QUADRUPOLE MOMENTS FOR ISOMERIC STATES WITH NORMAL AND INTRUDER CONFIGURATIONS IN NEUTRON-DEFICIENT Pb NUCLEI*

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The quadrupole interaction of the 11^- and 12^+ isomers in ^{192,194}Pb nuclei has been investigated in the electric field gradient of metallic Bi polycrystalline lattice by the method of time-differential observation of the γ-rays perturbed angular distribution. The electric field gradient strength of the host Bi lattice has been calibrated by using as probe the 12^+ isomer in ^{194}Pb. The intrinsic quadrupole moments derived for the 11^- isomers described by the $\pi(1h_{9/2}1i_{13/2})$ intruder configuration are compared with the predictions of mean-field and interacting boson models.

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1. Introduction

The neutron-deficient Pb nuclei offer one of the best illustrations of the phenomenon of shape coexistence. Spherical states associated with the $Z = 82$ shell closure are coexisting at low excitation energies with deformed states involving particle–hole [np–nh] proton excitations across the closed shell. High-spin isomers involving a broken pair two-proton configurations are of particular interest since the measurement of their static moments can

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provide direct information on the underlying structure and deformation. In the even-mass $^{188-196}$Pb isotopes isomeric states with $I^\pi = 11^-$ described by the $\pi(1h_{9/2}1i_{13/2})$ two-proton intruder configuration are coexisting with $I^\pi = 12^+$ isomers involving a $\nu(1i_{13/2})^2$ quasineutron configuration. Static quadrupole moments of the intruder isomers in ^{194,196}Pb were reported in [1–3].

An experimental program devoted to precise static moment measurements in light Pb nuclei has been recently undertaken at the XTU-Tandem of Laboratori Nazionali di Legnaro. Spectroscopic quadrupole moments for three short-lived isomeric states in ^{193}Pb, one of them being the band-head of a magnetic rotational band involving the coupling of the 11^- two-proton intruder excitation with a $(1i_{13/2})$ quasineutron, have been reported in [4,5]. In this contribution we present results of new investigations, dedicated to the isomeric states in ^{192,194}Pb.

2. Experimental procedure and results

The isomeric states were populated and aligned in the ^{168}Er(^{28}Si,4n)^{192}Pb and ^{170}Er(^{29}Si,5n)^{194}Pb reactions using pulsed beams (pulse width of 2 ns, repetition periods of 1.6 or 3.2 μs). The spectroscopic quadrupole moments have been investigated by applying the time-differential γ-ray perturbed angular distribution (TDPAD) method. The excited nuclei were subject to the quadrupole interaction with the electric field gradient of the polycrystalline lattice of metallic Bi in which they were implanted in beam. The γ-rays were detected by planar and 20% efficiency HPGe detectors. Sample delayed spectra registered in-between the beam pulses with planar Ge detectors are illustrated in Fig. 1. Time spectra and TDPAD modulation spectra for the

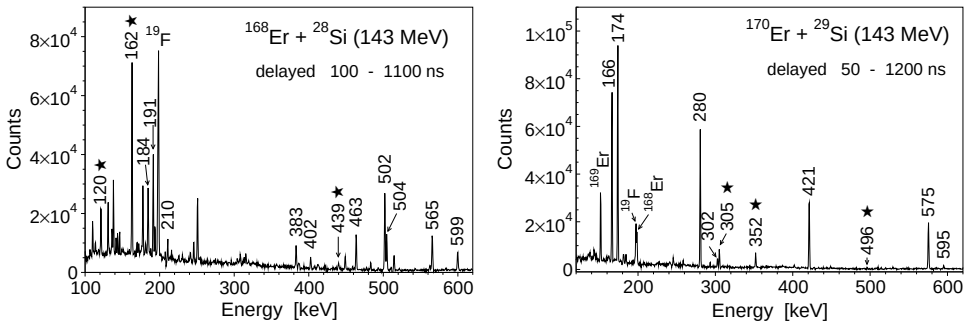

Fig. 1. Delayed energy spectra corrected for the background due to long-lived activities, for ^{192}Pb (left) and ^{194}Pb (right), registered with planar Ge detectors. The γ-rays belonging to the decay of the isomers in Pb are labelled by energy. The γ-rays de-exciting the 11^- isomers are marked by a star.

11^- isomers are shown in Fig. 2. The deduced values for the quadrupole coupling constant $\nu_{\rm Q} = Q_{\rm s}V_{zz}/h$ were 96(6) and 10.6(11) MHz for the 11^- and 12^+ states in ^{192}Pb, and 120(8) and 16.2(6) MHz for the corresponding states in ^{194}Pb. Precise absolute values for spectroscopic quadrupole moments $Q_{\rm s}$ were obtained from the measured $\nu_{\rm Q}$ based on a reliable calibration of the electric field gradient for Pb in the Bi crystalline lattice, $V_{zz}({\rm PbBi}) = 1.39(10) \times 10^{21}\,{\rm V/m^2}$, derived in the present experiment by using as probe the 12^+ state in ^{194}Pb with known quadrupole moment [4].

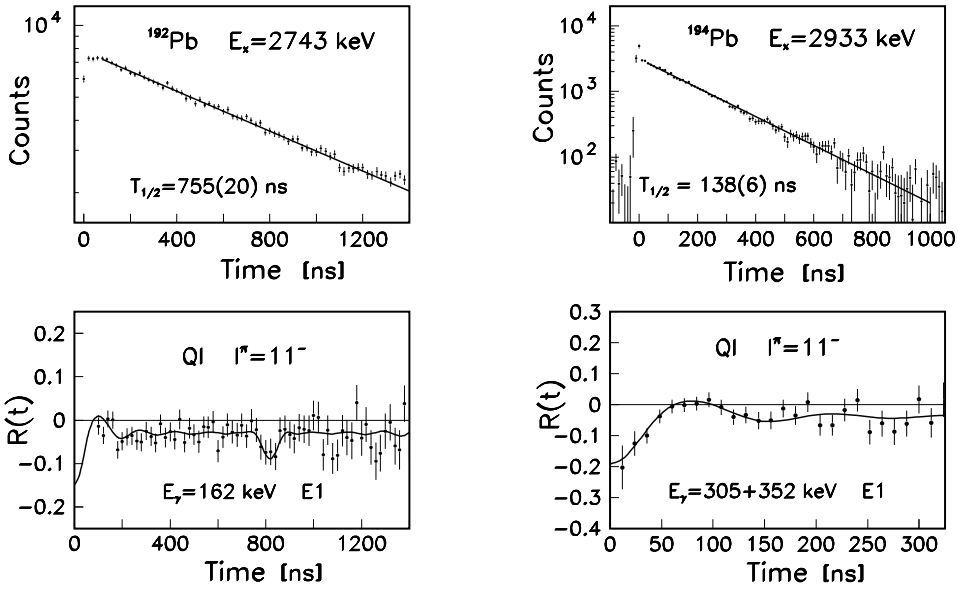

Fig. 2. Background-subtracted time spectra and TDPAD spectra showing the quadrupole interaction (QI) of the 11^- isomeric states in ^{192}Pb and ^{194}Pb in the polycrystalline lattice of metallic Bi.

3. Discussion

The absolute values of spectroscopic quadrupole moments of isomeric states in $^{192-196}$Pb, including the values determined in the present study, are collected in Table I. The 12^+ states with the $\nu(1i_{13/2})^2$ quasineutron configuration have rather small quadrupole moments, which are decreasing with the decrease of the neutron number. This behaviour is due to the change in the occupation number of the neutron $1i_{13/2}$ orbital, and was nicely reproduced with the pairing plus quadrupole model, as discussed in [4]. The larger quadrupole moments assigned to the 11^- states indicate an increased collectivity. Assuming for these states an axially symmetric configuration

with $K = 11$ the intrinsic quadrupole moments Q_o were derived as shown in Table I. The properties of the oblate states in neutron-deficient Pb have been investigated within various mean-field approaches [7–9] and the interacting boson model [10]. The Q_o values calculated for the 11^- isomers in a HFB self-consistent approach [7] are given in the table for a comparison with the experimental values. In the last column are shown Q_o values for the [$2p$–$2h$] oblate band, calculated in the frame of IBM [10]. They were obtained in the assumption of a pure $K = 0$ band, and therefore, are the lower limits for the absolute values of intrinsic quadrupole moments.

TABLE I

Quadrupole moments for coexisting isomeric states in ^{192,194,196}Pb.

Nucleus	E_x (keV)	I^π	$\lvert Q_s\rvert(e\text{b})$	$\lvert Q_o\rvert(e\text{b})$	$Q_o^{\text{HFB}}(e\text{b})$	$Q_o^{\text{IBM}}(e\text{b})$
^{192}Pb	2623	12^+	0.32(4)[a]			
	2743	11^-	2.9(3)[a]	3.8(4)	−5.47	−2.85
^{194}Pb	2628	12^+	0.48(3)[b]			
	2933	11^-	3.6(4)[a]	4.7(5)	−5.36	−2.48
^{196}Pb	2694	12^+	0.65(5)[c]			
	3192	11^-	3.6(6)[d]	4.7(8)	−5.10	−2.38

[a]From present study.
[b]From Ref. [4], used in the present study for the V_{zz}(PbBi) calibration.
[c]From Ref. [6].
[d]From Refs. [1, 3].

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