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COULOMB EXCITATION OF ^{142}Xe*

C. Henrich[a], Th. Kröll[a], K. Arnswald[b], C. Berger[c]
C. Berner[c], T. Berry[d], V. Bildstein[e], J. Cederkäll[f], D. Cox[g]
G. de Angelis[h], H. De Witte[i], G. Fernández Martínez[a]
L. Gaffney[j], G. Georgiev[k], S. Ilieva[a], A. Illana Sisón[i]
R. Lozeva[l], M. Matejska-Minda[m], P.J. Napiorkowski[m]
J. Ojala[g], J. Pakarinen[g], G. Rainovski[n], M. Ramdhane[o]
P. Reiter[b], H.-B. Rhee[a], D. Rosiak[b], M. Seidlitz[b], B. Siebeck[b]
G. Simpson[o], J. Snäll[f], V. Vaquero Soto[p], M. Thürauf[a]
M. von Schmid[a], N. Warr[b], L. Werner[c], M. Zielińska[k]

[a]TU Darmstadt, Germany
[b]University of Cologne, Germany
[c]TU München, Germany
[d]University of Surrey, United Kingdom
[e]University of Guelph, Canada
[f]Lund University, Sweden
[g]University of Jyväskylä, Finland
[h]INFN-LNL, Italy
[i]KU Leuven, Belgium
[j]CERN-ISOLDE, Switzerland
[k]CEA Saclay, France
[l]CSNSM Orsay, France
[m]University of Warsaw, HIL Warszawa, Poland
[n]SU Sofia, Bulgaria
[o]LPSC Grenoble, France
[p]CSIC Madrid, Spain

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The even–even nucleus ^{142}Xe lies north-east of the doubly magic ^{132}Sn on the neutron-rich side of the nuclear chart. In order to gain further information on the octupole collectivity and the evolution of quadrupole collectivity in this region, a "safe" Coulomb excitation experiment was carried out at the new HIE-ISOLDE facility (CERN) at the end of 2016. As the gamma-ray detector the Miniball spectrometer was used. Beam and target nuclei were detected using C-REX, *i.e.* an array of segmented Si detectors, covering forward as well as backward angles in the laboratory frame.

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1. Introduction

The neutron-rich nucleus ^{142}Xe lies north-east of the doubly-magic ^{132}Sn, in a region through which the r process is expected to pass. Experimentally, this area is quite interesting as both single-particle and mean-field approaches can be applied by theory. The nucleus ^{142}Xe has only two protons less than ^{144}Ba, which exhibits the largest octupole collectivity in the region [1].

In order to investigate the collectivity of ^{142}Xe further, Coulomb excitation is a perfect tool as it gives access to the $B(\mathrm{E2})$ strengths. Besides, the spectroscopic quadrupole and octupole moments and $B(\mathrm{E3})$ values are accessible via this method.

In an earlier campaign at REX-ISOLDE, ^{142}Xe and lighter even–even Xe isotopes were investigated at an energy of 2.7 MeV per nucleon (IS411) [2, 3]. Back then only the first 2^+ and 4^+ states were observed. The transitions de-exciting the latter had very low statistics resulting in large uncertainties. Only with the availability of the new HIE-ISOLDE facility, sufficient beam energies can be reached so that the probability for multi-step processes is largely increased. This is crucial for populating high-lying states such as the first 6^+ state and those with higher spins. Also, and more importantly for this case, a higher energy makes single-step excitations to the first 3^- state possible.

2. Experiment

The Coulomb excitation measurement took place at HIE-ISOLDE in 2016. It was a successful experiment with a total beam time of about 70 hours.

The ^{142}Xe nuclei were produced using the ISOL technique and were accelerated to 4.5 MeV per nucleon by the HIE-ISOLDE post-accelerator [4]. Afterwards, they were delivered to the Miniball experimental area. A 4 mg/cm^2 thick ^{206}Pb target was mounted inside the target chamber together with C-REX, a particle detector consisting of segmented silicon detectors, which detected both scattered beam and recoiling target nuclei. The silicon detector array consisted of 2 Double Sided Silicon Strip Detectors (DSSSD) and 4 barrel silicon detectors. The DSSSDs covered a θ laboratory range of 22° to 62° and 153° to 172°, respectively. They are composed of 4 quadrants, each being segmented 16-fold in θ and 12-fold in ϕ. The barrel detectors are strip detectors with 16 resistive strips and cover 102° to 153° in θ in the laboratory frame. For more details, see the description of T-REX in Ref. [5]. (C-REX is an adaptation of T-REX, modified to meet the requirements of the Coulomb excitation experiments.) The gamma rays were detected by the 24 six-fold segmented high purity germanium crystals of the Miniball array [6].

3. Analysis

The detected gamma rays have to be Doppler-corrected using the spatial information provided by both gamma-ray and particle detectors. This is crucial as the gamma rays are emitted in flight and their energy is shifted due to the Doppler effect.

Figure 1 shows the preliminary gamma-ray spectrum in comparison to that obtained at REX-ISOLDE in 2005. They are both Doppler-corrected with respect to xenon. Besides the fact that a factor of 20 and 40 higher statistics has been obtained for the first 2^+ and 4^+ state, respectively, also the positive partity states of the yrast band up to the 8^+ state are visible. This clearly proves the aforementioned advantage of the beam energies available at the new HIE-ISOLDE facility.

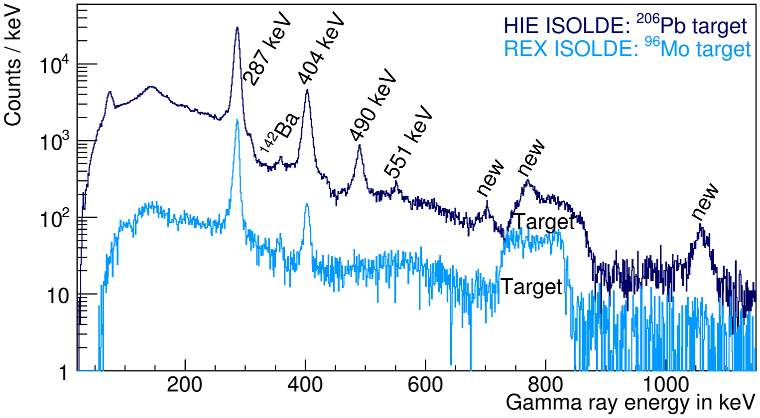

Fig. 1. Preliminary Doppler-corrected gamma-ray spectrum measured at HIE-ISOLDE in comparison to the spectrum obtained at REX-ISOLDE. Both spectra are Doppler-corrected with respect to xenon. Note the transitions observed in the more recent measurement that have not been visible at REX-ISOLDE.

Note that two different target materials were used in the two experiments, ^{96}Mo at REX-ISOLDE and ^{206}Pb at HIE-ISOLDE, therefore, their lowest transitions appear at different positions. These energies are wrongly corrected, as the Doppler correction is performed with respect to the scattered projectile.

As the only contaminant ^{142}Ba is visible. This is due to two main reasons. Firstly, as xenon is a noble gas, it is easily extracted from the Cold Plasma Ion Source at ISOLDE's primary target and all other contaminants are suppressed. Secondly, ^{142}Xe has a short lifetime of only 1.23 s. Its daughter nucleus is the odd–odd nucleus ^{142}Cs with a lifetime of 1.68 s. In this odd–odd isotope, the B(E2) strength is spread over many transitions rather than being concentrated in the $0^+ \rightarrow 2^+$ transition like in the even–even isobars. ^{142}Cs decays to ^{142}Ba, whose transition from the first 2^+ state to the ground state is indicated in Fig. 1. The number of counts in this peak can be estimated using the Bateman equations in order to estimate the beam composition, and then normalizing the yield to that for the transition from the first 2^+ to the ground state of ^{142}Xe. The calculated 1300 counts reproduce the shown peak nicely.

There is no transition at 971 keV visible. At this energy, based on prompt fission fragment spectroscopy following the spontaneous fission of ^{248}Cm [7], a candidate transition was proposed to be the decay of the first 3^- state to the first 2^+ state. However, the respective coincidences have not been observed following neutron-induced fission of ^{235}U [8] nor in the spontaneous fission of ^{252}Cf [9]. It should be noted though that there are three peaks visible, which have not been observed before, and they lie in the same energy range where the missing $3^- \rightarrow 2^+$ transition is expected.

Estimating the expected number of counts using the aforementioned published $B(\mathrm{E3}; 0^+ \rightarrow 3^-)$ value in ^{144}Ba [1] yields (4000 ± 1700) counts in the $3^- \rightarrow 2^+$ transition. The uncertainty was estimated by taking the uncertainty of the $B(\mathrm{E3}; 0^+ \rightarrow 3^-)$ value in ^{144}Ba into account. This corresponds roughly to the measured number of counts in the peaks in Fig. 1 that have not been observed previously.

Moreover, given the fact that a candidate for a gamma band in ^{140}Xe was found [10], it would not be too surprising to find a second 2^+ state in the given energy range, especially as 2^+ states are readily populated by Coulomb excitation.

Figure 2 shows the spectrum of only those gamma rays which were detected in coincidence with the backwards facing DSSSD. The transitions in the yrast band up to the first 8^+ state are well visible. The background is very low. As the multi-step excitation probability is highest under scattering angles close to 180°, population of higher-lying states is more likely. Unsurprisingly, the ratio of the $8_1^+ \rightarrow 6_1^+$ and $2_1^+ \rightarrow 0_{\mathrm{gs}}^+$ transition intensities is 27 times higher in coincidence with the backwards-facing DSSSD than with the forwards-facing one. This spectrum shows the advantage of the better angular coverage of C-REX as opposed to merely placing a particle detector under forward angles.

The analysis is ongoing with the aim to determine the nature of the unknown and known states corresponding to the observed transitions. Gamma–gamma coincidences will be particularly useful for the analysis of the unknown transitions. Further information will be gained by a least-squares search using the GOSIA code [11]. We aim to determine the reduced transition probabilities and the spectroscopic quadrupole moments utilizing this method.

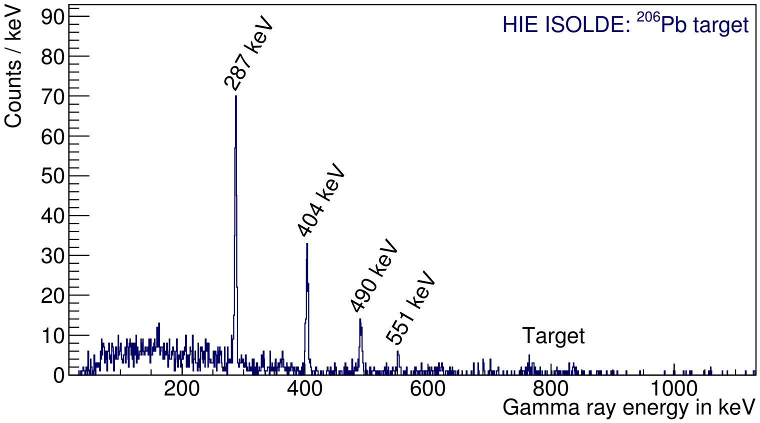

Fig. 2. Preliminary full statistics gamma-ray spectrum in coincidence with the backwards-facing DSSSD. The spectrum is Doppler corrected with respect to xenon.

Additionally, with the large statistics, it may be possible to determine the g-factors of the lowest lying states using the recoil-in-vacuum technique.

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REFERENCES

[1] B. Bucher *et al.*, *Phys. Rev. Lett.* **116**, 112503 (2016).
[2] Th. Behrens, Ph.D. Thesis, TU München, 2009.
[3] C. Henrich, Master Thesis, TU Darmstadt, 2014.
[4] Y. Kadi *et al.*, *J. Phys. G: Nucl. Part. Phys.* **44**, 084003 (2017).
[5] V. Bildstein, *Eur. Phys. J. A* **48**, 85 (2012).
[6] N. Warr *et al.*, *Eur. Phys. J. A* **49**, 40 (2013).
[7] W. Urban *et al.*, *Eur. Phys. J. A* **16**, 303 (2003).
[8] S. Ilieva *et al.*, *Phys. Rev. C* **94**, 034302 (2016).
[9] G. Fernández Martínez, Ph.D. Thesis in preparation, TU Darmstadt, 2018.
[10] W. Urban *et al.*, *Phys. Rev. C* **93**, 034326 (2016).
[11] T. Czosnyka *et al.*, *Bull. Am. Phys. Soc.* **28**, 745 (1983).