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Status Report and Addendum to the ISOLDE and Neutron Time-of-Flight Committee

IS524: Coulomb excitation of neutron-rich odd-A Cd isotopes

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Abstract

Aim of experiment IS524 is the “safe” Coulomb excitation of neutron-rich odd-A Cd isotopes. We propose to remeasure ^{123}Cd as first odd isotope. The experiment aims to determine the B(E2) values connecting excited states with the ground state as well as the long-lived $11/2^-$ isomer. The proposed study profits from the unique capability of ISOLDE to produce beams containing Cd in the ground state or in the isomeric state.

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Requested shifts: 18

1. Motivation, experimental setup/technique

For medium and heavy mass nuclei with A > 100, only the two regions around doubly magic nuclei are experimentally accessible: the stable ^{208}Pb and the radioactive ^{132}Sn. IS524, as continuation of the programme of IS411 aims, for the determination of B(E2) values and quadrupole moments in neutron-rich odd-A Cd isotopes.

Although near to the doubly magic ^{132}Sn, neutron-rich Cd isotopes exhibit a number of surprising features. Often considered as textbook examples for spherical vibrators, based on transition probabilities this interpretation has been recently doubted. Well known is also the anomalous behaviour of the excitation energies of the first 2^+ states which could be solved by beyond mean calculations and, very recently, also by the shell model (see discussion in [Bön14,Bön15]). These questions concerning the quadrupole collectivity can be addressed by transition strengths and quadrupole moments which are measured best by "safe" Coulomb excitation. Coulomb excitation studies of odd-A Cd isotopes may give a unique insight into the deformation-driving roles played by different orbits in this region.

We employ the "safe" Coulomb excitation in inverse kinematics. The γ-rays are detected by MINIBALL and both the scattered projectiles and the recoiling targets are detected by a DSSSD, the so called CD detector [War13]. If installed, the T-REX array in Coulex configuration can be used as well. In order to minimise the systematic errors, the analysis is preferably done relatively to the excitation of the target whose electromagnetic properties are well known. In odd isotopes, compared to even isotopes, more matrix elements enter the analysis. Additionally, the excitation path, via E2, can be different from the de-excitation, e.g. via M1. Applying techniques, like the maximum likelihood analysis, is more challenging.

Similar work has been done for the even isotopes ^{122,124,126}Cd (IS411) [Beh09, Thü12, Ili14] and ^{128}Cd (IS477) [Bön14, Bön15]. In the programme of IS524, ^{123}Cd was chosen for the first experiment because its level scheme and the assignment of γ-rays seemed to be known well [Huc89]. As described in the Section, this level scheme is not correct.

On top of the motivation described already in the original proposal, the interest in the odd Cd isotopes increased in last some years even more because of results from collinear laser spectroscopy and mass measurements. For the $11/2^-$ isomer, the linear increase of the electric quadrupole moments along the Cd chain, $^{107-129}$Cd, and the behaviour of the magnetic dipole moments are not understood so far [Yor13]. As laser spectroscopy can only explore diagonal matrix elements of long-lived states, the Coulomb excitation approach gives complementary information for short-lived states. Mass measurements of the ground state and the isomer revealed that the excitation energy of the isomer is not 316 keV [Huc89] but 144 keV [Kan13]. The latter confirms our finding that the level scheme needs a revision.

The measurement proposed here will considerably improve experimental knowledge on the Cd isotopes in this interesting region of the nuclear chart by adding observables which are otherwise difficult or not at all accessible. The findings will challenge modern nuclear theory, e.g. the shell model applying new realistic interactions recently developed to describe neutron-rich In and Cd isotopes, see e.g. [Tap14a,Tap14b,Bön15].

2. Status Report

The isotope ^{123}Cd has been investigated in one run for the 6 shifts which have been approved (see Fig. 1) [Har14]. Because of a vacuum leak in the primary target, as for IS477 again a Cd run unfortunately suffered from a damaged primary target, not the full proton beam intensity could be used and the target could not heated up to the optimal temperature. This resulted in a considerably smaller beam intensity than expected.

Already from the single yields discrepancies from expectations based on the published level and decay scheme became evident. The yield for γγ-coincidences was small (this was the idea of the experiment to have only few multiple excitations!). However, some new assignments could be found, e.g. the 412 keV (if identical with the 410 keV in [Huc89]), is not a ground state transition. Some new transitions not observed in coincidence with known transitions could not be placed in the level scheme, like some components of the multiplet around 640-680 keV. Some B(E2) and B(M1) as well as quadrupole moments could be extracted. For the ground state and the isomer, of course, the precise quadrupole moments from [Yor13] have been used in the analysis.

The aim to pin down the multipolarities of transitions from the angular distributions of the γ-rays could not be achieved at this level of statistics.

A short attempt was performed to change the g.s./isomer ratio in the beam by varying the frequency of the broad band laser. Small effects in the peak intensities, e.g. showing that the 376 keV transition is clearly an excitation on top of the isomer, could be observed giving hope that the narrow band laser will allow for a selective ionisation of the g.s. or the isomer enabling the excitation of states on top of these separately.

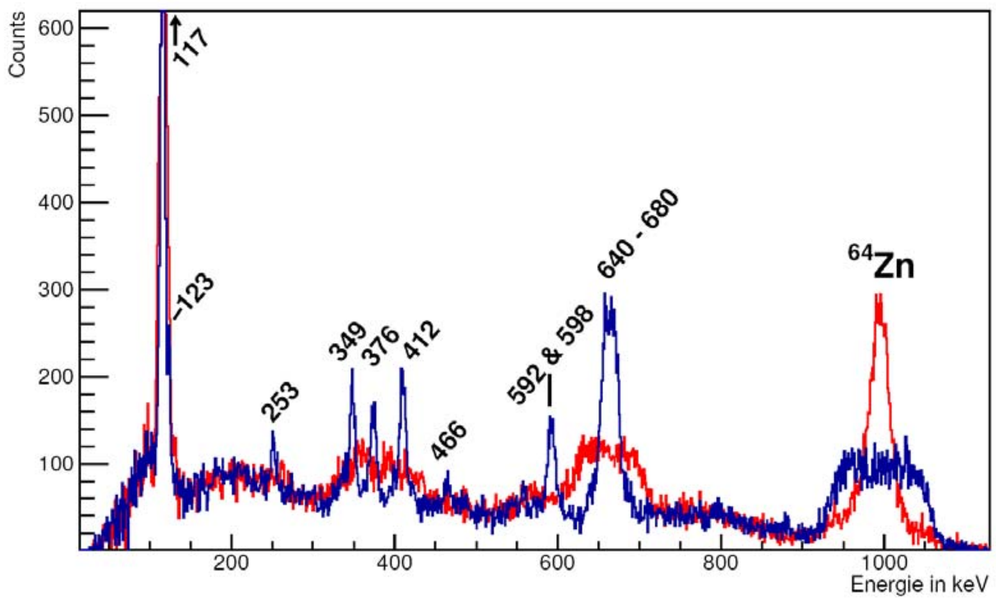

Fig. 1: Spectrum for ^{123}Cd on ^{64}Zn: Doppler correction with respect to the projectile (blue) and target (red) (Anna-Lena Hartig, TU Darmstadt)

Accepted isotopes: ^{123}Cd

Performed studies: Coulomb excitation of ^{123}Cd at around 3MeV/u

3. Addendum

Future plans with all requested shifts (including available shifts):

(i) Envisaged measurements, beam energy, and requested isotopes

In contrast to the assumption in the previous proposal, the published level scheme of ^{123}Cd is not correct. Therefore, the selective ionisation of either the ground state or the isomer (or at least two settings with clearly different g.s./isomer ratio) is important and a narrow band laser scan has to be performed first. The yield can be monitored by the different characteristic γ-rays from the β-decay of both states. This measurement could be performed also at the IDS.

Given the number of matrix elements entering the analysis, the actual experiment should be performed still at 3 MeV/u to restrict multiple Coulomb excitation to two steps maximum. Transitions not in coincidence with other γ-rays are then clearly direct transitions to the ground state or the isomer. We still aim to pin down the multipolarities of transitions from the angular distributions.

(ii) Have these studies been performed in the meantime by another group?

No, low-energy beams of neutron-rich Cd are available at ISOLDE only.

(iii) Number of shifts (based on newest yields and latest REX-EBIs and REX-trap efficiencies) required for each isotope

Applying the narrow band laser, the beam intensity will be lower compared to the previous estimate. Therefore, we ask for 8 shifts per laser setting (g.s. or isomer) to obtain for each statistics at least a factor of 10 better than shown in Fig. 1 plus 2 shifts for the narrow band laser scan. The required yield is estimated assuming conservatively an efficiency of 3% for HIE-ISOLDE like for REX-ISOLDE.

isotope	yield (/uC)	target – ion source	Shifts (8h)
123Cd	3E6	UCx - neutron converter - RILIS	18

Total shifts: 18

4. References:

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[Tap14b] J. Taprogge et al., Phys. Lett. B 728, 233 (2014)

5. Appendix

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[Thü12] M. Thürauf, Master thesis (TU Darmstadt, 2012)

[Ili14] S. Ilieva et al., Phys. Rev. C 89, 014313 (2014)

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[Bön15] S. Bönig et al., submitted to Phys, Rev. Lett.