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# Weak coupling in $^{143}$Nd

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High-spin states of $^{143}$Nd have been studied using the $^{130}$Te($^{18}$O,5$n$) reaction at 85 MeV. The yrast states observed up to a tentatively assigned spin of 45/2 can be described in a remarkably simple way by the weak coupling of an $f_{7/2}$ neutron to the $^{142}$Nd core nucleus. Our results demonstrate that $^{143}$Nd is one of the best known examples of weak coupling at high angular momentum.

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The $N=83$ isotopes are some of the best candidates in the Periodic Table for weak coupling. Low-energy states in the semimagic $N=82$ nuclei are generated primarily by excitations of their valence protons (for example, see [1,2]). Consequently, the valence neutron of an $N=83$ nucleus should not interfere with the excited states of its $N=82$ core, and the coupling between the valence neutron and the core may be weak. Caussyn *et al.* [3] demonstrated that the yrast states of the $N=83$ isotope $^{143}$Nd up to $J=33/2$ could be explained by the weak coupling of $f_{7/2}$ and $i_{13/2}$ neutrons, although it was not clear which of these two neutrons was responsible for a number of the states reported in that work. Piiparinen *et al.* [4] have proposed that in the $N=83$ isotone $^{145}$Sm, yrast states up to $J=25/2$ can be explained with the $f_{7/2}$ neutron alone, suggesting that the structure of $^{143}$Nd may be even simpler than that proposed in Ref. [3]. In this paper, we report on a $\gamma$-$\gamma$ coincidence study of high-spin states in $^{143}$Nd. The results we report here suggest that the yrast states in $^{143}$Nd can be explained by weakly coupling the $f_{7/2}$ neutron to the $^{142}$Nd core even at spins as high as 45/2. As a result, $^{143}$Nd appears to be one of the best examples known of weak coupling at high spins.

The nucleus $^{143}$Nd was produced using the $^{130}$Te($^{18}$O,5$n$) reaction at 85 MeV with a thick target of enriched $^{130}$Te. The $^{18}$O beam was produced by the Florida State University Superconducting Linear Accelerator. The $\gamma$-$\gamma$ coincidence data were taken with the Florida State University–University of Pittsburgh array [5], which consisted of 8 Compton-suppressed Ge $\gamma$-ray detectors for this experiment. Spectra gated on two of the $\gamma$ rays placed in the level scheme (339 and 570 keV) are shown in Fig. 1. Spin assignments for the new states in $^{143}$Nd were made using directional correlations of oriented nuclei (DCO) ratios extracted from the $\gamma$-$\gamma$ coincidence data.

The level scheme deduced in the present work is shown in Fig. 2, and includes 27 new states and 45 new $\gamma$ rays. This new level scheme agrees with that presented in Refs. [3,6] up to the $29/2^+$ state at 4635 keV. The previous level scheme [3,6] includes five $\gamma$ rays (215, 365, 428, 448, and 495 keV) above the 4635 keV state. These $\gamma$ rays are included in the present level scheme as well, although the arrangement for the 215, 448, and 495 keV $\gamma$ rays is different here than in Refs. [3,6]. In addition, the present level scheme includes levels up to 10756 keV and a number of new nonyrast levels at energies as low as 3620 keV. These low-energy nonyrast levels were not observed in the $^{140}$Ce($\alpha$,$n$) study of Wrzesinski *et al.* [7].

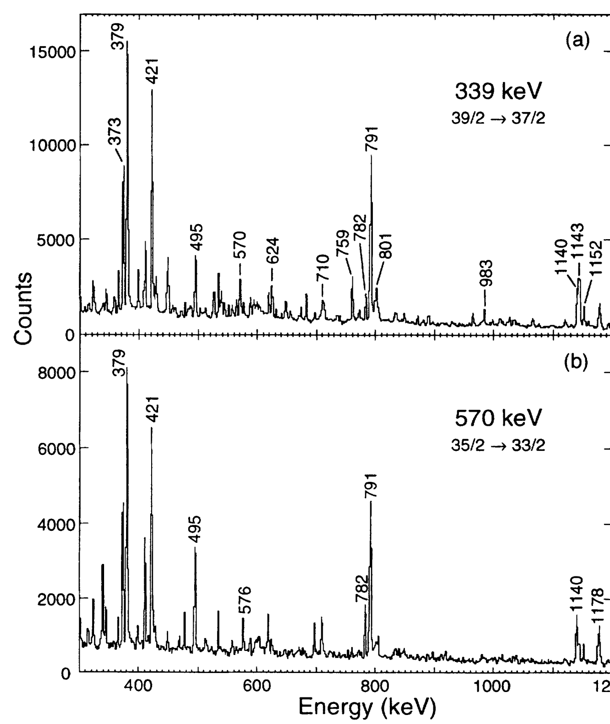


FIG. 1. Background-corrected $\gamma$-ray spectra gated on the (a) 339 keV and (b) 570 keV transitions.

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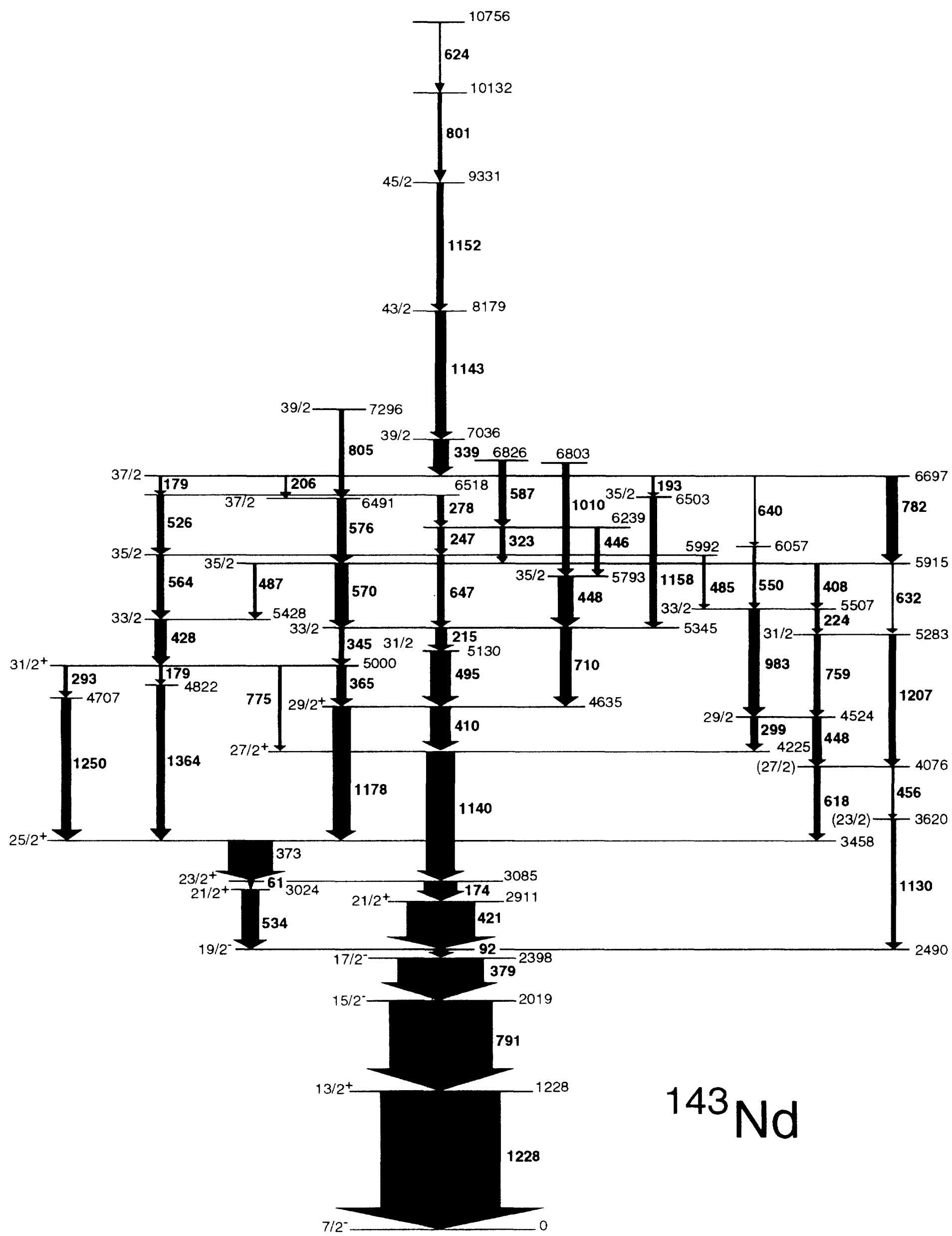


FIG. 2. Level scheme of $^{143}$Nd deduced in the present work.

The spin assignments for the previously known states up to the 4635 keV state were determined [6] on the basis of $\gamma$-ray angular distribution data, and parity assignments were made up to the same state (with the exception of the 3024 keV state) using the electron conversion coefficients reported in Ref. [3]. The parity assignment for the 3024 keV state is made here on the basis of evidence for the 61 keV transition populating it. The 373 keV $\gamma$ ray appears in the spectrum obtained by gating on the 534 keV $\gamma$ ray, although the 61 keV $\gamma$ ray is only weakly observed in that gate. To account for the intensity of the 373 keV transition observed in the 534 keV gate, the 61 keV transition must have a larger electron conversion coefficient than that of an $E1$ transition of that energy. Therefore, the transition must have $M1$, $E2$, or mixed $M1/E2$ character, and the 3024 keV state must have the same parity as the 3085 keV state, which is positive.

The spin assignments proposed for states above 4635 keV are based on DCO ratios measured here, for which the analysis is performed using the method described in Ref. [8]. The DCO analysis required observing the $\gamma$ rays of interest in gates on stretched quadrupole transitions, only two of which were previously known (the 1140 and 1178 keV transitions). Consequently, the DCO analysis was performed only for $\gamma$ rays which can be seen in the gates on the 1140 or 1178 keV transitions. Our primary reservation concerning the spin assignments for the new states is that it is possible that one of the few transitions which we assign to be stretched quadrupole might instead be a mixed $M1/E2$ transition with the specific admixture that gives a DCO ratio identical to that of a stretched quadrupole transition. While this is unlikely, it cannot be dismissed.

Figure 3 compares the present results on yrast states in

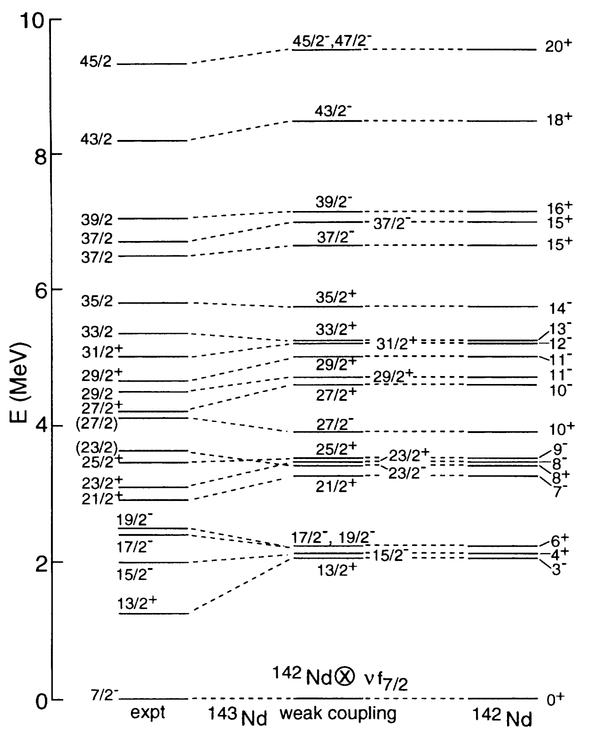


FIG. 3. A comparison of the yrast states (and several nonyrast states) seen in $^{143}$Nd with the predictions of a simple weak coupling model described in the text. The corresponding states of $^{142}$Nd [1,2] are also illustrated.

$^{143}$Nd to a simple weak coupling picture in which these states arise from the coupling of an $f_{7/2}$ neutron to states in the $^{142}$Nd core nucleus. In addition, a number of nonyrast states in $^{143}$Nd are included because they are also easily identified with states in $^{142}$Nd. For this comparison, it is assumed that no interaction between the neutron and core states exists, so the excitation energies of states predicted for $^{143}$Nd are simply equal to those of the corresponding states in $^{142}$Nd. This model is quite simple; nevertheless, it is quite successful in reproducing the energies of yrast states in $^{143}$Nd.

Data from the $^{142}$Nd$(d,p)$ reaction [9] explain why the yrast levels do not involve the high-spin $h_{9/2}$ and $i_{13/2}$ neutron orbits. An analysis of the centroids of single neutron strengths observed in the $^{142}$Nd$(d,p)$ reaction [9] shows that the $h_{9/2}$ and $i_{13/2}$ orbits occur 1.23 and 1.46 MeV higher, respectively, than the $f_{7/2}$ neutron orbit. These relative single-particle energies should not change at high angular momentum because the nuclear spin is built on intrinsic single-particle excitations and not nuclear rotation.

The one state in Fig. 3 that deviates strongly from the simple weak coupling picture is the $13/2^+$ state at 1228 keV. The state is clearly not simple since it has both a strong $E3$ transition (34 Weisskopf units) deexciting to the ground state [9], indicating a large octupole component, and a substantial $L=6$ spectroscopic factor (0.45) in the $^{142}$Nd$(d,p)$ reaction, indicating a significant $i_{13/2}$ single neutron component. This state has a strong collective component, unlike the other states shown in Fig. 3.

A comparison of branching ratios for corresponding states in $^{142}$Nd and $^{143}$Nd could provide an additional test of the weak coupling model. However, the $\gamma$-ray decay patterns in the two nuclei are somewhat different because of the sensitive dependence of $\gamma$-ray intensity on transition energy. As a result, there is only one state in $^{143}$Nd for which the $\gamma$-ray branching ratio can be compared to that of the corresponding state in $^{142}$Nd. Furthermore, information on $\gamma$-ray intensities in $^{142}$Nd has not yet been published in a form that allow this comparison to be performed at present [1,2].

Many additional states have been seen in the present study and are included in Fig. 2. Recent results on neighboring nuclei such as the $N=83$ isotone $^{144}$Pm [10] suggest that these other states can be explained in terms of a spherical shell model description using the valence protons and neutrons.

The apparent success of the weak coupling model at high spins in $^{143}$Nd suggests that the $J\leqslant 20$ yrast states of the core nucleus $^{142}$Nd are composed of couplings of valence protons and do not involve the breaking of the closed neutron shell. If the neutron core was broken in the $^{142}$Nd yrast states, then the interaction of the additional $f_{7/2}$ neutron in $^{143}$Nd with the neutron particle-hole excitations of the core would probably cause a greater deviation of the weak-coupling prediction from the data. This would be particularly true if the particle-hole excitation of the core involved an $f_{7/2}$ neutron.

In summary, we have measured high-spin states in $^{143}$Nd to an excitation energy of 10.7 MeV, and have found that the yrast states up to $J=45/2$ can be successfully explained by the weak coupling of an $f_{7/2}$ neutron to states in the $^{142}$Nd core nucleus. The measurement of the parities of the $J>29/2$ states via a conversion electron–$\gamma$-ray coincidence experiment is necessary to confirm the success of the weak coupling picture.

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