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Short Note

Rotational bands in the near-drip-line nucleus ^{128}Nd

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Abstract. The even-even nucleus ^{128}Nd was studied via in-beam γ-ray spectroscopy using the ^{40}Ca + ^{82}Mo reaction at 190 MeV. Two new bands were observed besides the yrast one, that has been extended up to spin 34^+. Configurations were assigned to the three bands by analysing their rotational properties and by comparison with the neighboring even-even nuclei.

PACS. 23.20.Lv Gamma transitions and level energies – 21.10.Re Collective levels – 21.60.Ev Collective models – 27.60.+j $90 \leq A \leq 149$

The study of neutron-deficient nuclei in the $A \sim 130$ mass region is expected to give important information about the lowest quasiparticle excitations near the proton drip line, which determine the lifetimes of the proton-emitting states of the nuclei beyond the drip line. The recently identified proton emitters ^{117}La [1], ^{131}Eu and ^{141}Ho [2,3] are strongly deformed, and their measured lifetimes are well described by model calculations [4]. There remains several isotope chains for which the proton emitters were not yet discovered, even if several attempts have been made. This is the case for the Pr ($Z = 59$) and Pm ($Z = 61$) nuclei, which have proton numbers smaller (larger) by one unit with respect to the Nd isotopes. In order to enrich our knowledge of the lowest excitations in nuclei close to the predicted proton emitters, we have studied the level structure of ^{128}Nd, the lightest Nd isotope where excited states have been observed. The previous spectroscopic data on ^{128}Nd comes from the work of Lister *et al.* in 1985 [5], who identified the first four transitions of the ground-state band, and of Moscrop *et al.* in 1989 [6], who extended the ground-state band up to spin 14^+.

Much progress was recently done in the study of the neutron-deficient Nd nuclei, thanks mainly to the use of very large γ-ray detector arrays, like EUROBALL, GAMMASPHERE and GASP, in conjunction with charged particle and/or neutron detectors. The most recently studied is the ^{130}Nd isotope [7]. Four bands were reported in this nucleus, one of which being interpreted as highly deformed with $\beta_2 = 0.32$.

In the present work high-spin states in ^{128}Nd were populated by bombarding a self-supporting 0.5 mg/cm^2 thick ^{92}Mo target with a 190 MeV ^{40}Ca beam of 5 pnA intensity. The beam was provided by the XTU Tandem accelerator of the Laboratori Nazionali di Legnaro. The experimental setup consisted of the GASP array for γ-ray detection and the ISIS ball for charged-particle detection [8].

The GASP array with 40 Compton-suppressed Ge detectors and the 80 element BGO ball was used for a γ^n coincidence measurement. Light charged particles (p, d, t and α-particles) were detected with the ISIS ball, which is composed of 40 $\Delta E - E$ Si telescopes. Events were written on tape when two or more Ge detectors fired in coincidence with at least two BGO detectors. A total of 3.5×10^9 Compton-suppressed events have been collected.

The ^{128}Nd nucleus was populated via the 2p2n channel. The charged particles from each event were identified as protons or α-particles. The events were then sorted according to the number of charged-particle detectors that fired in coincidence. For each charged-particle combination, E_γ-E_γ and E_γ-E_γ-E_γ matrices were produced off-line for further analysis. The level structure of ^{128}Nd has been derived mainly from the analysis of the 2p-gated data; however, the weak high-energy transitions are more

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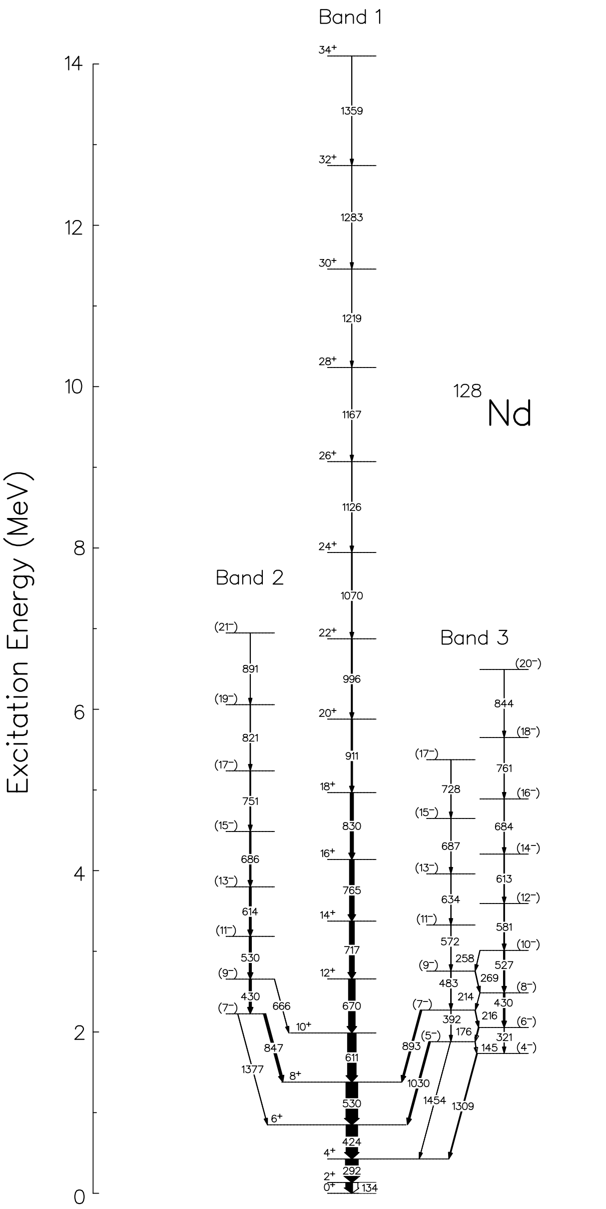

Fig. 1. Level scheme of ^{128}Nd deduced from the present work. The transition intensities are proportional to the width of the arrows.

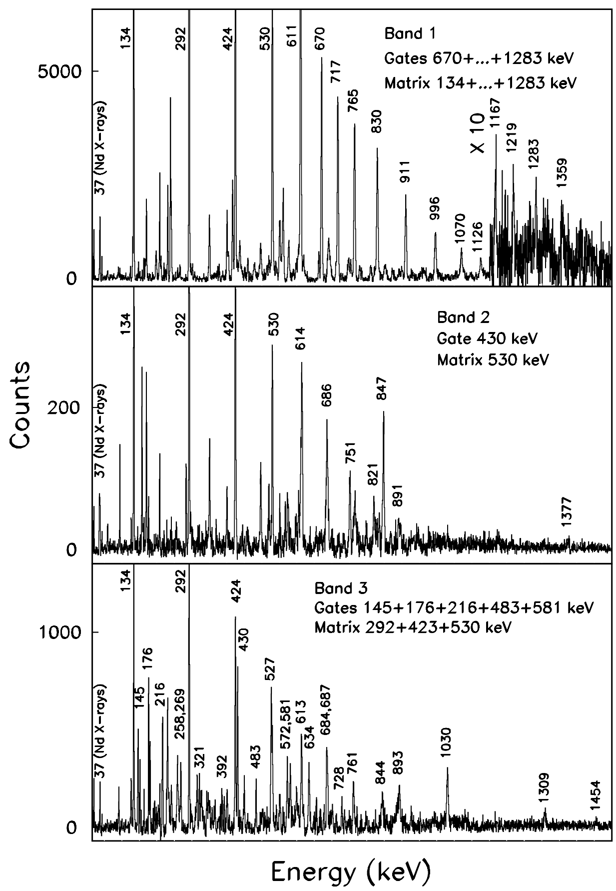

Fig. 2. Summed triple coincidence γ-spectra obtained by gating on relatively clean transitions of the matrix with no conditions on the charged-particle detector. The unlabeled transitions come from contaminations of other strongly populated reaction channels.

easily identified in double-gated spectra with no condition on the detected protons.

The decay scheme of ^{128}Nd resulting from the present analysis is shown in fig. 1. The spins of the new levels have been inferred (when possible) from a directional correlation orientation (DCO) analysis as described, *e.g.*, in [9]. Unfortunately, it has been impossible to derive DCO ratios for the transitions linking the new identified bands to the yrast band, and therefore the spins and parity of the side bands could not be established. Coincidence spectra for each of the three bands of ^{128}Nd obtained by double gating on selected clean γ-rays are shown in fig. 2.

The ground-state band is observed up to spin $I = 34^+$ and shows, like in the neighboring ^{126}Ce and ^{124}Ba isotones [10,11], two crossings (see fig. 3), one at $\hbar\omega \sim 0.35$ MeV which is due to the alignment of two $h_{11/2}$ protons, and one at $\hbar\omega \sim 0.55$ MeV which is due to the aligment of two $h_{11/2}$ neutrons.

Bands 2 and 3 are very similar to two bands in ^{124}Ba that were assigned negative parity on the basis of a linear polarization measurement of the linking transitions [12], as well as to the bands 2 and 3 in ^{126}Ce [10]. Our band 2 is also very similar to band 2 observed recenly in the neighboring ^{130}Nd nucleus [7]. Band 3 consists of two sequences of quadrupole transitions connected in the lower part by dipole transitions. Its signature splitting is very small and crossings are observed in both signature partners slightly below and above $\hbar\omega \sim 0.3$ MeV (see fig. 3 (bottom)). The crossing due to the alignment of two $h_{11/2}$ protons is therefore not Pauli blocked, indicating the absence of a $h_{11/2}$ proton in the configuration of band 3. The possible negative-parity two-neutron configurations should involve orbitals identified in the neighboring odd-even ^{131}Nd nucleus [13]: $h_{11/2}[523]7/2^-$, $d_{3/2}[411]1/2^+$ and $d_{5/2}[402]5/2^+$. The small signature splitting of band 3 before the crossing, which is similar to the $d_{5/2}$ band of

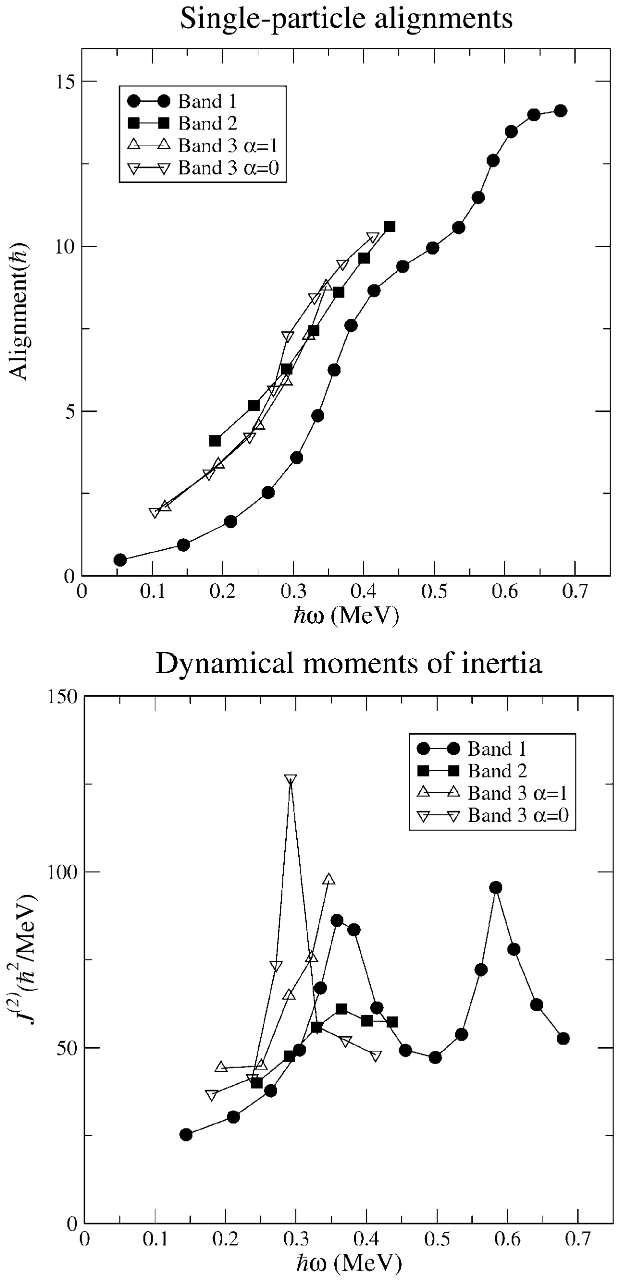

Fig. 3. Single-particle alignments (top) and dynamical moments of inertia (bottom) for the bands observed in ^{128}Nd. The Harris parameters used to extract the angular momentum of the core are $J_0 = 17\hbar^2/\text{MeV}$ and $J_1 = 25\hbar^4/\text{MeV}^3$.

^{131}Nd, strongly suggest a $\nu(h_{11/2}, d_{5/2})$ configuration for this band.

Band 2 is connected to band 1 mainly by the strong 847 keV transition, for which we were not able to extract reliable DCO ratios. The assigned spins and parities indicated in fig. 1 are only temptative, being based on similarities with other bands observed in the neighboring nuclei. However, one can guess that band 2 is based on the remaining negative-parity $\nu(h_{11/2}, d_{3/2})$ configuration involving the favored signature of the $d_{3/2}[411]1/2^+$ orbital, for which we expect a large signature splitting, with the lower partner lying close to the Fermi surface. This can explain therefore the observation of only one sequence of quadrupole transitions in band 1. However, one cannot exclude the intruder $\nu(i_{13/2}, h_{9/2})$ configuration for band 2. In fact, its dynamic moment of inertia is larger than that of the other bands (see fig. 3 (bottom)), having values close to 60 $\hbar^2$/MeV, which are similar to the values of the highly deformed bands in the heavier Nd nuclei. It could also be that the high $J^{(2)}$-values are due to the presence of a crossing in the observed spin range, which would occur at the same frequency as in band 1 (see fig. 3). In both alternative configurations one expects to have the proton crossing at rotational frequencies similar to the that of the first crossing in band 1. Therefore, on the basis of the present data, we could not assign a definite configuration to band 2. More spectroscopic information is necessary to understand the structure of the observed bands, like angular distributions, polarization and lifetime measurements. In order to figure out if there exists a band crossing in band 2, it would be also desirable to extend the side bands to higher spins.

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