

STUDY OF OCTUPOLE COLLECTIVITY
IN ^{146}Nd AND ^{148}Sm USING THE NEW COULOMB
EXCITATION SET-UP AT ALTO*

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For certain combinations of protons and neutrons in atomic nuclei, a rise of a reflection asymmetry is expected. Experimental E3 strengths, which as a function of the neutron number peak at around $N \approx 88$ and $N \approx 134$, indicate enhanced octupole correlations as predicted by theory. Low-energy Coulomb excitation is a highly successful method for establishing the evolution of nuclear shapes, through the measurement of cross sections, to

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populate excited states that can be directly related to the static and dynamic moments of the charge distribution of the nucleus. A Coulomb excitation experiment at the ALTO facility, Orsay was performed recently to study collective properties of ^{146}Nd and ^{148}Sm . In particular, the strengths of the $\langle 3^- || E3 || 0^+ \rangle$ and $\langle 1^- || E3 || 4^+ \rangle$ matrix elements will provide a clear distinction between octupole vibration and rigid deformation.

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1. Introduction

The nuclei in the vicinity of neutron number $N \approx 88$ are known to have low-lying negative-parity bands that decay to the positive-parity yrast states through the E1 transitions. The enhancement of the $B(E3, 0^+ \rightarrow 3^-)$ values indicate enhanced octupole collectivity in this region. Similar correlations are observed in the $N \approx 56$ and 134 regions [1]. While this can explain the appearance of the reflection asymmetry, it is unclear whether such a behaviour is static or dynamic. However, the nature of the octupole correlations can be studied by determining the E3 matrix elements connecting states in the negative-parity band to the positive-parity ground-state band [2]. It is possible to clearly distinguish between octupole vibration and rigid deformation by measuring the $B(E3, 4^+ \rightarrow 1^-)$ value that should be close to zero in the case of octupole vibration, and larger than the $B(E3, 0^+ \rightarrow 3^-)$ value for static octupole deformation [3–5]. Unfortunately, the E3 transitions are not directly observable by decay, since the E1 and E2 transition rates are several orders of magnitude faster. However, the E3 matrix elements can be determined from the Coulomb excitation cross sections. The atomic nuclei ^{146}Nd and ^{148}Sm (both with $N = 86$) have such low-lying negative-parity bands, where the 3^- state lies energetically below the 1^- state. These nuclei, which are found in the transitional region between the spherical $N = 82$ and well-deformed $N \geq 90$, provide a great opportunity to study octupole correlations.

2. Experimental set-up

The Coulomb excitation (COULEX) of ^{148}Sm and ^{146}Nd was performed at the Institute of Nuclear Physics of Orsay (IPNO) ALTO facility in January/February 2015 with the use of a dedicated COULEX set-up (see Fig. 1): HPGe detectors to register gamma rays from the de-excitation of the target nucleus in coincidence with scattered beam particles. It formed part of the first Coulomb excitation campaign at ALTO. The experiment was conducted using the MINORCA spectrometer (Miniball [6] and ORgam Campaign at ALTO). Thus, the set-up was a coupling of two arrays: 8 Miniball triple

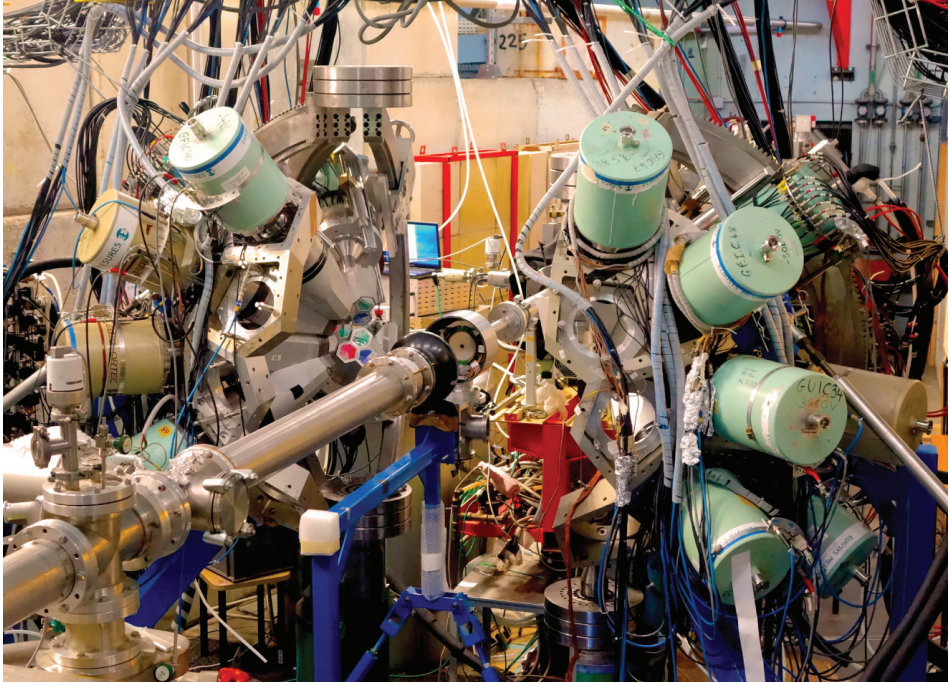


Fig. 1. The Coulomb excitation set-up at ALTO: MINORCA Ge array with the DSSSD particle detector. ORGAM detectors are placed at forward angles and Miniball cluster detectors are placed at backward angles with respect to the beam direction. The set-up is open for access to the target.

cluster detectors and 15 Compton suppressed Eurogam Phase-I HPGe detectors. The MINORCA set-up has a photopeak efficiency of 7.3% at 1332 keV. A new annular Double-Sided Silicon Strip Detector (DSSSD) was used for particle detection. It was placed within the reaction chamber at backward angles with respect to the beam direction, covering an angular range from 120 to 160 degrees in the laboratory frame. The inner diameter of the detector is 10 mm, the outer is 85 mm (Fig. 2). On the front side, the DSSSD detector is composed of 64 annular junction strips with 16-fold electronic segmentation. On the back side, it has 32 ohmic radial strips, alternately (even-odd) paired resulting in a 16-fold electronic segmentation. The Si wafer of 0.52 mm thickness is mounted onto a custom-made printed circuit board with six straight high-density connectors to guide the total of 96 signals to the Miniball CD detector's preamplifiers. For hardware particle-gamma coincidences, MESYTEC STM-16+ amplifiers were used. In order to exploit the dependence of the Coulomb excitation probabilities on the proton number Z , two beams were used: 182 MeV ^{58}Ni ($Z = 28$) and 104

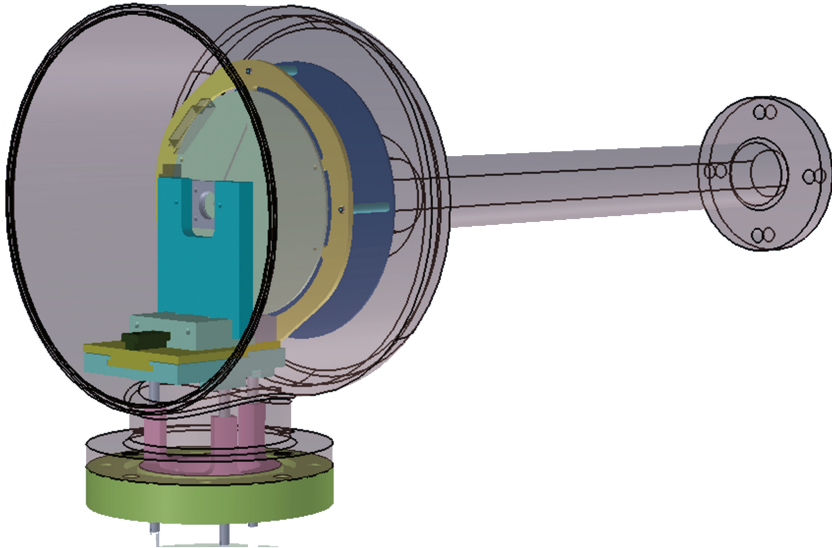


Fig. 2. Technical drawing of the Double-Sided Silicon Strip Detector placed within the reaction chamber.

MeV ^{32}S ($Z = 16$). Both beam energies were chosen such that “safe energy” condition is satisfied, which ensures a purely electromagnetic interaction between the collision partners for all scattering angles [7]. A 1.6 mg/cm^2 ^{146}Nd target isotopically enriched to 97.4% and a 1.5 mg/cm^2 ^{148}Sm target enriched to 96.4% were used.

3. Preliminary analysis and future outlook

The gamma-ray energy spectra show strong population of the ground-state band of positive-parity states, excited by direct and multiple E2 Coulomb excitation. There is a substantial population of the octupole band of negative-parity states, excited via E3 transitions. The quadrupole collective structure was populated up to the 6^+ state (see Fig. 3). Moreover, the 1^- and 3^- states of the octupole band were observed for both studied nuclei. Measured gamma-ray intensities combined with existing spectroscopic data, such as lifetimes of low-lying states and branching ratios, will allow for the extraction of a set of matrix elements between all populated states in ^{146}Nd and ^{148}Sm by using the least square fitting code GOSIA [8].

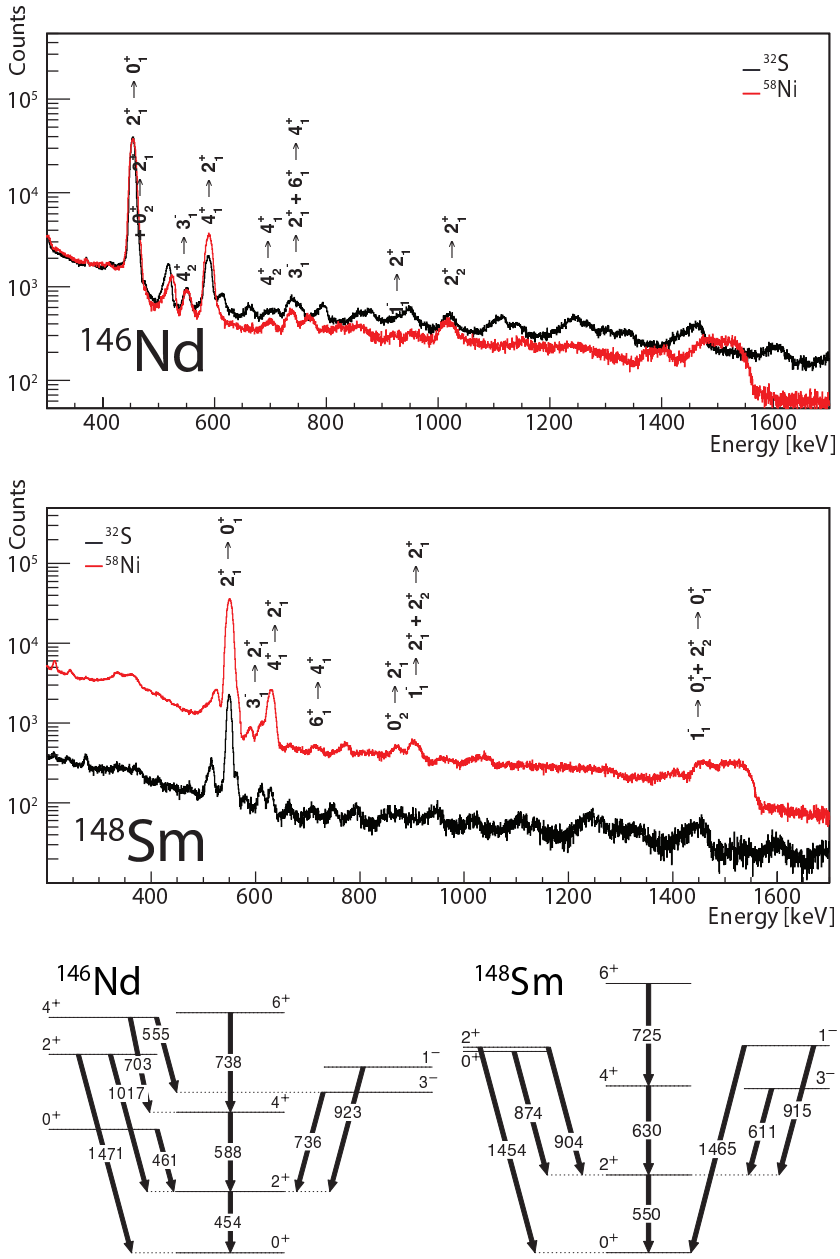


Fig. 3. (Colour on-line) Doppler-corrected gamma-ray energy spectra obtained in the described experiment for ^{146}Nd and ^{148}Sm together with corresponding partial level schemes. Different colours correspond to both used beams — ^{32}S and ^{58}Ni .

4. Summary

The 6^+ , second 4^+ and 1^- states in ^{146}Nd were, for the first time, excited via Coulomb excitation. Further analysis aims to determine the electromagnetic properties of the studied nuclei, in particular the $\langle 3^- || E3 || 0^+ \rangle$ and $\langle 1^- || E3 || 4^+ \rangle$ matrix elements in ^{146}Nd and ^{148}Sm .

The DSSSD detector, used for the first time in the described experiment, will be combined with PARIS array (LaBr₃+NaI phoswich detectors [9]) in two upcoming COULEX experiments to be performed at ALTO.

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