New structure features revealed in isomeric spectroscopy in the $Z \sim 82$, $N \sim 104$ region

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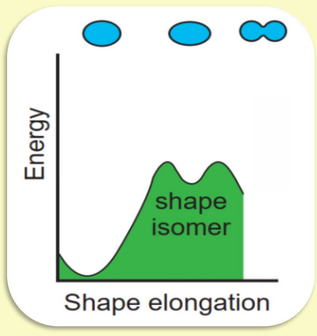
A prompt and delayed γ-ray spectroscopy of the ^{187}Pb, ^{183}Hg and ^{188}Bi isotopes produced in the reaction ^{50}Cr + ^{142}Nd -> ^{192}Po* has been performed at the Argonne Gas-Filled Analyzer. Several new isomers were identified and new structure features by the isomeric study were revealed in these isotopes in the $Z \sim 82$, $N \sim 104$ region.

1. Introduction

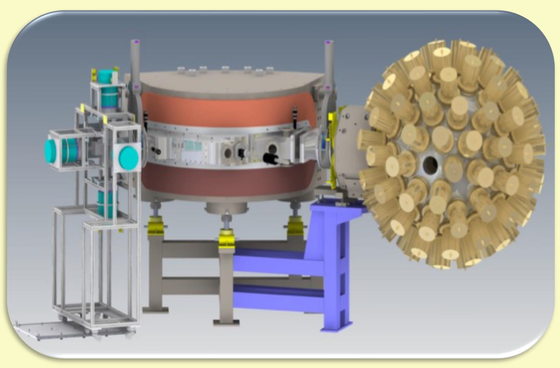
Isomeric states, first observed about 100 years ago , play an important role in nuclear physics. For shape isomers, the hindrance mainly results from the distinct shape change between initial and final states. Neutron-deficient nuclei around mid-shell at $N \sim 104$ in the lead region provide many examples of shape coexistence and shape isomers. Furthermore, a global study based on the macroscopic-microscopic model predicted that an island of shape-isomers exist around in this nuclear region.



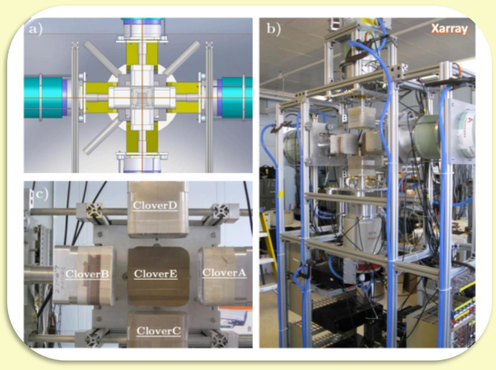
Schematic view of shape isomer.
P. Walker, et al., Nature 399, 6731 (1999).

2. Experiment

The experiment was carried out at Argonne Gas-Filled Analyzer (AGFA) , at ANL. The ^{187}Pb, ^{183}Hg and ^{188}Bi nuclei were produced in the ^{50}Cr + ^{142}Nd ->^{192}Po* reaction. Prompt γ rays at the target position were detected by the Gammasphere (GS) array. Four clover HPGe detectors (X-array) were installed surrounding the DSSD chamber for the isomeric γ-ray measurements.



Schematic view of the AGFA and the detector system.



The X-array at ANL.

3. A shape isomer and triple shape coexistence in ^{187}Pb

In ^{187}Pb, a new 5.15(15)-μs isomeric state at 308 keV above the spherical $3/2^-$ ground state (gs) was identified, see Fig .1. A strongly-coupled band is observed on top of this isomer, which is nearly identical to the one built on the prolate $7/2^-[514]$ Nilsson state in the isotone ^{185}Hg, as shown in Fig .2. Based on this similarity and on the result of the potential-energy surface calculations presented in Fig .3, the new isomer in ^{187}Pb was proposed to be prolate with $J^\pi = 7/2^-$ and classified as a shape isomer. The retarded character of the 308-keV transition with a deduced $B(E2) = 5.6(2) \times 10^{-4}$ W.u. can be well explained by the significant difference between the prolate bandhead and spherical gs. Taken together with an earlier identification of a presumably oblate $(3/2^-_2)$ excited state at 375 keV, triple shape coexistence is now established for the negative-parity states in ^{187}Pb.

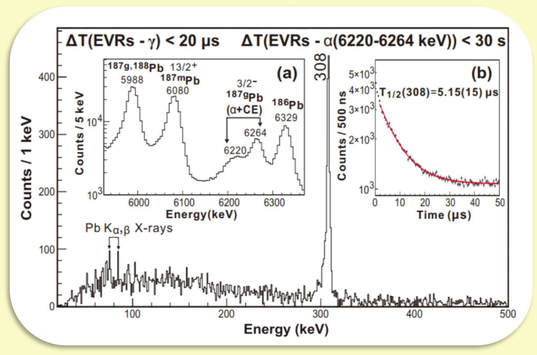


Fig. 1: The delayed γ-ray spectrum of ^{187}Pb. The inset (a) shows a part of the α-decay spectrum. The inset (b) shows the associated fitting for the half-life of the 308-keV decay.

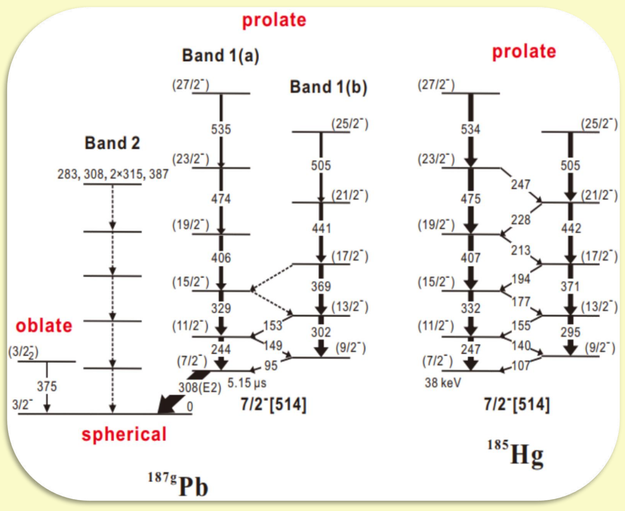


Fig. 2: Proposed level scheme built on ^{187g}Pb and partial level scheme of ^{185}Hg.

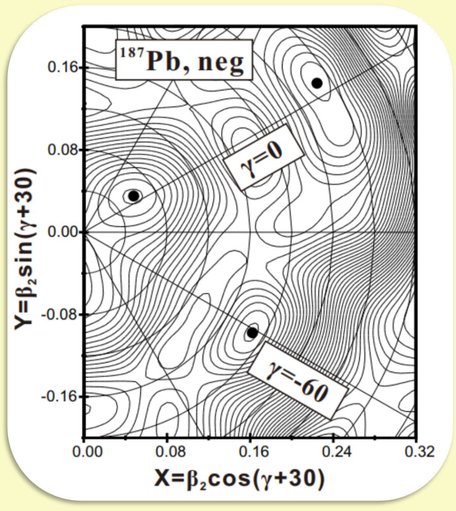


Fig. 3: Potential-energy surface for ^{187}Pb negative-parity configurations.

4. A shape isomer in ^{183}Hg

In ^{183}Hg, the decay of the nearly spherical $13/2^+$ isomeric state was first observed following the α decay of the $13/2^+$ isomer in ^{187}Pb. Figure 4 shows the delayed spectrum obtained by the $\alpha - \gamma$ delayed correlation. a 105-keV $M1$ transition was identified as originating from a new isomer in ^{183}Hg, and the half-life of this isomer was measured to be $T_{1/2}$ = 290(30) μs. This isomer was proposed to deexcite by a retarded $M2$ transition, which can be explained by the notable shape change between the initial prolate state and the final nearly-spherical state, see Fig 5. Furthemore, Fig .5 also shows the systematics for the decays of the $13/2^+$ isomers in odd-A $^{175-185}$Hg.

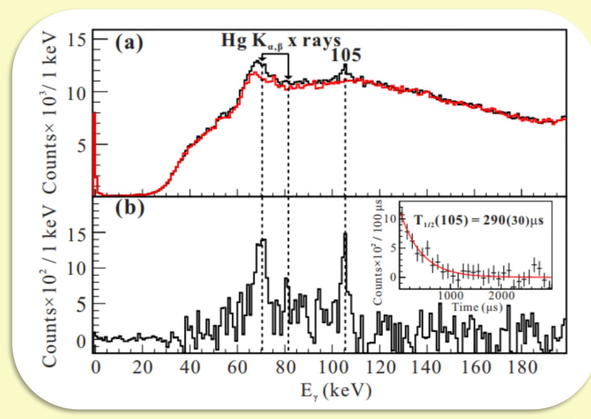


Fig. 4: (a) The γ-ray energy spectrum (black) collected within the delayed-time window and the background spectrum (red) tagged by a random-time window. (b) The background subtracted γ-ray energy spectrum. The inset of panel (b) shows the the corresponding half-life fitting for the isomer.

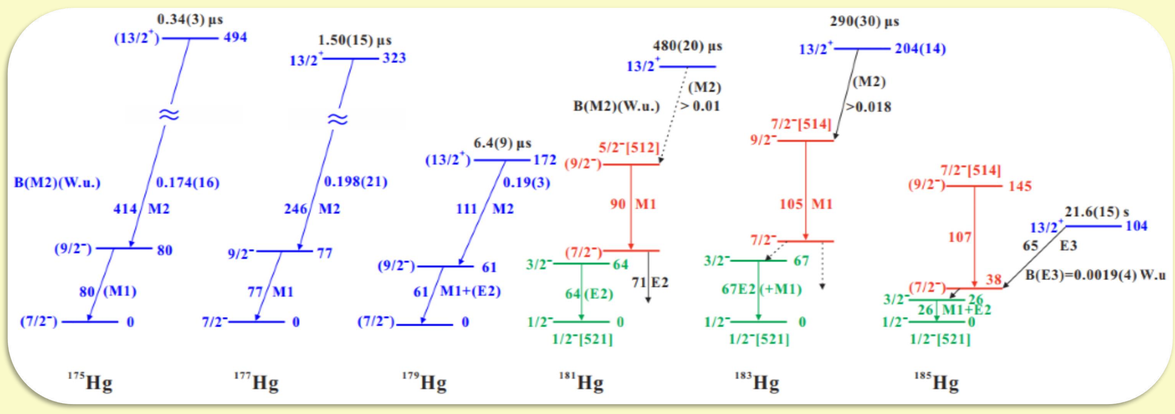


Fig. 5: The decay paths of the $13/2^+$ isomers in odd-A $^{175-185}$Hg. Different structures/bands are shown in different colors, all near-spherical states are drawn in blue. In ^{175,177,179}Hg, the gs and the first excited states are proposed to be near-spherical. In ^{181,183,185}Hg, the prolate $1/2^-[521]$ gs bands are shown in green, while the $5/2^-[512]$ and $7/2^-[514]$ prolate bands are plotted in red. The Weisskopf single-particle transition probabilities of the decays deexciting the $13/2^+$ isomers are shown.

5. A new isomer and excited states in ^{188}Bi

A new 0.25(5)-μs isomeric state decaying via 52-, 81-, 143- and 243-keV transitions to the (10^-) ^{188m}Bi was identified. However, due to the lack of statistics, we cannot prove any $\gamma\gamma$ coincidences between the 52-, 81-, 143- and 243-keV γ rays. Therefore the decay scheme cannot be established. Furthermore, several prompt γ rays were identified and assigned to the (10^-) ^{188m}Bi and $1^{(+)}$ ^{188g}Bi. All of these delayed and prompt γ rays are schematically shown in Fig. 6. The partial level schemes for neighboring ^{187,189}Bi are also shown in Fig. 6, and the prompt 319-366-462-keV cascade in ^{188m}Bi could show a similarity to the decoupled prolate rotational bands in ^{187,189}Bi.

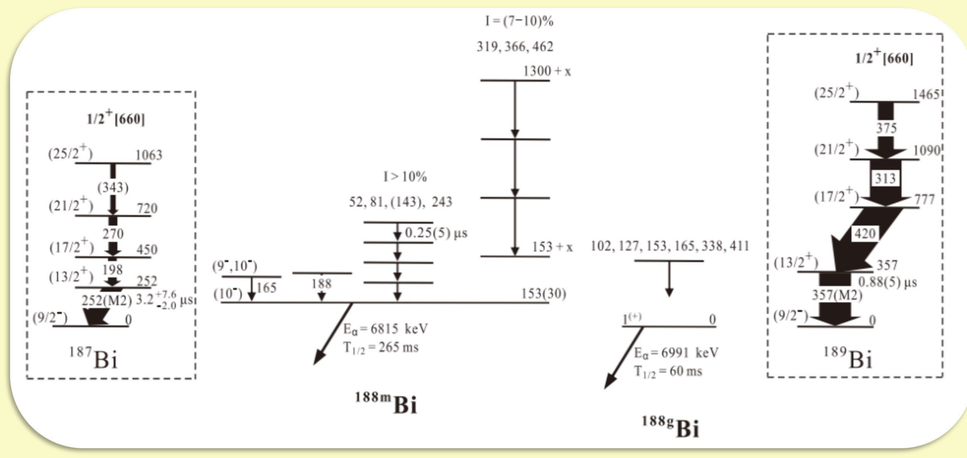


Fig. 6: Proposed decay scheme for ^{188}Bi and partial level schemes for ^{187,189}Bi.

6. Conlusion

In short, the ^{187}Pb, ^{183}Hg and ^{188}Bi in the Z~82, N~104 region display new structure characters by the present work. A shape isomer was identified and a triple shape coexistence in negative-parity states is established in ^{187}Pb. Meanwhile the decay of the $13/2^+$ isomeric state in ^{183}Hg was identified for the first time, and the isomer was also classified as a shape isomer. A new 0.25(5)-μs isomer and a prompt cascade were identified above the ^{188m}Bi, and a number of γ rays were also observed on top of ^{188g}Bi.