is the drawback of this microscopic description.

Experimental data is used to test the above mentioned theoretical predictions. So far the experimental knowledge of the heaviest cadmium nuclei above $A = 124$ is limited to the half-life information and neutron emission probabilities which were obtained from the beta-delayed neutron emission experiments done at ISOLDE, CERN [6]. In addition the lowest yrast states are proposed up to ^{130}Cd based on γ singles data collected at ISOLDE [7]. Some of these first yrast states are also detected in a microsecond isomer decay experiment at LOHENGRIN, Grenoble [8]. As a complementary method to the decay studies, an experiment using Coulomb excitation has recently been done at REX-ISOLDE facility at CERN to obtain $B(E2)$ values for ground state to the first 2^+-state transition of ^{122,124}Cd [9].

2 Experimental techniques and results

Few years back we have launched a program to study the structure of neutron-rich cadmium isotopes via β decay of silver isotopes. The aim of this experimental program is to complete the cadmium level schemes up to medium spins that are reachable by this method, main emphasis being on studying the evolution of vibrator and intruder states as the neutron number increases.

Experiments were carried out using on-line isotope separator technique to produce beta decaying silver source.

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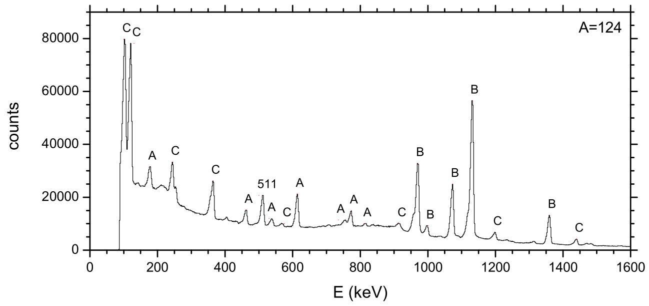

Fig. 1. Beta gated gamma spectrum taken with multichannel analyser from mass $A = 124$. Peaks from transitions following the decay of ^{124}Ag, ^{124}In and ^{124m}In are marked with A, B and C, respectively.

Silver itself was produced in induced fission of uranium target nuclei.

Lighter mass neutron-rich cadmium isotopes $A =$ 116, 118 and 120 were studied at the ion guide isotope separator on-line (IGISOL) facility of the University of Jyväskylä [10,11]. At IGISOL the symmetric fission of a natural uranium target was induced by 25 MeV protons with an intensity of 5 to 10 μA. Fission fragments were then thermalised as 1+ ions in helium gas and transported with gas flow out of the stopping chamber after which ions were guided through a differential pumping region by electric fields and finally accelerated to 40 keV energy. After mass separation the beam was implanted in to a movable collection tape inside a thin cylindrical plastic scintillator. Implantation point was viewed by four germanium detectors placed in close geometry. Data were collected in β-γ and γ-γ triggered event mode. Every event was also time stamped with a 1 ms resolution relative to the tape movement cycle.

Based on the collected data a considerable number of newly found states and transitions were assigned to decay schemes of ^{116m}Ag, ^{118m}Ag, ^{120g}Ag and ^{120m}Ag. For more details see refs. [12,13].

For the IGISOL facility ^{122}Ag is at the limit of feasible yield. Therefore, it was necessary to continue towards the heavier isotopes at ISOLDE, CERN, where thick target together with resonant ionisation laser ion source provide much higher silver yields. Detection set-up consisting of thin plastic scintillator and five large germanium detectors was used to get γ-γ coincidence data of the decays of ^{116,118,120}Ag. As the analysis of the collected data is not yet started we can show only a beta gated multichannel analyser spectrum of one of the germanium detectors from mass $A = 124$ as an example of the data (see fig. 1). Collection time of this spectrum was one fifth of the total time spent on mass $A = 124$.

3 Discussion and outlook

Experiments done at IGISOL on the β decay of silver isotopes have led to an observation of a large number of new levels in ^{116,118,120}Cd. Especially, newly found 1869.7 keV 4^+ level in ^{116}Cd and 2023.0 keV 2^+ level in ^{118}Cd enables suggestion of a complete set of quadrupole three-

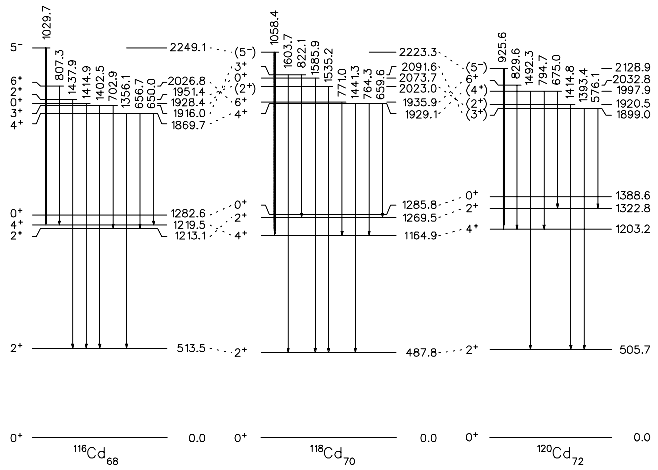

Fig. 2. Partial level schemes showing the vibrational states up to the three-phonon quintuplet in ^{116,118,120}Cd nuclei [13].

phonon quintuplet in both of these nuclei. For more details about new levels and reassignments see refs. [12,13]. Also in ^{120}Cd candidates for three-phonon states are suggested, see fig. 2. Study of the β decay properties has also shown that the decays of ^{116m}Ag and ^{118m}Ag are similar but the decay of ^{120m}Ag is different as the decay strength is spread over more levels in ^{120}Cd, which might indicate the onset of occupation of $h_{11/2}$ neutron orbital.

In order to test the predictions of different theoretical models, in addition of extending the level schemes, further measurements of $B(E2)$ values and angular correlations are needed. Therefore, for instance a level life-time measurement of these heavier cadmium isotopes with advanced time-delayed technique by Mach *et al.* [14] would have an interest from the theory point of view.

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