First observation of low-lying strongly-coupled prolate band in neutron-deficient semi-magic ^{187}Pb

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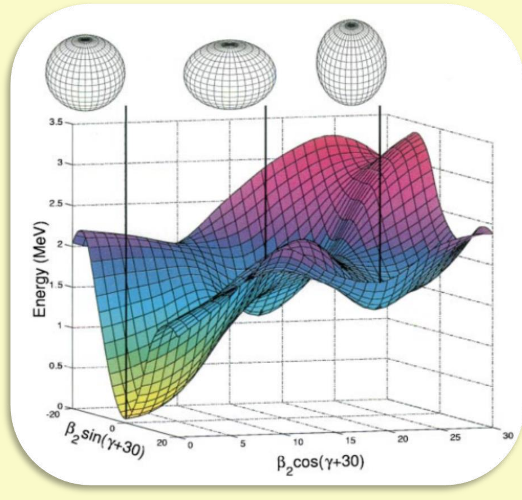
A prompt and delayed γ-ray spectroscopy of neutron-deficient isotope ^{187}Pb has been performed using the recoil-decay tagging and the isomer-decay tagging techniques at Argonne Gas-Filled Analyzer (AGFA). A new 4.66(4) μs isomer and a prolate strongly-coupled band on it were identified. Combining this result with previous studies, evidence for triple shape coexistence at low energy has been found in negative parity configurations in ^{187}Pb.

1. Introduction

The coexistence of different shapes at low excitation energy within the same nucleus is a well-established phenomenon in the vicinity of the closed shells, exhibiting the complexity of nucleus as a quantum many-fermion system. Some of the best examples of shape coexistence are observed in neutron-deficient Pb isotopes in the vicinity of the N = 104 neutron midshell, in which the coexistence at low energy of spherical, oblate and prolate configurations was reported.

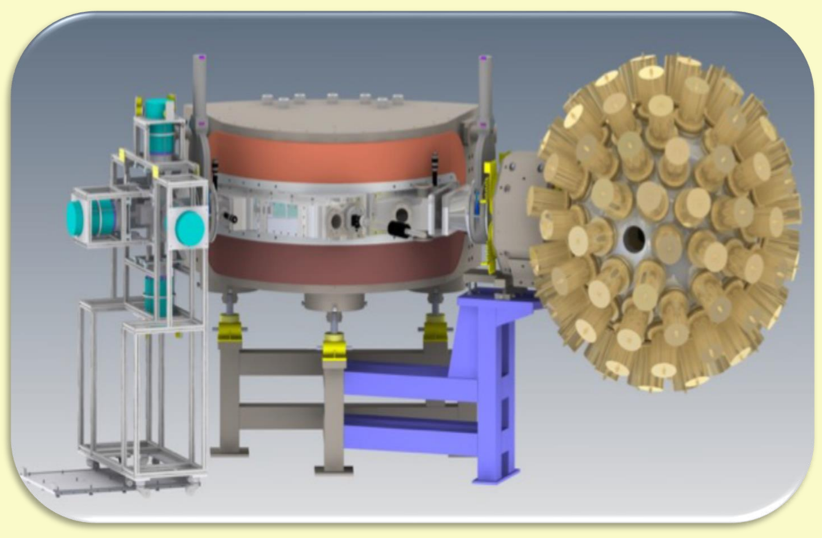


Schematic view of the triplet shape coexistence in ^{186}Pb. A. N. Andreyev, et al., Nature 405, 430 (2000)

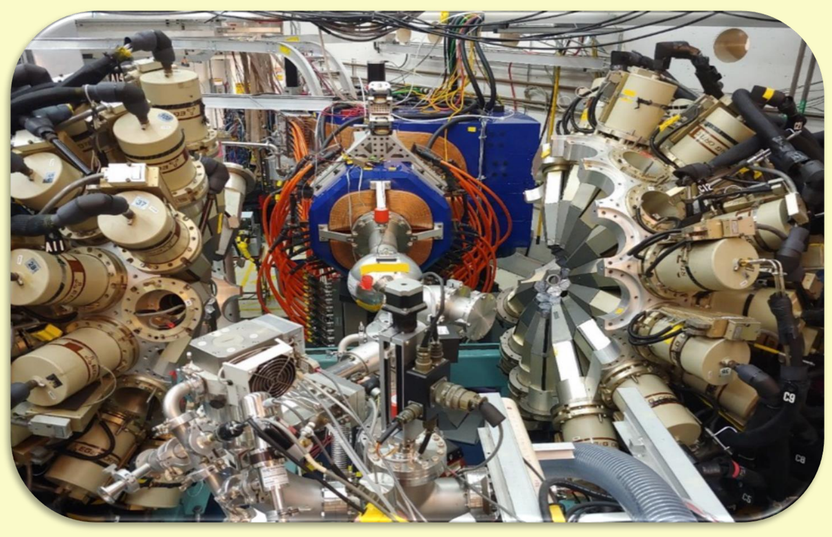
In this Poster, we present the observation of a new microsecond isomeric state with $I^{\pi} = (7/2^-)$ in ^{187}Pb and a prolate rotational band built on this new isomer, leading to a pronounced shape coexistence in ^{187}Pb.

2. Experiment

The experiment was carried out at Argonne Gas-Filled Analyzer (AGFA) , at ANL. The ^{187}Pb nuclei were produced in the ^{142}Nd(^{50}Cr, 2p3n) reaction. The recoil-decay tagging (RDT) and the isomer-decay tagging (IDT) techniques were used to provide unambiguous γ-rays assignment to ^{187}Pb.



Schematic view of the AGFA and the detector system.



The Gammasphere array and target chamber at ANL.

3. Results

The α decay scheme of ^{187m,g}Pb is shown in Fig. 1. The spectrum of delayed γ-rays of ^{187}Pb at the focal plane was shown in Fig. 2. A 308-keV γ-ray was identified as a isomeric decay from a new isomeric state in ^{187}Pb. The half-life of the isomer is extracted to be 4.66(4) μs. Fig. 3(a) and (b) show the prompt γ spectra obtained by tagging on the delayed 308-keV γ line (IDT method, 6220- and 6260-keV (^{187g}Pb) decay line (RDT method), respectively.

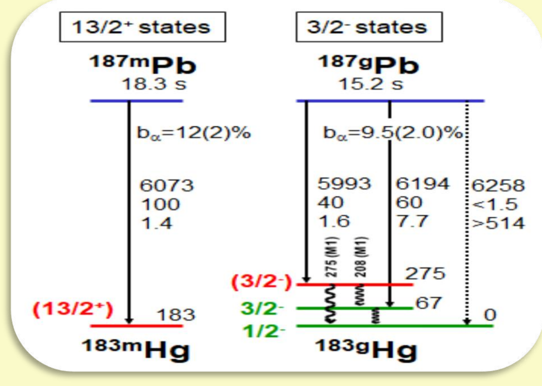


Fig. 1: The α decay scheme of ^{187m,g}Pb.

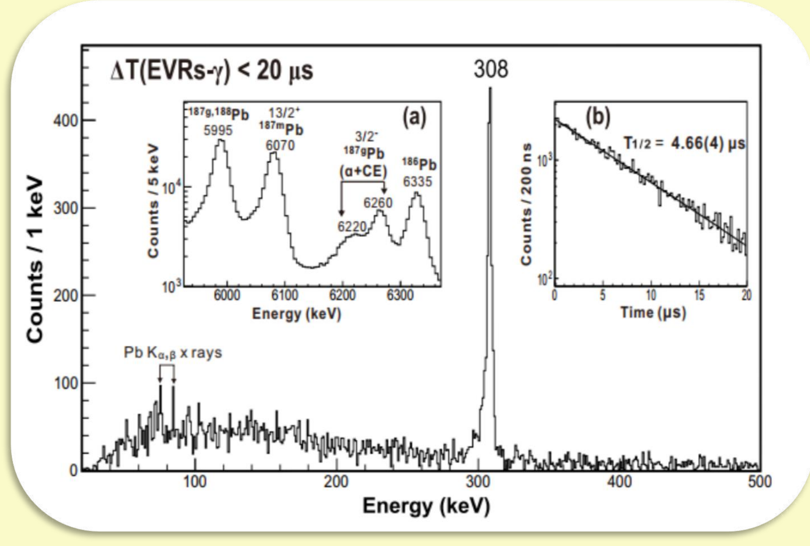


Fig. 2: The delayed γ-ray spectrum of ^{187}Pb. The inset (a) shows a part of the α-decay spectrum. The inset (b) shows the time distribution and associated single exponential fit for the 308-keV decay.

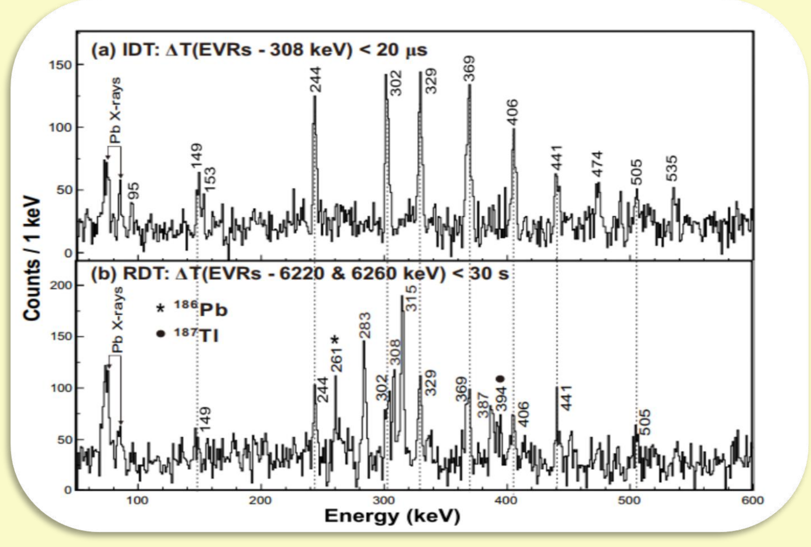


Fig. 3: The prompt γ-ray spectra of ^{187}Pb in GS obtained by tagging on the delayed 308-keV γ line (a) and 6220-6260-keV decay line (b). The contaminations in panel (b) are labeled.

A proposed level scheme of ^{187g}Pb is shown in Fig. 4, representative $\gamma\gamma$ coincidence spectra are given in Fig. 5. A rotational band with two signature branches built on the 4.66 μs isomer was established. Fig. 4 also shows a known strongly-coupled prolate 7/2$^-$[514] band in the isotope ^{185}Hg. A clear similarity between the new Band 1 in ^{187}Pb and the band in ^{185}Hg can be noted, with nearly identical transitions in both bands.

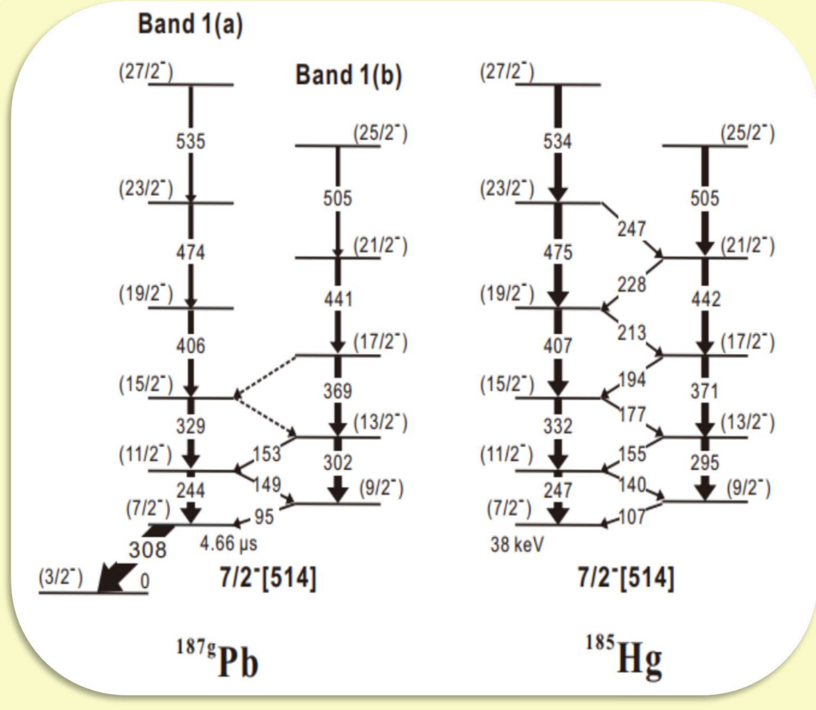


Fig. 4: Proposed level scheme built on ^{187g}Pb and partial level scheme of ^{185}Hg.

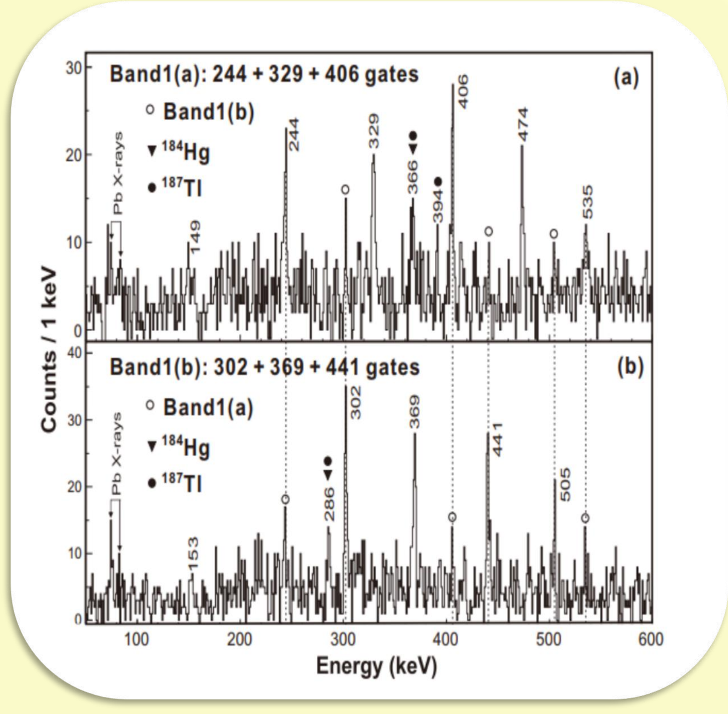


Fig. 5: (a) and (b): Sum-gate spectra of Band 1(a) and 1(b).

4. Discussion

To compare the rotational properties of the (7/2$^-$) bands in ^{187}Pb and ^{183,185}Hg, the experimental aligned angular momenta i and Routhians e' are plotted in Fig. 6. The angular momentum alignment is very similar and gradual at lower rotational frequencies for these 3 cases. The experimental Routhians of these bands are also consistent with each other, further confirming that the three bands are almost identical and the prolate deformation of the (7/2$^-$) bands in ^{187}Pb.

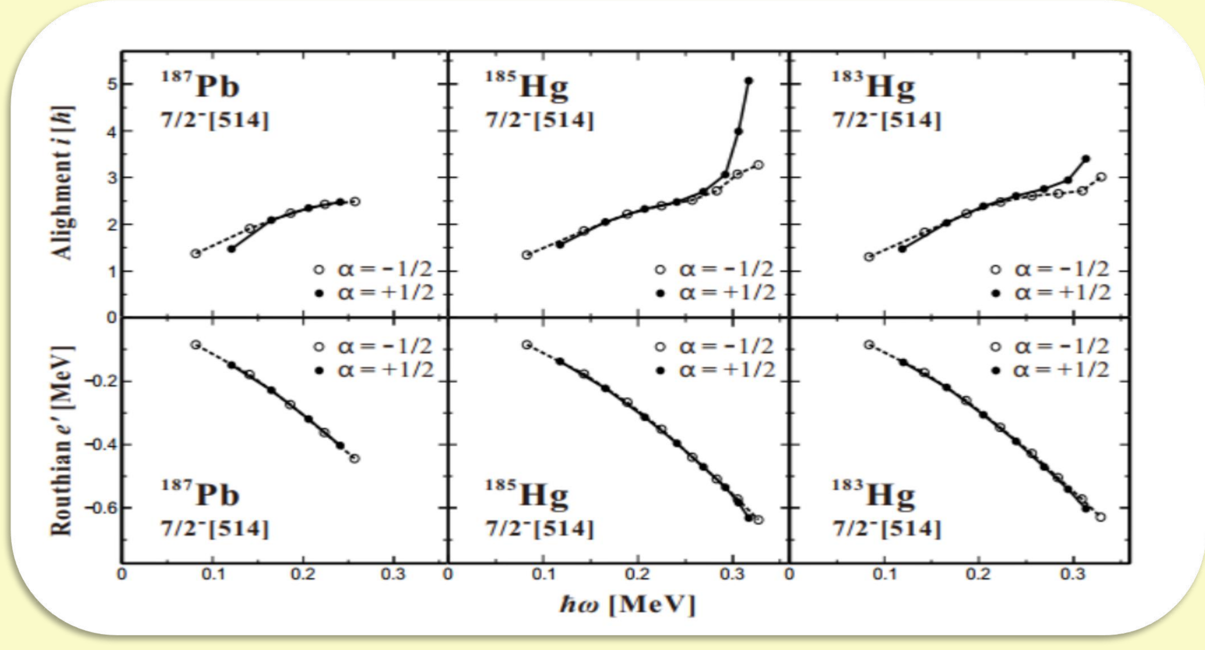


Fig. 6: The aligned angular momenta i (top row) and experimental Routhians (bottom row) of the Band 1 in ^{187}Pb in comparison to the 7/2$^-$[514] bands in ^{183,185}Hg.

To understand better the low-lying states in ^{187}Pb, the PES calculations for $^{183-193}$Pb were performed. Fig. 7 (a) shows the calculated PES for negative parity states in ^{187}Pb, where three coexisting minima - spherical, oblate and prolate can be clearly seen. Fig. 7 (b) compares the calculated and experimental excitation energies, where known, for the lowest negative-parity bandhead states in $^{183-191}$Pb.

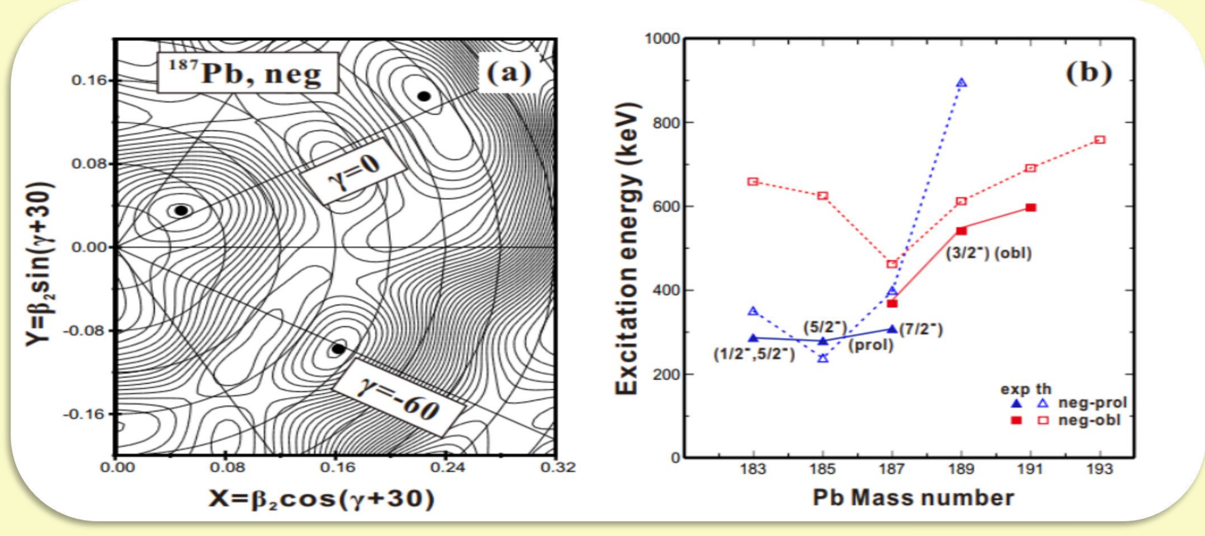


Fig. 7: PES for ^{187}Pb negative parity configurations (a) and the systematics of the excitation energies of shape minima in the light odd-mass lead isotopes (b).

5. Conlusion

In summary, we have established a prolate rotational band on top of the new (7/2$^-$) isomer with a half-life of 4.66(4) μs in ^{187}Pb using the IDT and RDT methods. This band is nearly identical to the prolate strongly coupled 7/2$^-$[514] band in ^{185}Hg. Together with an earlier identification of presumably oblate (3/2$^-$) excited state at 375 keV, the phenomenon of triple shape coexistence in now established for the negative parity states in ^{187}Pb, as it was earlier proposed for the positive parity states.