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g-factor measurements of isomeric states in ^{174}W

M. Rocchini[1,2], A. Nannini[2], G. Benzoni[3], B. Melon[2], P.R. John[4,5], C.A. Ur[5], R. Avigo[3,6], D. Bazzacco[5], N. Blasi[3], G. Bocchi[3,6], S. Bottoni[3,6], A. Bracco[3,6], F. Camera[3,6], S. Ceruti[3,6], F.C.L. Crespi[3,6], G. Georgiev[7] A. Giaz[3,6], A. Gottardo[8], S. Leoni[3,6], R. Menegazzo[4,5], D. Mengoni[4,5], C. Michelagnoli[9] B. Million[3], V. Modamio[10], A.I. Morales[3,6], D.R. Napoli[10], M. Ottanelli[2], L. Pellegri[3,6], A. Perego[1,2], J.J. Valiente-Dobon[10] and O. Wieland[3]

[1] Università degli Studi di Firenze, Firenze, Italy
[2] INFN, Sezione di Firenze, Firenze, Italy
[3] INFN, Sezione di Milano, Milano, Italy
[4] Università degli Studi di Padova, Padova, Italy
[5] INFN, Sezione di Padova, Padova, Italy
[6] Università degli Studi di Milano, Milano, Italy
[7] CSNSM, Orsay, France
[8] CNRS, Paris, France
[9] GANIL, Caen, France
[10] INFN - Laboratori Nazionali di Legnaro, Legnaro (PD), Italy

Abstract

The experimental setup GAMIPE used for gyromagnetic factor measurements at Laboratori Nazionali di Legnaro and a recent experimental work regarding K-isomers in ^{174}W are described. Aim of the experiment is to study the detailed structure of the isomeric states wave functions, by the measurement of the magnetic dipole moments. This piece of information can provide interesting hints for theoretical models. Preliminary results concerning the population of the isomers of interest and half-lives are presented.

1 Introduction

The study of the high-K states in the region of mass A $\sim$ 180 has attracted in recent years much experimental and theoretical work, aiming at obtaining insight on specific nuclear structure aspects [1]. The knowledge of the properties of these long-living states may be useful also for practical applications in medicine and for energy storage methods [1, 2].

In axially deformed symmetric systems, away from closed shell, the most common kind isomers are the so called K-isomers. The name refers to the projection K of the nuclear angular momentum on the symmetry axis. The existence of this kind of isomers is due to the approximate conservation of K: the transition from a state characterized by K_i to another state with K_f is governed by the selection rule $\Delta\mathrm{K} = |\mathrm{K}_f - \mathrm{K}_i| \leq \lambda$ being λ the transition order. Transitions that violate this rule have been observed and are called K-forbidden. Such transitions are strongly hindered, resulting in long-lived isomeric states. In the study of these transitions it is useful to define the degree of forbiddenness $\nu = \Delta\mathrm{K} - \lambda$ and the hindrance factor

$$F = \frac{T_{1/2}^{exp}}{T_{1/2}^{W}} \tag{1}$$

which is the half-life of the level respect to the corresponding Weisskopf estimate.

K-isomers have been observed in many regions throughout the Segrè chart and have been extensively studied in past years. However many important properties of such states are not well understood yet, in particular those related to their de-excitation towards levels with lower K values. One of the model used to describe the K-hindered decays for the deformed nuclei (characterized by the parameters of Hill-Wheeler γ, β) is the γ-tunneling, in which the transition from an initial state to a final state is described like a tunneling of the nucleus through a barrier of γ degree of freedom, along a line of constant β deformation [3].

The levels structure of ^{174}W has been recently studied and twenty rotational bands have been identified, two of them built on isomeric levels of spin 12^+ and 8^- with half-lives of 128 ns and 158 ns, respectively [4, 5]. An interesting open issue in the decay pattern of ^{174}W is the decay mechanism of the level 12^+, which decays mainly directly to the 10^+ level of the ground state band with an E2 transition at 1879 keV. This transition is characterized by high degree of forbiddenness, $\nu = 10$, but the hindrance factor comparable to those of other similar states in mass region A $\sim$ 180, could not be described by the above-mentioned γ-tunneling model. A satisfactory explanation of this discrepancy remains to be found, in particular other contributions can be considered, as the K-mixing mechanism. The K-hindrance in gamma decay by using quasi-continuum gamma spectroscopy techniques, was recently studied [6]. The results show that a K-mixing process due to temperature effects plays an important role already also at rather low excitation energy and could be the basic, general phenomenon, responsible for the K-hindrance to the gamma decay, both for discrete excited rotational bands and specific isomeric states with large K-values. Therefore, the knowledge of the detailed structure of the know high-K isomers in ^{174}W, given by the evaluation of the static magnetic dipole moment, can give useful hints for the theoretical modelling of their decays.

In this contribution we report about the preliminary results about a recent measurement of the gyromagnetic factors of the isomeric levels in ^{174}W, with the goal of assign their quasi-particle configuration. Attempts to give a quasi-particle configuration assignment were already performed by Tandel *et al.* [4] on the basis of experimental in-band branching ratios, from which $|g_K - g_R|/Q_0$ were derived. These analysis are, however, dependent on the assumption concerning the quadrupole deformation and the effects associated with the reduction of the pairing correlations on both the rotational g factor g_R and the alignment. In this respect the knowledge of the static magnetic dipole moment is of crucial importance, as it provides independent information on the composition of the wave-functions.

2 Experimental details

The isomeric states were populated in the ^{162}Dy(^{16}O, 4n)^{174}W reaction (81.1% of the total cross section estimated by CASCADE code [7] and also experimentally confirmed [5]) using an 84 MeV ^{16}O beam delivered by the XTU-Tandem, at the Laboratori Nazionali di Legnaro. The beam has been pulsed into packets of 2 ns duration and repetition time of 800 ns to register the complete decay of the isomers of interest. The target consisted in a layer of ^{162}Dy with a thickness of 500 μg/cm^2 and a backing of Pb with a thickness of 50 mg/cm^2 to implant the ^{174}W nuclei and let them decay at rest. In order to reduce the dealignment effects due to the interaction with radiation-induced defects, the target was heated to a temperature of 400 K in a special oven. This temperature was monitored with an automatic control system that can provide a constant temperature with an error of about 0.5 K. For the detection of gamma rays we have used the GAMIPE apparatus that consists of 4 GASP-type HPGe detectors, placed at 12 cm from the target and positioned at $\pm 45°$ and $\pm 135°$ respect to the beam axis between the yokes of an a electromagnet that can provide magnetic field of the order of 10 kG.

The half-lives of the levels of interest are suitable for the application of the Time Differential Perturbed Angular Distribution (TDPAD) technique. This technique consists in the observation of the anisotropy of gamma emission of an ensemble of oriented nuclei located in an external magnetic field, in function of the time. In this way it is possible to obtain the Larmor frequency and so the gyromagnetic factor. The target was located in the gap of the electromagnet, set to a magnetic field $B = 14.65$ kG applied perpendicular to the beam-detector plane, for observing 2-3 complete oscillations in the range of 3 $T_{1/2}$. Data have been acquired by using commercial digital electronics adapted for the TDPAD measurements. A new structure supporting the HPGe detectors has been utilized during this experiment, now every single detector can be positioned individually.

3 Preliminary results

Energy and time signals, recorded as difference with the beam radiofrequency, for each HPGe detector, were recorded in list-mode and analysed offline. Data were sorted in two kinds of correlation matrices: time signals of each detector were correlated to the measured γ-ray energies and then coincidences between emitted γ-rays were registered in γ-γ 2D matrices. Using the first kind of matrices it's possible to obtain time-gated energy spectra and energy-gated time spectra, useful to obtain the Larmor frequency and to measure half-lives. The γ-γ matrices were used to obtain coincidence spectra, useful for the identification of the transitions in the populated channels.

The delayed energy spectrum obtained from a γ-γ matrix by imposing the coincidence with the transition $12^+ \longrightarrow 10^+$ of 1879 keV and a time condition in-between the beam bursts is reported in *fig.* 1. The transitions belonging to states of the yrast line are clearly visible. As mentioned above isomeric 12^+ state mainly de-excites towards the ground state band.

From our data it was possible to give a confirmation of the half-life of the 12^+ isomer. The decay spectrum of the $12^+ \longrightarrow 10^+$ gamma transition are reported in *fig.* 2 as a function of the time, measured with respect to the pulsed beam. The measured value of the half-life is $T^{exp}_{1/2} = 124(21)$ ns and is compatible with the adopted value $T^{ado}_{1/2} = 128(8)$ ns [4]. The higher error

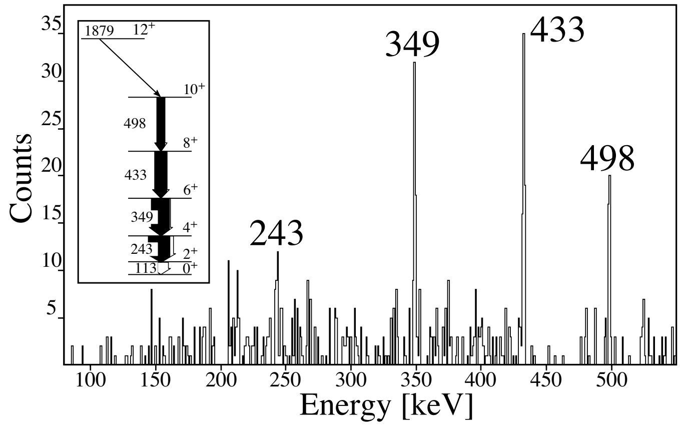

Figure 1: Delayed energy spectrum obtained from γ-γ matrix by imposing an energy condition on the $12^+ \longrightarrow 10^+$ transition and a time condition in-between the beam bursts, background subtraction has been performed (in the box on top left is shown the decay pattern of the isomeric level 12^+).

obtained in this work is due to the fact that the apparatus is not optimized for half-life measurements.

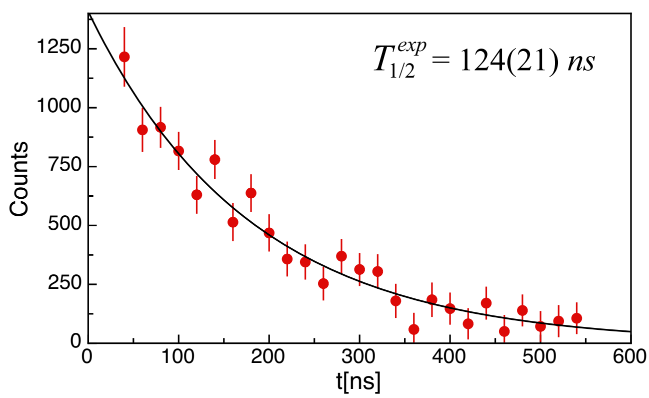

Figure 2: Exponential decay of the isomeric level 12^+ observed with respect to the pulsed beam (on top right is shown the obtained half-life).

4 Summary and perspectives

Preliminary results, obtained in a g-factor measurement with TDPAD technique in ^{174}W performed at the Laboratori Nazionali di Legnaro, have been presented. The first results of the analysis showed a clear evidence of the population of the isomers of interest. Also the value of the half-life of the 12^+ isomeric level is confirmed. For the determination of the g-factor of this level the analysis is still in a preliminary phase due to the low population rate of the 12^+ level and to the presence of a high background contribution. We expect to reach a 3% precision in the g-factor value which is usually achieved in similar experiments (see for example [8]).

The knowledge of the wave-function composition of the isomeric states in ^{174}W, obtainable with the experimental results of this experiment, could be very useful for a better understanding of the decay of K-isomers, in particular for the evaluation of the K-mixing contribution.

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