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Search for the Jacobi shape transition in light nuclei

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Abstract. The γ-rays following the reaction 105 MeV $^{18}O + ^{28}Si$ have been measured using the EUROBALL IV, HECTOR and EUCLIDES arrays in order to investigate the predicted Jacobi shape transition. The high-energy γ-ray spectrum from the GDR decay indicates the presence of large deformations in the hot ^{46}Ti nucleus, in agreement with new theoretical calculations based on the rotating liquid-drop model.

PACS. 24.30.Cz Giant Resonances – 21.60.Ev Collective models

1 Introduction

It is known that an atomic nucleus may change its equilibrium shape from spherical (or prolate) to oblate with increasing angular momentum. In hot nuclei the size of the oblate deformation increases with the angular momentum and at a certain critical value of spin an abrupt change of the equilibrium shape is expected, with the nucleus following a series of triaxial and more and more elongated shapes. This phenomenon, called nuclear Jacobi transition [1], was studied in the past using, among others, classical and semi-classical models; for a recent discussion, see *e.g.* ref. [2] and references therein. Recently developed LSD (Lublin-Strasbourg Drop) model [3] has been used to calculate the Jacobi transition mechanism in the ^{46}Ti nucleus; the results are illustrated in fig. 1.

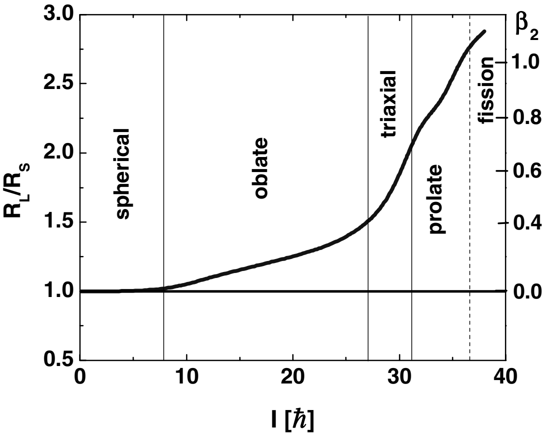

Fig. 1. Long-to-short axis ratio and the β_2 parameter for the equilibrium deformation as a function of spin, obtained from the LSD model calculations for ^{46}Ti.

The experimental signatures of such an abrupt change of the nuclear shape are expected to be found in observables related to the moment of inertia. Especially promising for the search of the Jacobi nuclear shape transitions are: i) the γ-decay of the Giant Dipole Resonance (GDR) built on such states; ii) the giant backbend of the $E2$ γ-transition energies [4]; iii) the angular distribution of the emitted charged particles.

So far, the problem of Jacobi transition in light nuclei has been addressed by studying the GDR γ-decay from compound nuclei $^{45}Sc^*$ [5] and $^{46}Ti^*$ [6,7]. In both cases

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† Deceased.

the data indicate the presence of large deformations that could be related to the Jacobi transition. Let us mention that in the case of ^{45}Sc* the GDR measurement was inclusive, while for ^{46}Ti* it was associated with different γ-multiplicity values.

In medium-mass nuclei the possible giant backbend of the quasi-continuous $E2$-radiation due to the Jacobi transition was investigated recently by Ward *et al.* [4].

In order to address the interesting question of the Jacobi shape transition in more detail, and to obtain simultaneous information on the GDR decay, the $E2$ quasi-continuum and charged-particle angular distribution, a new experiment for ^{46}Ti* has been recently performed. In addition in this experiment, we were studying the fission limits imposed by the angular momentum. Some results from this measurement are presented here and discussed.

2 The experiment

The experiment was performed at the VIVITRON accelerator of the IReS Laboratory of Strasbourg (France), using the EUROBALL IV Ge array coupled to the HECTOR array [8] and the charged-particle detector EUCLIDES. The ^{46}Ti compound nucleus was populated in the ^{18}O + ^{28}Si reaction at 105 MeV bombarding energy. The excitation energy of the ^{46}Ti was 86 MeV and the maximum angular momentum $l_{\max} \approx 34\hbar$. For this experiment the EUROBALL consisted of 26 germanium clover and 15 cluster detectors (all with the BGO anti-Compton shields), and 75% of the Inner ball consisting of 83 BGO crystals, which together with the germanium detectors resulted in the 65% efficiency for the multiplicity determination. The 8 large-volume BaF$_2$ detectors of the HECTOR array were placed in the forward hemisphere, together with 4 small BaF$_2$ detectors which provided a good time reference signal. The EUCLIDES detector consists of 40 silicon telescope detectors covering approximately 90% of the solid angle. The trigger condition was such that events having at least 2 clean Ge signals and one high-energy γ-ray were accepted. EUCLIDES was running in the "slave" mode, *i.e.* its events were accepted only if the trigger condition was fulfilled. A total number of 10^8 events was collected, in which the γ-ray energy in the BaF$_2$ detector was $E_\gamma > 4$ MeV.

3 Results and discussion

The results of the previous measurement [6,7] correspond to the data gated only by γ-ray multiplicity; here we focus on the partial results from the new experiment, obtained with more restrictive condition allowing for a good identification of the fusion-evaporation channel. In particular, the data shown in fig. 2 were obtained by gating with the known transitions in ^{42}Ca —the residual nucleus originating in the decay of the ^{46}Ti compound nucleus at the highest angular momenta. The left-hand side of the figure shows the spectrum on a logarithmic scale, together with the statistical model calculation, in which the GDR strength function was assumed to be a superposition of 3 Lorentzian components. The upper right part shows the extracted absorption cross-section using the method described in, *e.g.*, [5]. The lower right part shows the results of the shape averaging (see, *e.g.*, [7]) assuming a shape distribution following the LSD potential energy calculations for $I = 22\hbar$ (oblate equilibrium shape) and $I = 30\hbar$ (elongated 3-axial equilibrium shape due to the Jacobi transition —see fig. 1). As can be seen, the prediction for $I = 30\hbar$ resembles remarkably well the data, therefore suggesting the presence of the Jacobi transition in hot ^{46}Ti. Further analysis, concentrating on the $E2$ quasi-continuum and the angular distributions of charged particles is in progress. This is expected to provide a more consistent picture. While the GDR γ-decay and charged particles are mainly probing the hot part of the phase space, with the analysis of the $E2$ continuum we expect to determine whether or not the Jacobi shape transition is still present near the yrast line.

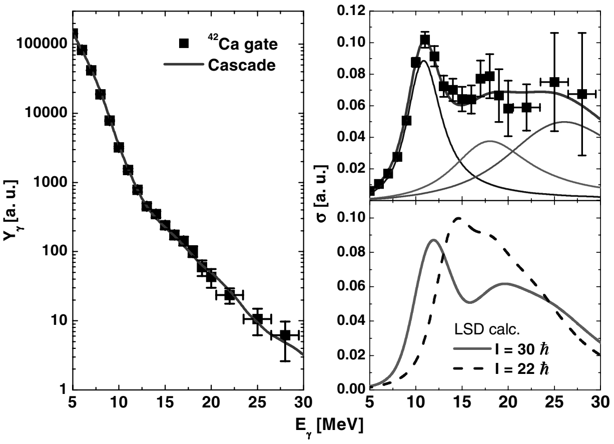

Fig. 2. Left: spectrum of the γ-rays from the decay of the GDR built in hot ^{46}Ti in coincidence with the discrete transitions in the residual nucleus ^{42}Ca, together with the Cascade calculations assuming 3-Lorentzian GDR strength function with $E_{\mathrm{GDR}} = 10.8$, 18 and 26 MeV. Upper right: experimentally obtained GDR absorption cross-section and the GDR strength function used in Cascade calculations. Bottom right: thermal shape fluctuation predictions based on potential energies from the LSD model calculations for $I = 22\hbar$ and $I = 30\hbar$.

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