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Short note

First observation of excited states in the neutron-rich nucleus ^{138}Te

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Abstract. The very neutron-rich nucleus ^{138}Te produced in the spontaneous fission of ^{248}Cm has been investigated using the EUROGAM II γ-ray multidetector array. The excited states of ^{138}Te observed for the first time indicate that the region of ground state deformation beyond the doubly magic nucleus ^{132}Sn has yet not been reached.

PACS. 23.20.Lv Gamma transitions and level energies – 25.85.Ca Spontaneous fission – 27.60.+j 90≤A≤149

Shape evolutions in nuclei with mass numbers near 132 are strongly influenced by shell closures. An indication of the stable, axially-symmetric, spheroidal deformation in nuclei is given by the ratio of the excitation energies of the first 4^+ and 2^+ levels and it amounts to 3.33 for good rotational nuclei. On the neutron-rich side of the doubly magic nucleus ^{132}Sn, the locus of the transition from single-particle to collective behaviour is unknown. For example, the four-valence particle nucleus ^{136}Te displays a level scheme typical of single-particle behaviour. In order to search for the expected transition, the present work investigates the very neutron-rich nucleus ^{138}Te.

The ^{138}Te nuclei were obtained as secondary fragments in the spontaneous fission of ^{248}Cm. The source consisted of about 5 mg of ^{248}Cm, in the form of oxide, embedded uniformly in a pellet of potassium chloride. The radioactive source was placed in the centre of the EUROGAM II array [1], which consisted in this experiment of 52 escape-suppressed Ge detectors including 24 four-crystal CLOVER detectors and which was augmented by the addition of 4 low-energy photon spectrometers. A total of approximately 2.5×10^9 threefold or higher coincidence events was collected within a period of 11 days.

The level scheme of ^{138}Te was constructed by examining double gated monodimensional γ spectra. Information on the multipolarities of γ rays could not be obtained due to the fact that the yield of ^{138}Te in the spontaneous fission of ^{248}Cm is too weak. Since no γ lines in ^{138}Te were known prior to the present work, the γ lines were identified through the coincidence relationship with the complementary Ru fission fragments. The result of applying this identification technique, which is described in detail in previous publications [2,3], is shown in Fig. 1.

The partial level scheme of ^{138}Te obtained in this work is shown in Fig. 2. The ordering of the levels is based

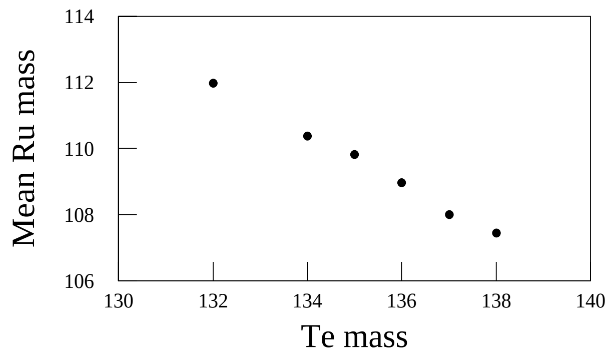

Fig. 1. Plot of the mean mass of Ru fragments which accompagny specified Te fragments. The smooth trend in the data points is the basis for the assignment of new γ-rays lines to ^{138}Te

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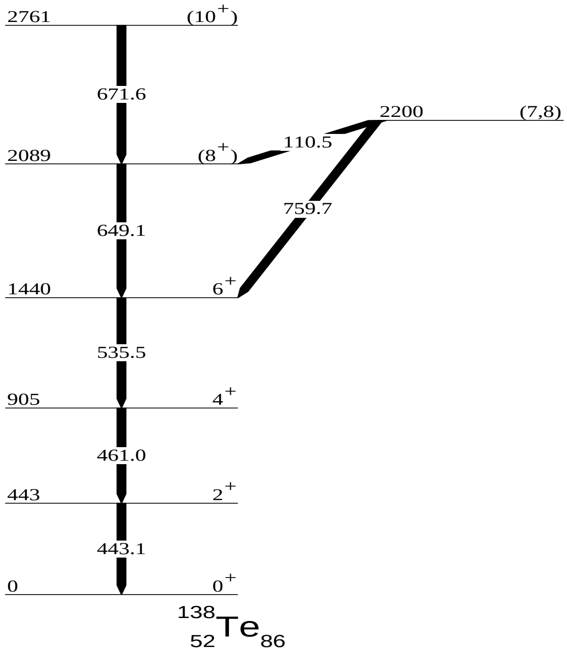

Fig. 2. Level scheme of ^{138}Te obtained in the present work. Level and γ-ray energies are given in keV

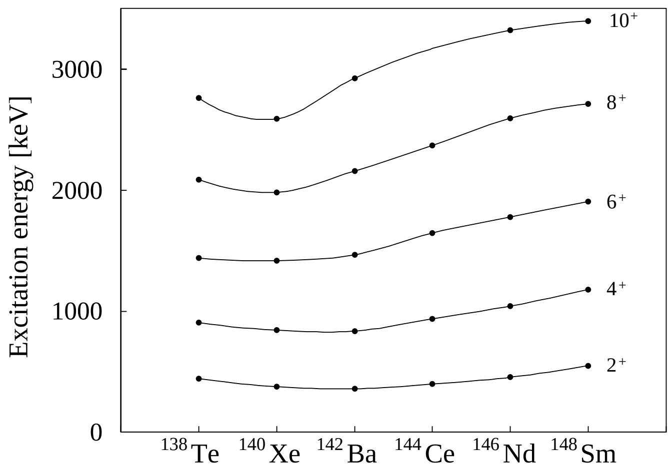

Fig. 3. Systematics of levels for the ground state bands of N = 86 isotones. Data are taken from this work and [3–7]

on relative intensities of γ rays. Spin assignments of 2^+, 4^+ and 6^+ to the three first excited states are based on the systematics of the ground-state bands in neighbouring N=86 isotones as can be seen in Fig. 3.

The ratio of the excitation energies of the first 4^+ and 2^+ levels, $E(4^+)/E(2^+) = 2.04$, indicates that ^{138}Te is not a strongly deformed nucleus. A more precise analysis, namely the description of states in closed and near-closed shell nuclei, uses the plots of $E(I^+)/E(2^+)$ versus $E(4^+)/E(2^+)$, called also Mallmann's plots [8]. The values for $E(6^+)/E(2^+)$ and $E(8^+)/E(2^+)$, 3.26 and 4.71, respectively, are in agreement with the α root of [8] and point to a vibrational description of the ^{138}Te nucleus.

Concurrently, Hartree-Fock plus BCS calculations [9] based on the new SLy4 Skyrme interaction [10] and a density dependent δ pairing [11] indicate that the ^{138}Te nucleus lies just at the transition between a spherical ^{136}Te and a prolate ^{140}Te. Moreover, as seen in Fig. 4, ^{138}Te exhibits a very β soft prolate minimum consistent with the present experimental data.

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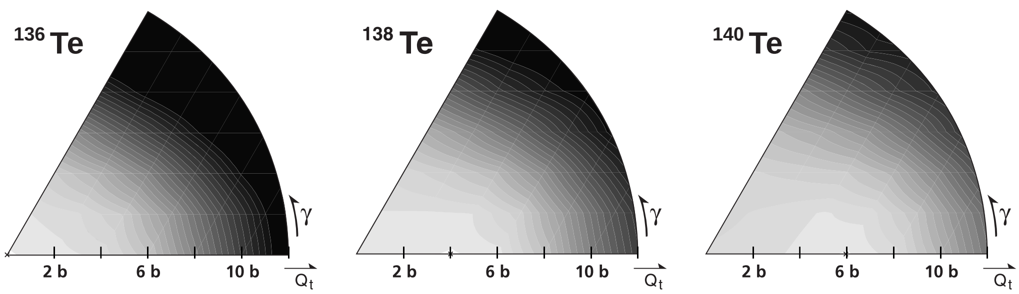

Fig. 4. Potential energy surfaces in the (Q_t,γ)-plane for ^{136,138,140}Te calculated via Hartree-Fock plus BCS code. The distance between contour lines is 500 keV. The minima are indicated by asterisks