LIFETIME MEASUREMENT IN THE $N = Z$ NUCLEUS ^{44}Ti*

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The Recoil Distance Doppler-Shift method has been used to measure the lifetime of the first 3^- state in the $N = Z$ ^{44}Ti nucleus, populated *via* the ^{40}Ca(^{6}Li$, pn)^{44}$Ti reaction. State-of-the-art analysis techniques have been employed to determine the experimental lifetime, resulting in a $B(E3; 3^-_1 \rightarrow 0^+_1) \approx 3$ W.u.

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1. Introduction

The nuclei with proton number between 20 and 28 ("$f_{7/2}$-shell nuclei") constitute a testing ground for the competition between single-particle and collective degrees of freedom in the establishment of the nuclear structure. The number of valence particles above the ^{40}Ca core is, in fact, small enough to allow for Shell Model (SM) calculations in the full pf shell but, at the same time, these nuclei are sufficiently heavy to display collective behavior [1].

In the level scheme of the $N = Z$ ^{44}Ti nucleus with only four valence particles (two protons and two neutrons) a large variety of structures can be found. As in the case of ^{48}Cr [2] the filling of $f_{7/2}$ and $p_{3/2}$ orbitals leads to quadrupole correlations. Recent g-factor measurements [3] of the 2^+_1 state are consistent with a rotational-like behavior. On the other hand, the excitation energies of the lowest-lying levels of the ground-state band

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point to a vibrational-like structure, as previously observed in the case of the 2_1^+ states in ^{42,44}Ca [4], and explained as due to large admixtures of $2p$–$2h$, $4p$–$4h$ excitations of the ^{40}Ca core.

The non-natural parity side band built on the 3^- state, recently extended to high spins [5,6], resembles very much the ground state band to which also it is connected with $E1$ transitions, that are strictly forbidden in the long-wavelength limit between $T = 0$ states in $N = Z$ nuclei. Observation of such $E1$ transitions points to mixing with higher-lying $T = 1$ states. The possibility to extract the weak isospin mixing probability is however limited by the accurate understanding of all the underlying mechanisms leading to the investigated transition. In the case of ^{44}Ti octupole correlations might appear from the coupling of the $\Delta j = \Delta l = 3$ $s_{1/2}$ and $f_{7/2}$ orbitals to enhance the $E1$ transition probabilities.

2. The experiment

The lifetime of the 3_1^- state in ^{44}Ti has been measured by means of the Recoil Distance Doppler-Shift (RDDS) method. Low-lying excited states in ^{44}Ti were populated via the $^{40}\mathrm{Ca}(^6\mathrm{Li}, pn)^{44}\mathrm{Ti}$ reaction. The target consisted of 0.5 mg/cm^2 ^{40}Ca evaporated onto a 2 mg/cm^2 Ta foil (facing the beam). The recoils were stopped into a 8 mg/cm^2 Au layer, mounted together with the target in the IFIN-HH plunger device. The beam was delivered by the IFIN-HH Tandem accelerator at an energy of 21 MeV and measurements were performed at 6 target-to-stopper distances, ranging from 4 to 300 μm. Since the average velocity of the recoiling nuclei was $\approx 6 \times 10^{-3}c$, the corresponding time of flights were in the $\approx$ 2–170 ps range. Gamma rays were detected by 8 HPGe detectors, arranged at backward (145°) and forward (35°) angles, as depicted in Fig. 1.

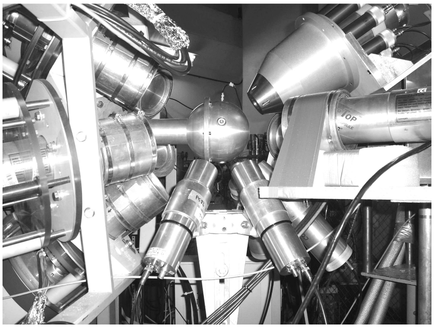

Fig. 1. Experimental setup. In the centre of the picture the chamber of the plunger device is visible, surrounded by 8 HPGe detectors. Five of the germanium detectors were set at 145° and 3 at 37° with respect to the beam axis. An array of 5 $\mathrm{LaBr_3}$ [7] was also mounted below the reaction chamber during the experiment.

3. Data analysis and preliminary results

The collected gamma–gamma coincidences have been analyzed with the Differential Decay Curve Method [8]. According to this procedure the lifetime of the level of interest is obtained evaluating for each target-to-stopper distance x the intensities of the shifted (s, emission in flight) and unshifted (u, emission at rest) components of a transition (D) depopulating the level of interest, from the spectrum in coincidence with the shifted component of a direct feeder (P). These observables are related to the lifetime τ of the level by the relation:

$$\tau(x) = \frac{1}{v} \frac{\{P_s, D_u\}}{\frac{d}{dx}\{P_s, D_s\}}\,, \tag{1}$$

where v is the average recoil velocity, and $\{P_s, D_{u,s}\}$ refers, respectively, to the intensity of the unshifted and shifted components of D obtained in coincidence with the shifted component of P. It can be demonstrated that this evaluation is free from systematic errors arising from the unobserved feeding and the nuclear de-orientation effect [9].

The transitions considered in the determination of the lifetime of the 3^-_1 state in ^{44}Ti (P = 885 keV and D = 2093 keV) are shown in Fig. 2. In the same figure the normalized intensities of the shifted and unshifted

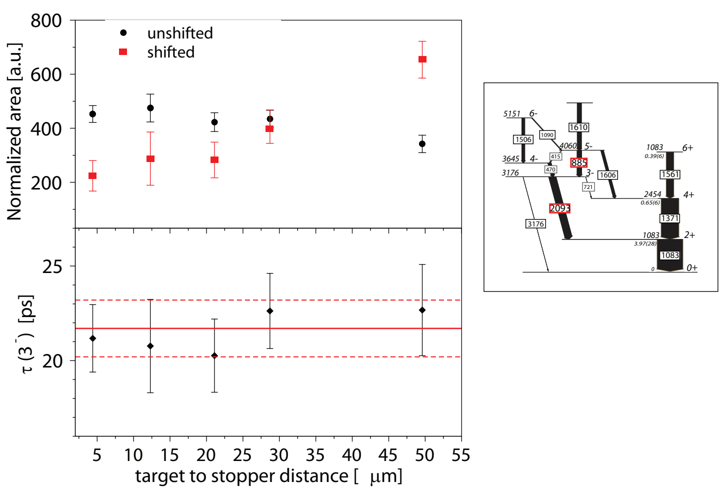

Fig. 2. Determination of the lifetime of the 3^-_1 state from the spectra observed at backward angles. The normalized intensities of the shifted and unshifted components of the 2093 keV transition and the corresponding tau-curve in the region of sensitivity are shown on the left-hand side. On the right-hand side the partial level scheme of interest is displayed (the energies of the transitions and the nuclear levels are reported in keV).

components of the 2093 keV transition are plotted as a function of x. The *tau curve* obtained from the relation (1) is plotted in the bottom panel of Fig. 2, for the distances in the *region of sensitivity*. The $B(E3; 3^-_1 \rightarrow 0^+_1)$ value deduced from the lifetime obtained as an average of the *tau curve* in this interval of distances is of the order of 3 W.u. (considering the branching ratio for the transition to the ground state obtained in [5], *i.e.* 2.0(3) %).

4. Summary

In this contribution we reported preliminary results on the lifetime measurement for the 3^-_1 state of the $N = Z$ ^{44}Ti. The corresponding reduced $E3$ transition strength is evaluated to be of about 3 W.u. The implications of this result in understanding the structure of the ^{44}Ti nucleus are in progress by means of large scale shell model calculations.

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