Coulomb Excitation of Neutron-Rich Cd Isotopes at REX-ISOLDE

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Abstract. We report on the “safe” Coulomb excitation of neutron-rich Cd isotopes in the vicinity of the doubly magic nucleus ^{132}Sn. The radioactive nuclei have been produced by ISOLDE at CERN and postaccelerated by the REX-ISOLDE facility. The γ-decay of excited states has been detected by the MINIBALL array. Preliminary results for the $B(E2)$ values of ^{122,124}Cd are consistent with expectations from phenomenological systematics.

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MOTIVATION

Already more than forty years ago, Grodzins found that the product between the $B(E2;0^+_{\rm gs} \rightarrow 2^+_1)$ value and the excitation energy $E(2^+_1)$ of the first 2^+_1 state in even-even nuclei has a smooth behaviour near to the valley of stability.

A significantly improved description could be obtained by multiplying Raman's version of this formula [2] with a function linear in $(N-\bar{N})$ [3] where $\bar{N}$ denotes the neutron number for which the nuclear mass within an isobaric chain reaches its minimum:

$$E(2^+_1)[\mathrm{keV}] \cdot B(E2;0^+_{\rm gs} \rightarrow 2^+_1)[e^2\mathrm{b}^2] = 2.57\, Z^2\, A^{-2/3}\ \left(1.288 - 0.088(N-\bar{N})\right). \quad (1)$$

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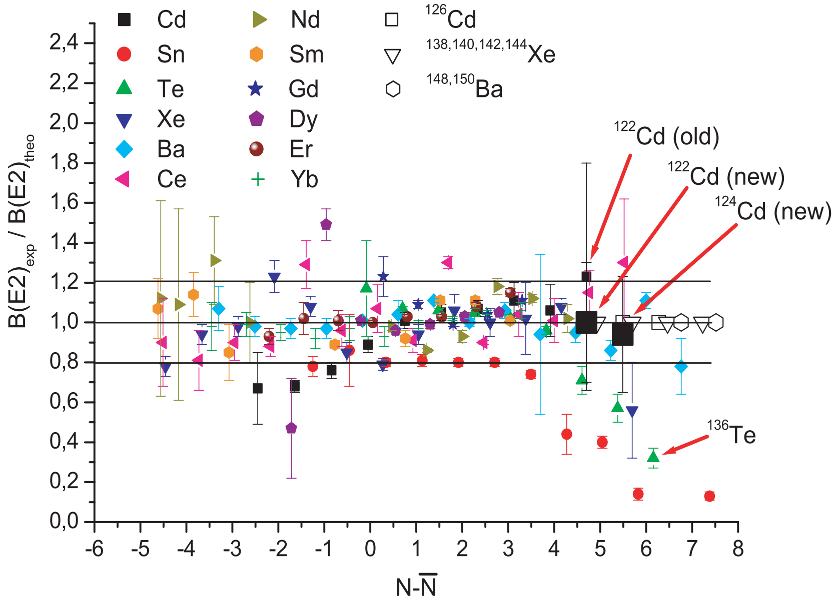

FIGURE 1. Experimental $B(E2)$ values [2] divided by values calculated with Eq. 1 (for ^{132}Sn this ratio is 3.2 and therefore outside of this diagram). Our preliminary data points for ^{122,124}Cd are shown as larger squares. Open symbols are nuclei to be measured next in our programme.

Fig. 1 shows that most of the experimental values agree with this simple fit within an error better than 20%.

However, recent experiments in the vicinity of ^{132}Sn have shown that for very neutron-rich nuclei far off the valley of stability the $B(E2)$ values are lower than the values expected from the extrapolation applying Eq. 1. In particular, this is the case for Te and Sn isotopes near $N = 82$ [4]. A new measurement indicates 30% larger $B(E2)$ values [5], however still lower than the expectation from systematics.

As theoretical explanation of this irregularity a reduced neutron pairing above $N = 82$ has been proposed [6]. Following this argumentation collectivity is build up mainly by neutrons resulting in low excitation energies accompanied by also low $B(E2)$ values, different to the naive understanding reflected in Grodzins' formula.

In the first campaign of our research programme performed at the REX-ISOLDE facility at CERN we extended such studies to neutron-rich Cd isotopes.

EXPERIMENTAL METHOD

The Cd nuclei have been produced by the ISOLDE facility at CERN utilising neutron induced fission in a UC_x target. The neutrons have been generated by the 1.4 GeV proton beam from the PS Booster impinging on a neutron converter target. The use of the neutron converter target reduced the proton-rich isobaric contaminants in the beam, in particular Cs isotopes. The Cd isotopes have been enriched further by selective

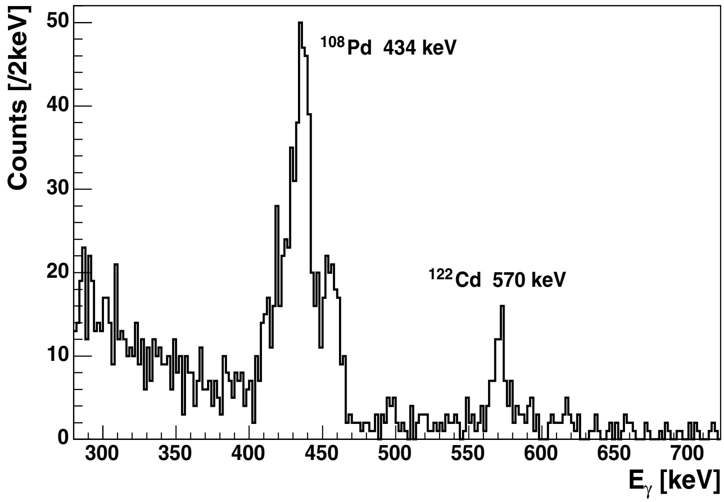

FIGURE 2. Part of the statistics obtained for ^{122}Cd. A preliminary Doppler correction has been applied (see text). The $2_1^+ \rightarrow 0_{gs}^+$ transition at 570 keV is clearly seen, as well as the wrongly Doppler corrected $2_1^+ \rightarrow 0_{gs}^+$ transition at 434 keV in ^{108}Pd.

ionisation with the Resonance Ionisation Laser Ion Source (RILIS). The energy of the Cd ions has been boosted from 60 keV to 2.86 MeV/u by the REX-ISOLDE postaccelerator [7]. Here, we benefited from the recent energy upgrade.

We employed γ-spectroscopy following "safe" Coulomb excitation of the radioactive beams impinging on Pd targets. The γ-rays deexciting the first 2^+ state were detected by the highly efficient MINIBALL spectrometer consisting of 8 triple clusters of six-fold segmented HPGe detectors [8]. The reaction kinematics was determined by detecting the scattered particles in a double-sided segmented Si detector (DSSSD) [9].

The isobaric contaminations of the beam have been determined by three methods: (a) γ-decays of the beam particles implanted into the beam dump; (b) switching the laser of the RILIS periodically on and off; and (c) measuring the beam composition with a $\Delta E - E$ telescope consisting of an ionisation chamber and a Si detector. In order to use the latter, the beam had to be switched to a different beamline.

PRELIMINARY RESULTS

The analysis of the data is in progress and we will present here only preliminary results.

The nucleus ^{122}Cd has been measured for about 9 hours with laser on. The total beam intensity was about 10^4 particles/s with a beam purity of approximately 70 %. Fig. 2 shows part of the statistics. The Doppler correction has been performed with respect to segments of the crystals of MINIBALL. The background seen below 350 keV originates from the 9-gap resonator newly introduced in REX for the energy upgrade.

For ^{124}Cd the measuring time was about 22 hours (laser on). The total beam intensity was about $1.7 \cdot 10^4$ particles/s with a purity of approximately 38 %.

From the cross sections, extracted from the respective γ-yields, the $B(E2)$ values of Cd have been determined relative to the well known $B(E2)$ values of the Pd isotopes. The preliminary results are 0.37 ± 0.11 e^2b^2 and 0.29 ± 0.09 e^2b^2 for ^{122}Cd and ^{124}Cd respectively. The precision of the $B(E2)$ value for ^{122}Cd already has been improved considerably compared to the 50% error of the previous measurement [10]. For the heavier isotope ^{124}Cd, a $B(E2)$ value has been determined for the first time. Both values are within the expectation from Eq. 1 as it can be seen in Fig. 1.

OUTLOOK

The production yields of the even isotopes $^{120-128}$Cd with the converter target and the RILIS have been measured in this campaign. The determination of the $B(E2)$ value of ^{126}Cd is feasible, which has been proven in a short test also experimentally. For heavier isotopes the yields are too low and such measurements are currently out of reach.

We will extend our studies towards more collective nuclei, in particular neutron-rich Xe and Ba isotopes, which are like Cd beams unique to ISOLDE. In a first test, already the "safe" Coulomb excitation of a ^{138}Xe beam has been demonstrated successfully. Finally, it is worth to be mentioned that also the measurement of the g-factor of the first 2^+ state in the even $^{132-136}$Te isotopes is on the way [11]. This can prove if the low $B(E2)$ value of ^{136}Te is indeed due to a large neutron contribution in its wave function.

Such investigations will shed further light on the irregular behaviour of $B(E2)$ values in this region and allow deeper insights into the isospin dependence of neutron pairing as well as the underlying physics of the phenomenological systematics.

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REFERENCES

1. L. Grodzins, Phys. Lett. 2, 88 (1962).
2. S. Raman et al., Atomic Data and Nuclear Data Tables 78, 1 (2001).
3. D. Habs, R. Krücken et al., CERN Proposal INTC-P-156 (2002).
4. D. C. Radford et al., Phys. Rev. Lett. 88, 222501 (2002); proceedings of INPC 2004 and ENAM'04.
5. C. Baktash et al., MAFF Workshop (2005).
6. J. Terasaki et al., Phys. Rev. C 66, 054313 (2002).
7. O. Kester et al., Nucl. Instr. and Meth. B 204, 20 (2003).
8. J. Eberth et al., Prog. Part. Nucl. Phys. 46, 389 (2001).
9. A. Ostrowski et al., Nucl. Instr. and Meth. A 480, 448 (2002).
10. N. V. Zamfir et al., Phys. Rev. C 51, 98 (1995).
11. K.-H. Speidel et al., CERN Proposal INTC-P-166 (2003).