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Probing the three shapes in ^{186}Pb using in-beam γ-ray spectroscopy

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Abstract. This measurement represents the first observation of a non-yrast band in the ^{186}Pb nucleus by employing the Recoil-Decay Tagging (RDT) technique. Previously known yrast levels have been confirmed and the band is extended up to level $I^\pi = (16^+)$.

PACS. 27.70.+q $150 \leq A \leq 189$ – 21.10.Re Collective levels – 23.20.Lv γ transitions and level energies – 25.70.Gh Compound nucleus

1 Introduction

Triple shape coexistence in the light Pb region has been an intriguing topic for more than a decade. At the neutron midshell prolate and oblate minima are driven down in energy providing a unique laboratory for nuclear structure studies [1]. In 2000 Andreyev *et al.* [2] carried out an α-decay fine-structure measurement associating the three lowest states ($I^\pi = 0^+$) in ^{186}Pb with three different nuclear shapes. The ground state of ^{190}Po has a mixed character of 2p and 4p-2h configuration (spherical and oblate, respectively). Based on the reduced α-decay widths and on in-beam γ-ray spectroscopy [3,4] the second minimum is associated with prolate shape. To confirm the structure of the third minimum, associated with oblate shape, it would be important to observe the band built above this state.

In-beam spectroscopy of ^{186}Pb has been hindered by 1) γ-ray background from fission and from various open fusion evaporation-reaction channels 2) low cross-section and 3) a relatively long half-life of 4.83(3) s [5] for tagging techniques. So far the examination of this nucleus has been based on recoil-γ^n ($n \geq 2$) coincidence measurements [3,4,6]. Recent improvements in tagging techniques at the Accelerator Laboratory of the University of Jyväskylä (JYFL) have made it possible to explore nuclei under these extreme conditions using the RDT technique.

2 Experimental aspects

Excited states of ^{186}Pb were populated in the ^{106}Pd(^{83}Kr, 3n)^{186}Pb reaction at a beam energy of 355 MeV. The target was a 1 mg/cm^2 thick metallic foil enriched in ^{106}Pd. Prompt γ rays were detected at the target position by the JUROGAM γ-ray spectrometer consisting of 33 EUROGAM Phase1 [7] and 9 GASP-type [8] Compton suppressed Ge detector modules.

Fusion-evaporation residues were separated from the primary beam and transported to the focal plane using the gas filled recoil separator RITU [9]. Recoils were implanted into the Double-Sided Silicon Strip Detectors (DSSSD), which are part of the GREAT [10] focal plane detector set-up. GREAT consists of two DSSSDs to detect the recoils and their decay products, a MultiWire Proportional Counter (MWPC) for energy loss and time-of-flight measurement of the recoils, a box of PIN-diodes to detect escaping α-particles and conversion electrons and a double-sided germanium strip detector for low-energy γ rays.

Data were collected using the Total Data Readout (TDR) system providing minimal dead time [11]. In this method, each channel is run independently and associated in software for event reconstruction. This is made possible by time-stamping each event with a global 100 MHz clock. Data were sorted and $\gamma\gamma$-matrices constructed using the analysis package GRAIN [12], whereas the analysis was completed with the software package RADWARE [13]. Prompt γ rays associated with the observation of a recoil together with a subsequent α decay at the same position

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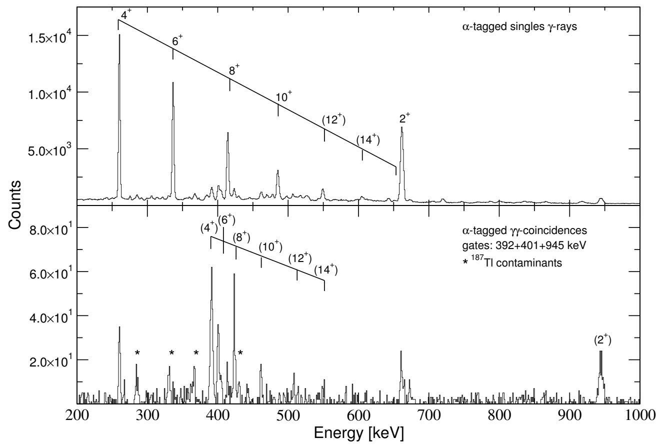

Fig. 1. γ-ray energy spectra measured with JUROGAM. Top: singles γ-ray energy spectrum gated with fusion-evaporation residues and tagged with ^{186}Pb α decays. Bottom: recoil-gated, α-tagged $\gamma\gamma$-coincidence spectrum with a sum of gates on the three lowest non-yrast transitions.

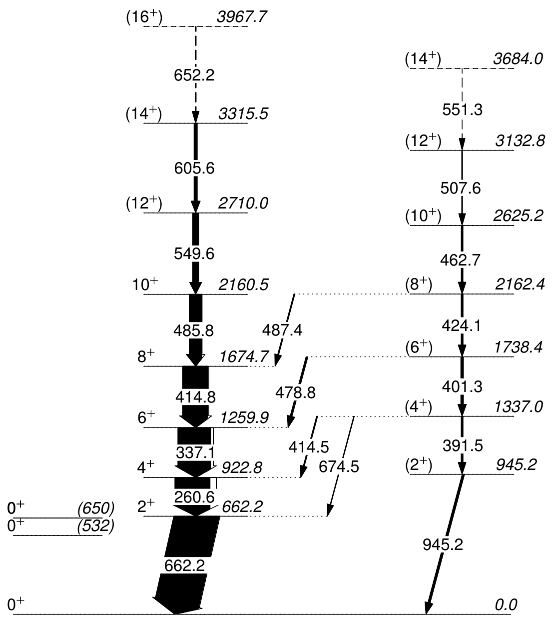

Fig. 2. Partial level scheme of ^{186}Pb deduced from the present data. (The two 0^+ states on the left side are taken from ref. [2].)

in the focal plane DSSSD within 15 s were selected in the data analysis. Escaping α particles within the same time window were collected using a PIN-diode box enhancing the $\gamma\gamma$-coincidence data by $\sim 6\%$. During 151 hours of effective beam time $\sim 1.06 \times 10^6$ α's were recorded. The cross section for the production of ^{186}Pb was estimated to be 185 μb.

3 Results

The power of JUROGAM + RITU + GREAT combined with the TDR system is substantiated in fig. 1, which shows two γ-ray spectra with different gating conditions.

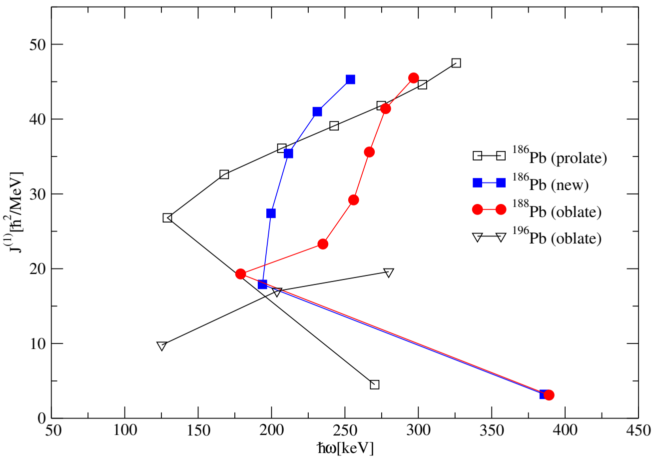

Fig. 3. Kinematic moment of inertia as a function of rotational frequency for a nuclei in the vicinity of ^{186}Pb. Data for other nuclei is taken from refs. [14,15].

The recoil-gated α-tagged γ-ray singles spectrum in the upper part presents the previously known yrast band and its extension up to $I^\pi = (16^+)$. In the lower part a recoil-gated α-tagged $\gamma\gamma$-coincidence condition is employed with a sum of gates on the three lowest non-yrast transitions.

The $\gamma\gamma$-coincidence data, transition energy sums and relative intensity arguments have allowed the level scheme shown in fig. 2 to be constructed. All spin and parity assignments are tentative at the present stage of the analysis.

The kinematic moment of inertia for the new band in ^{186}Pb is plotted in fig. 3 together with those for the prolate band in ^{186}Pb and proposed oblate bands in ^{188}Pb and ^{196}Pb. The behavior of the new band is somewhat similar to that of the oblate band in ^{188}Pb, but its origin is still open to debate.

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