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Abstract:

Systematic investigations of the shape transitional nuclei ^{186}Pt to ^{194}Pt by $(\alpha, xn\gamma)$ reactions have revealed a rich variety of high-spin structural phenomena, which can be qualitatively understood in terms of rotation alignment coupling and the interplay between collective and single particle excitation modes. Acute backbending in the positive parity yrast sequences of 188, 190, 192, ^{194}Pt is attributed to the intersection of rotation aligned $(\nu i^{-2}_{13/2})$ and $(\pi h^{-2}_{11/2})$ bands with the ground bands.

The level structure of the nuclei $^{186-194}Pt$, which span an important nuclear shape transition region, has been intensively studied by $(\alpha,xn\gamma)$ spectroscopy. In this Letter we wish to focus attention on several striking systematic aspects of the dominant low-lying high-spin excitation modes in these nuclei, which include

i) well decoupled $\nu i^{-1}_{13/2}$ bands in all the odd-A nuclei which indicate that the A $\geq$ 187 Pt nuclei are basically oblate

ii) backbending behavior at about spin 10 in the positive parity yrast sequences of all the even nuclei, which becomes increasingly more pronounced from ^{186}Pt to ^{192}Pt

iii) semidecoupled 5^- bands occurring systematically across the even Pt nuclei

iv) related $21/2^{(-)}$ bands in the odd Pt nuclei, which can be attributed to the coupling of an $i_{13/2}$ neutron hole with the members of the aforementioned 5^- bands.

The experiments were performed by bombarding isotopically enriched ^{192}Os(98%), ^{190}Os(95%), ^{188}Os(87%) and ^{186}Os(62%) targets with 28-50 MeV α-particle beams from the Michigan State University cyclotron. The techniques employed included comprehensive prompt and delayed γ-ray singles and $\gamma\gamma$ coincidence measurements, lifetime measurements, γ-ray angular distribution and excitation function determinations. On the basis of the results, extensive level schemes incorporating a wealth of new spectroscopic information have been constructed. For $^{186,188,190,192}Pt$ we generally confirm earlier results[1,2], which were however incomplete and limited to levels with spins $\leq$ 10. Nothing was previously known about the high-spin level structure of the odd Pt nuclei. Our data for ^{194}Pt are much less extensive than for the other nuclei, since the $(\alpha,2n)$ reaction only could be studied, and our proposed level scheme is based in part on earlier radioactivity findings[3,4].

The detailed results for the nine nuclei studied will be presented in forthcoming publications and the simplified level schemes of Fig. 1 display only the main systematic features of the level spectra. In the odd Pt nuclei, the $13/2^+$ states are low-lying isomers but in Fig. 1 they are displaced to zero excitation energy in order to accentuate the strong correlation between the energy spacings in the $\nu i^{-1}_{13/2}$ decoupled bands and the ground bands of the adjacent core nuclei. Since in this region the low-Ω orbits of the $i_{13/2}$ subshell are close to the Fermi surface only for negative values of β, the observation of these decoupled bands implies oblate deformations for the $A \geq 187$ Pt nuclei[5]. This conclusion must be qualified by a recognition that there is growing evidence for triaxial nuclear shapes in this region[6], and in ongoing investigations we are exploring the possibility of explaining the many positive parity levels observed in the odd Pt nuclei (see below) in terms of the coupling of an $i_{13/2}$ neutron hole to a triaxially deformed core.

The energy spacings in the positive parity yrast sequences of the even-A nuclei are most remarkable, particularly those of ^{190}Pt and ^{192}Pt, which have the appearance of extreme backbending type structures[7]. We have determined the half-lives of the 12^+ states in ^{190}Pt and ^{192}Pt to be $\sim$ 1.5 and 3.5 ns respectively, corresponding to $B(E2; 12^+ \rightarrow 10^+)$ values for the 192 and 105 keV transitions of about 15 and 39 single particle units (s.p.u.), which are appreciably smaller than the $B(E2; 2^+ \rightarrow 0^+)$ values of 70-80 s.p.u. reported for these nuclei[8]. In an earlier study[4], the B(E2) for the 339 keV $10^+ \rightarrow 8^+$ transition in ^{194}Pt has been estimated to be about 0.2 s.p.u. In all the even Pt nuclei the 2^+, 4^+, 6^+ and 8^+ levels are interpreted as ground band members since their energies are readily fitted with a VMI treatment. However, the 10^+ and 12^+ levels in ^{190}Pt, ^{192}Pt and ^{194}Pt are rather clearly of a different character and the clustering of the levels strongly suggests that they involve the stretch coupling of two high-j particles (holes). In this region, the most probable such configurations are $(\nu i_{13/2}^{-2})$, which gives rise to almost degenerate 10^+ and 12^+ states in light Pb nuclei[9], and $(\pi h_{11/2}^{-2})$, which is believed to dominate the composition of closely spaced 8^+ and 10^+ states observed at ~ 2.5 MeV in A > 190 Hg nuclei[10].

While a first glance at Fig. 1 might suggest that the $(\nu i_{13/2}^{-2})$ configuration alone is of importance in the Pt nuclei, more detailed consideration of the level systematics leads us to conclude that the $(\pi h_{11/2}^{-2})$ configuration is very probably also involved. Specifically, we propose that the isomeric 10^+ state in ^{194}Pt is predominantly of this two proton hole character and that the retardation of the 339 keV transition is attributable to the different natures of the 8^+ and 10^+ states. The close resemblance between the energy level irregularities in the ^{193}Pt $\nu i_{13/2}^{-1}$ decoupled band and the positive parity yrast sequence in the ^{194}Pt core nucleus implies the absence of $\nu i_{13/2}$ blocking effects and so one can conclude that the ^{194}Pt 10^+ state has a dominant intrinsic structure other than $(\nu i_{13/2}^{-2})$; this is almost certainly $(\pi h_{11/2}^{-2})$.

There appears to be every reason to expect the $(\pi h_{11/2}^{-2})$ excitation to occur at about 2.5 MeV in ^{190}Pt and ^{192}Pt as well as in ^{194}Pt since the three isotopes obviously differ only slightly in deformation. Possible 8^+ levels just below the $(\pi h_{11/2}^{-2})$ 10^+ levels would be populated very weakly at best in the yrast cascades because the de-excitation branches to the much lower-lying 8^+ ground band members are heavily favored by the $(E_\gamma)^5$ dependence of the transition probabilities. In fact, additional 10^+ levels have been located between the 10^+ and 12^+ levels of ^{188}Pt, ^{190}Pt and ^{192}Pt shown in Fig. 1. Fig. 2 displays a particularly interesting portion of the ^{190}Pt level spectrum, in which three 10^+ levels lying within a 168 keV interval have been established. The likely dominant intrinsic configurations appear to be $(\pi h_{11/2}^{-2})$ for the 2536 keV level and $(\nu i_{13/2}^{-2})$ for the close-lying 2702 keV 10^+ and 2727 keV 12^+ levels, while the 2604 keV level occurs near the expected energy of the 10^+ member of the ground band. Similarly, in ^{192}Pt the 12^+ level shown in Fig. 1 and a second 10^+ level observed 41 keV below it may be basically attributed to $(\nu i_{13/2}^{-2})$ and the lowest 10^+ level to $(\pi h_{11/2}^{-2})$. (Not surprisingly, the 10^+ ground band member expected at higher energy in this nucleus was not experimentally observed). Mixing between the 10^+ and 12^+ levels of the ground bands, the $(\pi h_{11/2}^{-2})$ and the $(\nu i_{13/2}^{-2})$ structures is expected. It can be shown by a simple three band mixing calculation that the mixing can account for the observed enhanced $12^+ \rightarrow 10^+$ transition rates in ^{190}Pt and ^{192}Pt and also for the relative intensities of the 123 and 192 keV γ-rays in ^{190}Pt (see Fig. 2). The structure of the bands built on the 12^+ yrast states in ^{190}Pt and ^{192}Pt provides further support for the proposed dominant $(\nu i_{13/2}^{-2})$ composition of these states. In the framework of the rotation alignment scheme, the angular momentum of the $(\nu i_{13/2}^{-2})$ J=12 configuration should be almost completely aligned by the Coriolis force along the nuclear rotation axis and the energy spacings in the rotation aligned bands built on these 12^+ states should resemble those of the ground bands of the core nuclei, just as is observed experimentally (Fig. 1).

The less dramatic energy level irregularities observed in ^{188}Pt are consistent with the foregoing interpretation. Here the lowest 10^+ level is probably now the ground band member, while the 12^+ level and a 10^+ level located 65 keV below it are tentatively assigned to the $(\nu i_{13/2}^{-2})$ configuration. Our proposal is that the pattern of backbending behavior in the series of even Pt nuclei (A = 188-194) is determined by the intersection of rotation aligned bands built on the $(\nu i_{13/2}^{-2})$ and $(\pi h_{11/2}^{-2})$ structures with the "normal" ground bands. While the energies of the two-hole structures remain fairly constant, the ground band moment-of-inertia decreases with increasing A, so that intersection occurs towards lower spin values as A increases. The overall picture brings to mind vividly the Stephens-Simon explanation[11] of backbending in well deformed prolate rare earth nuclei.

The lower levels in the ^{186}Pt ground band indicate that it is a fairly good rotational nucleus and it may well have prolate deformation[8,12]. At present, we report the gentle but definite backbending above the 10^+ ground band member as an experimental observation, without speculating as to which of several possible effects give rise to it.

Newly discovered $(10)^-$ isomers with half-lives of 47 and 230 ns located at 2298 and 2172 keV in ^{190}Pt and ^{192}Pt respectively are not included in Fig. 1 since a search for corresponding isomers in ^{188}Pt and ^{194}Pt proved fruitless. A fairly good case can be made for interpreting these as shape isomers analogous to the known[13] 9/2[505]ν, 11/2[615]ν 10^- isomer in ^{190}Os but firm assignments must await g-factor determinations. There is now no ambiguity about the parity of the 5^-, 7^-.... levels in the Pt nuclei. The 584 and 894 keV transitions in ^{188}Pt are known to be of E1 multipolarity[1], and in the present work, an analysis of the delayed γ-ray spectra accumulated between beam-bursts showed that the 344 and 153 keV transitions in ^{190}Pt and ^{192}Pt are also E1 in character. Recent model calculations by Vogel et al[14], incorporating our suggestion that the intrinsic structure of these states is dominated by two-quasiparticle components involving a decoupled $i_{13/2}$ neutron and a low-j neutron partner[2], have successfully reproduced the 5^-, 7^-, 9^-.... level ordering and enhanced B(E2) values observed in even Hg nuclei. Configurations of the type ($\pi h_{11/2}$, πj) may also contribute[10]. Undoubtedly a similar semidecoupled band description applies also to the 5^- bands seen across the Pt nuclei and it is noteworthy that unfavored even-spin band members, displaced towards higher energies in line with the theoretical predictions[14], have also been identified in the present work. The fact that the 5^- bands lie several hundred keV lower in the Pt nuclei than in the corresponding Hg isotones seems consistent with the occurrence of $(\nu i_{13/2}^{-2})$ excitations at lower energies in Pt than in Hg nuclei.

The $21/2^{(-)}$ levels in the odd Pt nuclei de-excite to the $21/2^+$ members of the decoupled bands and through several additional pathways, not shown in Fig. 1, involving unfavored members of the $i_{13/2}$ bands and other high-spin positive parity states. While the parity of the $21/2^{(-)}$, $25/2^{(-)}$, $27/2^{(-)}$ and $29/2^{(-)}$ levels has not been clearly established in our measurements, these sequences very probably correspond to the bands starting at $21/2^{(-)}$ seen in odd Hg nuclei, which have been attributed to combinations of the $\nu i_{13/2}^{-1}$ state with the 5^-, 7^-,.... states seen in the neighboring even nuclei[15,5]. The spin of 21/2 arises[5] because the second $i_{13/2}$ neutron can only be aligned to a maximum spin of 11/2. The clear parallel trends in excitation energy and the structural similarities between the 5^- bands in the even Pt and the $21/2^{(-)}$ bands in the odd Pt nuclei provide convincing and substantive support for the validity of this interpretation.

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Footnotes and References

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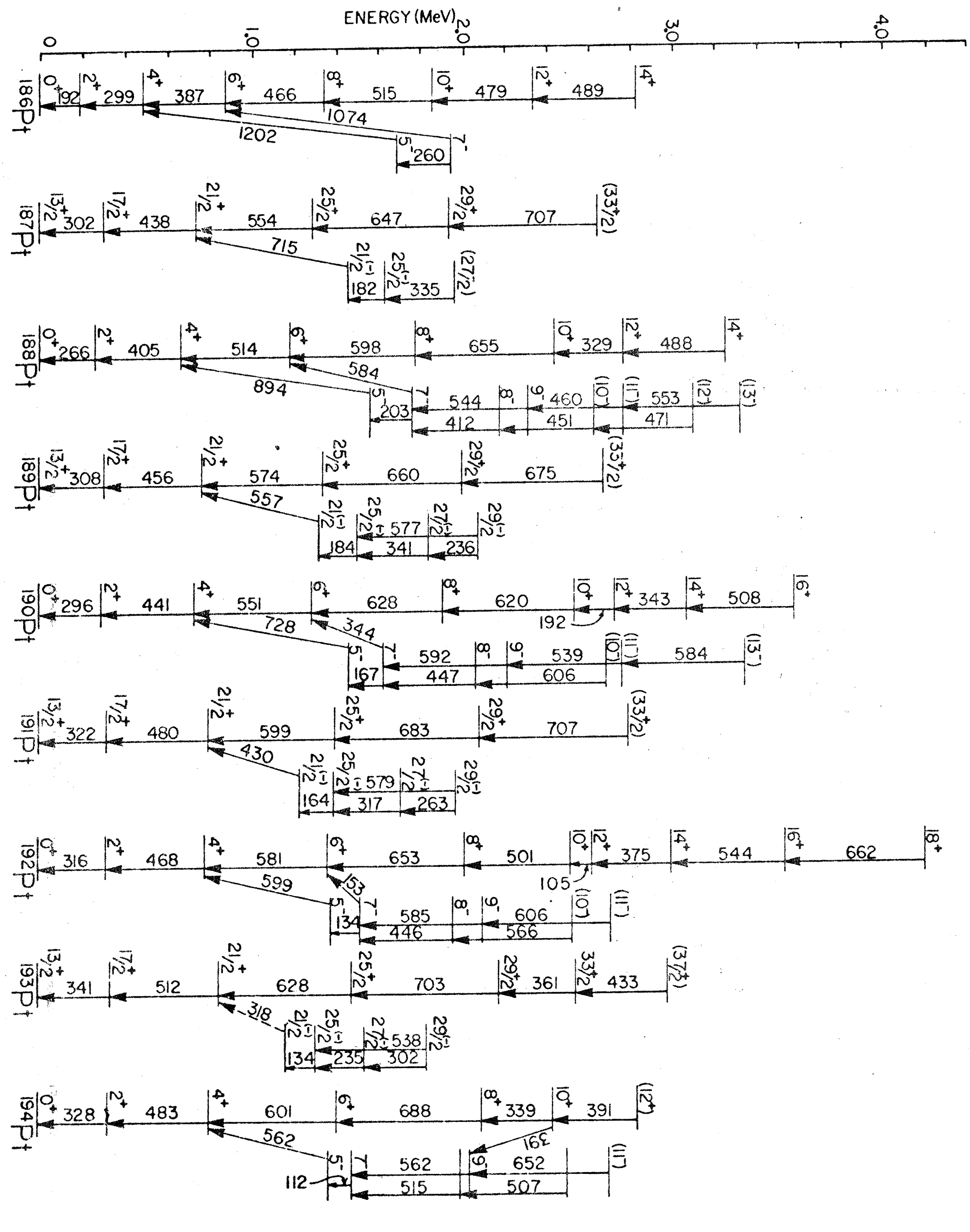
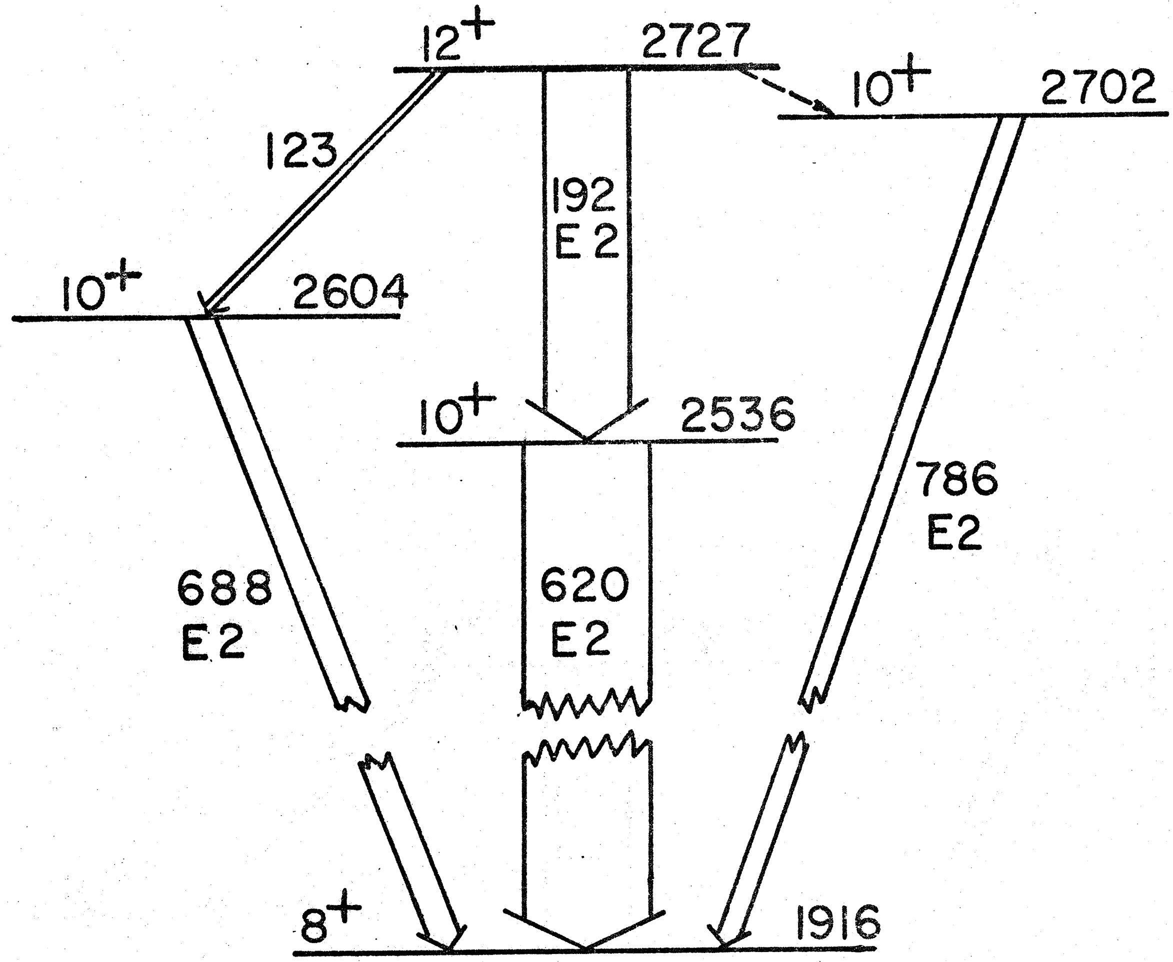
Figure Captions

Fig. 1. Level schemes of the nuclei $^{186-194}Pt$. Transition energies are given in keV. The $13/2^+$ states in the odd-A nuclei are low-lying isomers and not the ground states of these nuclei.

Fig. 2. A detail of the ^{190}Pt level scheme showing the three 10^+ states located.



ENERGY (MeV)
0
1.0
2.0
3.0
4.0
186Pt
187Pt
188Pt
189Pt
190Pt
191Pt
192Pt
193Pt
194Pt


12+
2727
10+
2702
123
192
E 2
10+
2604
10+
2536
786
E2
688
E2
620
E2
8+
1916