NUCLEAR STRUCTURE STUDIED VIA COULOMB EXCITATION* **

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Coulomb excitation has been proved as a powerful tool to study the electromagnetic structure of the nuclei. In particular this method is able to determine large sets of electric and magnetic multipole matrix elements, giving an insight into the overall structure of the nuclei in the low- energy and relatively low-spin excitation region. This application of multiple Coulomb excitation is exploited since almost two decades. In this contribution we would like to concentrate on a different usage of the Coulomb excitation technique — addressing specific physical problems by choosing the experimental conditions in a way that enhances the sensitivity to the effect under investigation. As an example the direct measurement of the E3 coupling between gamma-vibrational and pseudo-beta-vibrational bands in ^{148}Nd is discussed. The results presented demonstrate how relatively simple measurement can be designed to investigate non-trivial phenomena.

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1. Motivation

Since more than a decade heavy-ion induced Coulomb excitation provides the complete information about the electromagnetic structure of the nuclei in the spin and energy regions amenable by this method. The knowledge

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of the full sets of reduced electric and magnetic matrix elements coupling the low-lying collective levels allows to test the understanding of collective phenomena.

The real advantage of Coulomb excitation is the applicability of semiclassical, purely electromagnetic, description of both excitation and deexcitation process. Since no assumptions concerning the nuclear forces are necessary the results obtained are model-independent. Generally, the procedure of measuring the sets of matrix elements is to simultaneously fit the full set to the deexcitation gamma-ray yields collected with different beams (A, Z dependence) and observed in coincidence with scattered particles at different scattering angles (impact parameter dependence). In addition known spectroscopic information: lifetimes of the nuclear levels, E2/M1 mixing ratios, branching ratios and the values of previously measured matrix elements can be used to constrain the fit. The number of experimental data should overdetermine the number of parameters — matrix elements — sufficiently enough to ensure the uniqueness of the solution in the sense of finding a global minimum rather than a local one dependent on the initial conditions.

However, there are no clear criteria which could distinguish between local and global minimum just from the fitting procedure. Multiple Coulomb excitation of a given level can be intuitively viewed as the interference of many paths connecting this state to the ground state of an investigated nucleus via all possible intermediate states. The resulting excitation cross section is thus dependent on all matrix elements in the amenable structure which introduces the dependence not only on the sizes of these matrix elements, but also on their relative phases.

One method of verifying the uniqueness of the final result is to repeat the fitting procedure starting from different sets of initial matrix elements. As long as the fit converges to the same minimum it can be believed that the solution is unique. Experimentally direct verification of the multiple Coulomb excitation data is an independent measurement of level lifetimes which are straightforwardly connected to the transition matrix elements. Unfortunately, such a direct verification is not usually possible in case of E3 matrix elements due to the overwhelming competition of lower multipolarity transitions.

In case of ^{148}Nd the level energy of the second 0^+ state is, in addition, almost the same as the energy of the 1^- level (Fig. 1), so the only possible way of deexciting this state is the E2 transition to the yrast 2^+ state. When low-energy beams are used the population of the second 0^+ state is determined by the interference of two-step processes - E2$\times$E2 via first and second excited 2^+ states and E3$\times$E3 via 3^- state in the octupole band. The influence of higher-order excitations drops drastically with decreased beam energy. The experimental conditions were chosen to excite the second

0^+ state in such a way that the only possible deexcitation transition could be clearly seen and, simultaneously, that only two-step excitation processes were of importance. Since E2 matrix elements are known from both lifetime data and previous Coulomb excitation work and E3 matrix element between the ground state and the 3^- state was measured with high accuracy as it determines the excitation pattern of the octupolly deformed band [1], the only remaining unknown is the E3 matrix element of interest, connecting octupole and quasi-β bandheads. Thus, an experiment in which the excitation is limited to two-step processes provides, combined with previous data, almost direct way of determining the E3 coupling of the octupole and quasi-β bands.

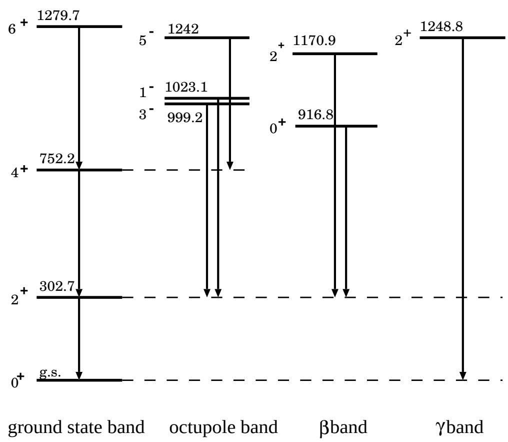

Fig. 1. γ-ray transitions and excited levels observed during the experiment with neon beam

2. Experimental

1.5 mg/cm^2 ^{148}Nd target was bombarded with 65 MeV ^{20}Ne beam from the Warsaw Heavy Ion Cyclotron. Deexcitation gamma-rays were detected in coincidence with the projectiles backscattered in the range 140–170 degrees with respect to the beam direction. The measurement was carried out using the 32 1×1cm PIN-diode array detector CUDAC [2] combined with three HPGe detectors.

Event-by-event data were sorted using backscattered particle energy and particle-γ timing gates. Doppler-shift correction was applied to each event based on the reconstruction of the kinematics.

3. Analysis

Gamma-yields resulting from the excitation of the states up to 6^+ in the ground-state band, two lowest states in the octupole band, two lowest levels in the β band and the bandhead of the γ band (Fig. 1) were used as an input to the Coulomb-excitation analysis code GOSIA [3]. Available spectroscopic data (level lifetimes and branching ratios [4]) were included. The value of the lowest E3 matrix element, connecting the ground state and the lowest unnatural parity state was taken from [1] as an experimental data point, *i.e.* as not a fixed quantity, but contributing to the minimized χ^2 function. Since this matrix element influences the data of the reported experiment the inclusion of the previously measured value provides a consistency test of the data derived from experiments described in [1] and our results.

4. Results

The value of the $\langle 0_2^+ \| E3 \| 3^- \rangle$ reduced matrix element resulting from our data is equal to 1000±300 $e{\cdot}\mathrm{fm}^3$ as compared to $\langle 0_1^+ \| E3 \| 3^- \rangle$=560±20 $e{\cdot}\mathrm{fm}^3$. This result is in perfect agreement with the value of 1050±100 $e{\cdot}\mathrm{fm}^3$ given in [1].

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