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Short Note

High-spin structures observed in the ^{101}Tc fission fragment

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Abstract. High-spin states have been studied in ^{101}Tc produced as a fission fragment in the reaction ^{176}Yb + ^{28}Si at 145 MeV. Gamma rays were detected with the EUROGAM2 array. The level scheme of ^{101}Tc has been extended up to 4.2 MeV excitation energy and several band structures are observed. Configurations are assigned to two new bands on the basis of their behaviour and of cranked Hartree-Fock-Bogolyubov calculations.

PACS. 23.20.Lv Gamma transitions and level energies – 25.85.w Fission reactions – 27.60.+j 90 ≤ A ≤ 149

The neutron-rich transitional nuclei in the A ≃ 100 mass region display complex structures which are amenable to neither shell-model calculations nor to geometrical model approaches. Near N = 58, the even-even nuclei exhibit a γ-softness in the ground-state band and recent macroscopic-microscopic calculations [1] predict that bands with various configurations occupy different regions on the (β_2, γ) plane. The present note reports on high-spin states in the odd-Z $^{101}_{43}$Tc$_{58}$ nucleus which had been already investigated up to I = 21/2 via the ^{100}Mo(^{7}Li,α2n) and ^{100}Mo(^{3}He,pn) reactions [2,3]. Higher spins were reached in the present study where ^{101}Tc was obtained as a fission fragment in the ^{176}Yb+^{28}Si reaction. The ^{28}Si beam, at a bombarding energy of 145 MeV, was provided by the Vivitron accelerator in Strasbourg. The target consisted of a 1.5 mg/cm^2 layer of ^{176}Yb deposited on a 15 mg/cm^2 Au backing which was used to stop the recoiling fragments. Gamma rays were recorded with the EUROGAM2 array [4] which consisted of 52 escape-suppressed spectrometers using 126 Ge detector elements. The acquisition system was triggered only when at least five unsuppressed Ge elements fired in prompt coincidence. A total of 54×10^7 Compton-suppressed coincidence events were written on magnetic tapes. The level scheme of ^{101}Tc was constructed by examining double-gated monodimensional γ spectra extracted from three-dimensional matrices E_{γ_1}-E_{γ_2}-E_{γ_3}. Gates were set on transitions in ^{101}Tc or in an isotope of niobium, the fission partner of technetium.

The low-energy portion of the level scheme (see Fig. 1) agrees with the one published by Savage et al. [3], which differs from the level structure obtained using the ^{100}Mo(^{7}Li,α2n) reaction [2] by the relative order of the 329 and 552 keV γ transitions. An assumed (19/2$^+$) state is proposed by Dejbakhsh et al. [2] at 2401 keV excitation energy; however no transition of 1001 keV connecting the 17/2$^+$ level has been observed in the present work. Another transition, namely the one of 771 keV energy, has been seen in coincidence with the 642 keV and 757 keV transitions and it may be issued from a 19/2$^+$ level. Transition multipolarities could not be determined since the recoil direction of the fission fragments is not detected. Nevertheless tentative spin assignments (values in parenthesis) have been made on the basis of (i) the spins of the lower members of a band (ii) the increase of spin values with excitation energies, since fusion-fission reactions populate yrast and yrare states [5] (iii) the systematics of lighter odd-Z Tc isotopes [6].

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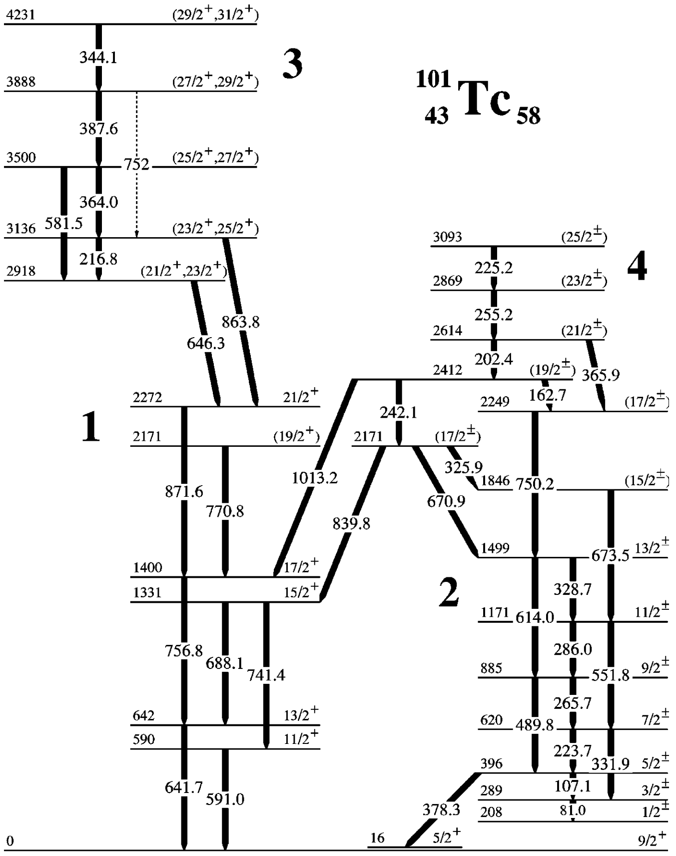

Fig. 1. Level scheme of ^{101}Tc obtained in the present work. Level and γ-ray energies are given in keV

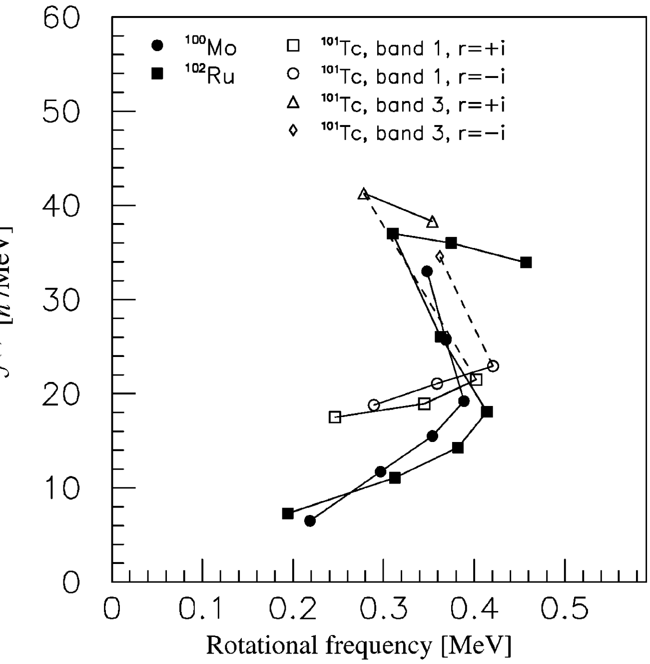

Fig. 2. Kinematical moment of inertia of bands 1 and 3 in ^{101}Tc along with those of the neighbouring even-even nuclei ^{100}Mo and ^{102}Ru

The level scheme is constituted of four band structures. The lower parts of two of them were already discussed in the previous studies. Band 1, which is the yrast band, has a $\pi g_{9/2}$ configuration, whereas band 2 is interpreted as arising from a $\pi p_{1/2}$ configuration mixed with other negative parity orbitals in an asymmetric rotor description. Two $(17/2^-)$ states are observed in the present work. A fit of the enegies of the states of band 2 by a rotational formula with K = 1/2 favors the level at 2249 keV as being the $17/2^-$ member of the band. The fact that the other $(17/2^-)$ state decays to both band 1 and band 2 corroborates this assertion.

The kinematical moment of inertia of band 1 followed by band 3 is compared in Fig. 2 with those of the ground-state bands of the neighbouring even-even nuclei ^{100}Mo and ^{102}Ru. Spins ranging from 23/2 to 31/2 have been assumed for the levels of band 3 in calculating the moment of inertia of the ^{101}Tc nucleus. The backbending in ^{101}Tc occurs at the same rotational frequency and at the same excitation energy ($\sim$ 3 MeV) as in ^{102}Ru where this behaviour is assigned to the alignment of a pair of $h_{11/2}$ neutrons [7]. Figure 3 displays the proton and neutron quasiparticle energies of the ^{100}Mo core calculated with a Woods-Saxon-Hartree-Fock-Bogolyubov (WSHFB) code [8,9] using the constant deformation parameters $\beta_2 = 0.244$ and $\beta_4 = 0.023$ [10]. The first alignment is found at $\hbar\omega = 0.4$ MeV, giving the configuration [aAB] $(\pi g_{9/2} \nu h^2_{11/2})$. The increase in angular momentum aligned onto the rotation axis is calculated to be $-\left(\frac{dE^\omega_A}{d\omega} + \frac{dE^\omega_B}{d\omega}\right) \simeq 8\ \hbar$, which exceeds slightly the one deduced from the experimental results (see Fig. 4).

The assignment of band 4 to a configuration is not so straightforward. One expects to observe also an alignment of a $\nu h_{11/2}$ pair in the $\pi p_{1/2}$ band which appears around 3 MeV excitation energy in the neighbouring even-even nuclei. However the transition from band 2 to band 4 happens at much lower energy ($\sim$ 2.3 MeV). Another possibility is an alignment of the quasiparticle proton configuration [ab] resulting in a $\pi p_{1/2} g^2_{9/2}$ configuration for band 4. But the frequency of the alignment predicted by the WSHFB calculations at $\hbar\omega \sim 0.5$ MeV, differs from the experimental value $\hbar\omega \sim 0.25$ MeV. A third and more plausible possibility is based on the systematics of odd-A N = 58,60,62 isotones where similar bands were interpreted as arising from the coupling of a $g_{9/2}$ proton to negative parity states of the even-even cores [11]. In this description, a $\pi g_{9/2} \nu h_{11/2} (g_{7/2}, d_{5/2})$ configuration is attributed to band 4.

To conclude, the level scheme of the neutron-rich odd-Z nucleus ^{101}Tc has been extended to spins of approximately $31/2\hbar$ and excitation energy of 4.2 MeV. Two new bands have been observed. One of these can be assigned as the $\pi g_{9/2} \nu h^2_{11/2}$ configuration on the basis of comparison with WSHFB calculations; the other may be understood as a $g_{9/2}$ proton coupled to negative parity states of the even-even core.

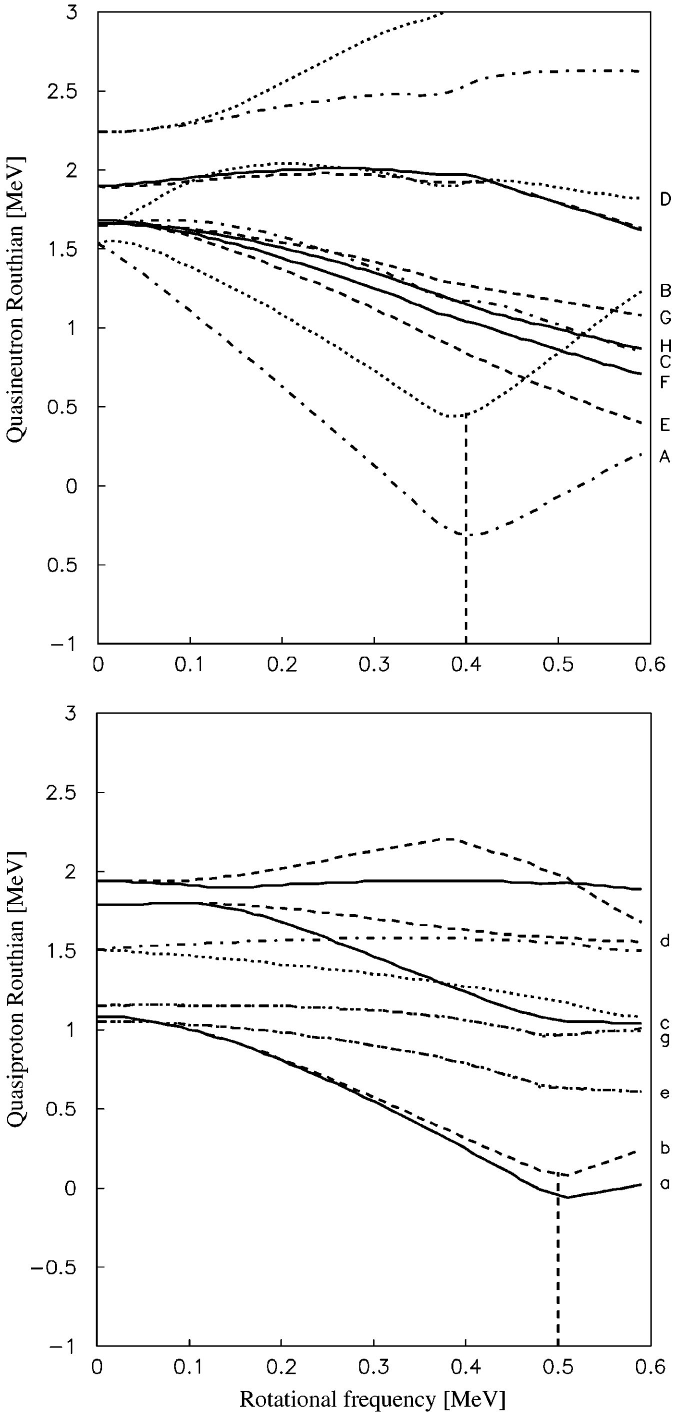

Fig. 3. Neutron (top) and proton (bottom) quasiparticle energies of the ^{100}Mo core. Quasiparticle routhians having parity and signature (π,r) equal to (+1,+1), (+1,-1), (-1,+1) and (-1,-1) are represented by continuous, dashed, broken and dotted lines, respectively

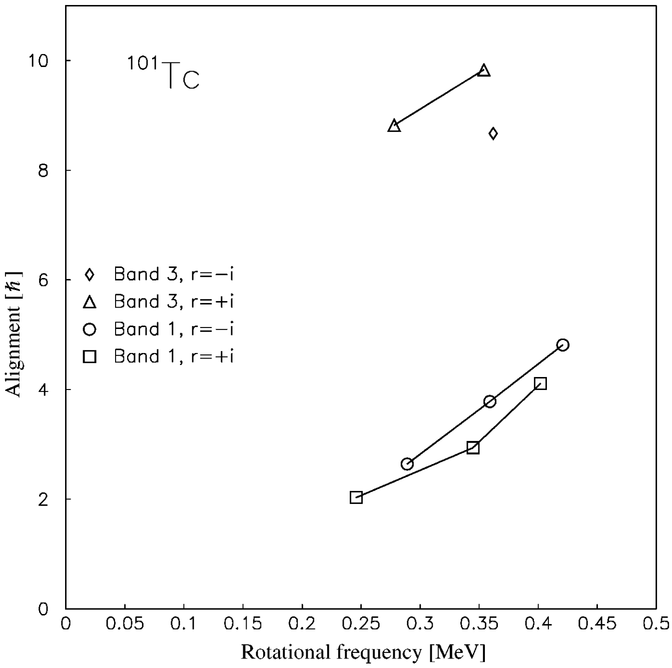

Fig. 4. Experimental alignments using the Harris parameters $\Im_0=8\hbar^2\cdot\mathrm{MeV}^{-1}$ and $\Im_1=20\hbar^4\cdot\mathrm{MeV}^{-3}$

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References

1. J. Skalski, S. Mizutori and W. Nazarewicz, Nucl. Phys. A **617**, 282 (1997)
2. H. Dejbakhsh, G. Mouchaty and R.P. Schmitt, Phys. Rev. C **44**, 119 (1991)
3. D.G. Savage et al., Phys. Rev. C **55**, 120 (1997)
4. P.J. Nolan, F.A. Beck and D.B. Fossan, Annu. Rev. Nucl. Part. Sci. **44**, 561 (1994)
5. M.-G. Porquet et al., *International Symposium on Exotic Nuclear Shapes, Debrecen, 1997*, APH N.S. Heavy Ions Physics **7**, 67 (1998)
6. K.O. Zell et al., Z. Phys. A **316**, 351 (1984)
7. D.R. Haenni et al., Phys. Rev. C **33**, 1543 (1986)
8. M.J.A. de Voigt, J. Dudek and Z. Szymański, Rev. Mod. Phys. **55**, 949 (1983)
9. S. Ćwiok et al., Comp. Phys. Comm. **46**, 379 (1987)
10. P. Möller et al., At. Data and Nucl. Data Tables **59**, 185 (1995)
11. F.R. Espinoza-Quiñones et al., Phys. Rev. C **55**, 1548 (1997)