Comment on "g Factor of the ^{99}Zr$(7/2^+)$ Isomer: Monopole Evolution in the Shape-Coexisting Region"

In a recent Letter [1], the magnetic moments μ of the ^{99}Zr ground state and the $7/2_1^+$ state were measured and, together with $\mu(3/2_1^+)$ and the $B(M1; 3/2_1^+ \to 1/2_1^+)$ and $B(E2; 7/2_1^+ \to 1/2_1^+)$ values, compared with IBFM-1 model predictions. The *phenomenological* neutron single-particle energies input to these calculations were compared with *experimental* values derived from transfer results [2]. An abrupt change at $N = 59$ was observed, which the authors linked to the type-II shell evolution [3]. The measurements reported in Ref. [1] provide valuable data and clearly indicate the complex nature of the low-lying levels of ^{99}Zr. However, the present Comment points to existing experimental data on ^{99}Zr that are at odds with the IBFM-1 calculations of Ref. [1], and, moreover, shows that a similar reproduction of the above observables can be achieved with IBFM parameter sets with greatly different single-particle energies.

The magnetic moment of the ^{99}Zr ground state obtained in Ref. [1], $\mu(1/2_1^+) = -0.930(4)\mu_N$, equals that measured in earlier work [4], $\mu = -0.930(1)_{\mathrm{stat}}(3)_{\mathrm{sys}}\ \mu_N$, and is essentially identical to that of the $J^\pi = 1/2^+$ ^{97}Zr ground state, $\mu = -0.937(2)_{\mathrm{stat}}(3)_{\mathrm{sys}}\ \mu_N$ [4]. The ^{97}Zr ground state's $\nu s_{1/2}$ assignment is firmly established by single-neutron-transfer measurements that yielded a spectroscopic factor of $S = 1.02$ [5]. This gives strong experimental evidence that the ^{97}Zr and ^{99}Zr ground states have $\nu s_{1/2}$ character [4]. The nature of the $3/2_1^+$ state in ^{99}Zr was discussed in Ref. [6], with a conclusion that the $\mu(3/2_1^+)$ value was consistent with a dominant $\nu d_{3/2}$ component, although a pure single-particle character of this state is unlikely. The IBFM calculations of Ref. [1], which use the deformed ^{100}Zr as the boson core, predict the $1/2_1^+$ ground state to have only a 1.5% $\nu s_{1/2}$ admixture. The predicted $\mu(1/2_1^+) = -1.29\ \mu_N$ is due to a highly mixed wave function with $\nu d_{5/2}$ (55.7%) and $\nu d_{3/2}$ (41.8%) neutron components. The calculated $3/2_1^+$ wave function has a 85.2% $\nu d_{5/2}$ component. These configurations seem at odds with the experimental data. The states predicted [1] to be dominated by $\nu s_{1/2}$ and $\nu d_{3/2}$ components are at 385 and 909 keV, respectively, vastly different from the experimental $1/2_1^+$ and $3/2_1^+$ energies.

Figure 1 displays the experimental single-particle energies from Ref. [2] for the odd-A Zr isotopes, and the observed $1/2_1^+$ and $3/2_1^+$ energies for ^{99}Zr. The ^{99}Zr $\nu d_{3/2}$ energy should be considered a lower limit; the transfer results indicated that the lowest $3/2^+$ state in ^{97}Zr had a spectroscopic strength much larger than other $3/2^+$ states, but with some strength at higher energies [5]. For the $\nu g_{7/2}$ orbital, the $7/2_1^+$ energy is used, with the same caveat. The lack of observed rotational bands built on the $3/2_1^+$ and $7/2_1^+$ states in ^{99}Zr favors a nearly spherical or weakly deformed shape although, as pointed out in Ref. [1], the g factor for the $7/2_1^+$ level exceeds the Schmidt limit for a $\nu g_{7/2}$ state indicating additional wave function components. The spherical or weakly deformed shape is further reinforced by the evolution of the charge radii along the Zr isotopic chain that shows a gradual increase until the dramatic change observed for ^{100}Zr [7].

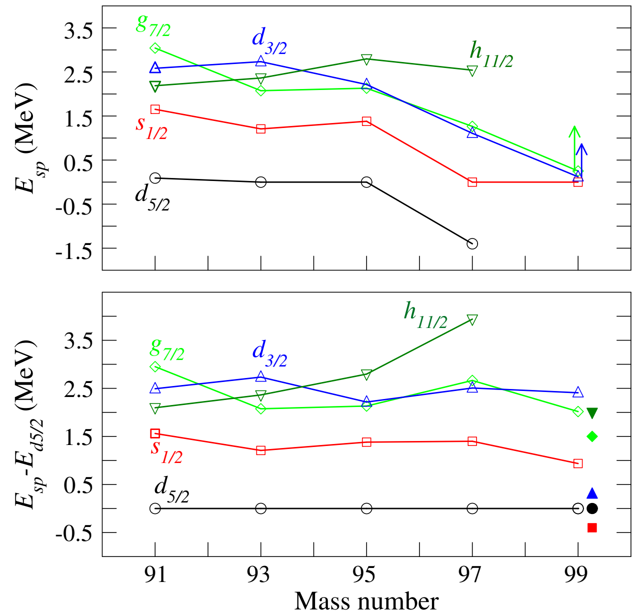

FIG. 1. Neutron single-particle energies for the odd-mass Zr isotopes, expressed as the excitation energies (top), where positive (negative) values indicate particle (hole) states, and relative to that of the $\nu d_{5/2}$ orbital (bottom). The values for $A =$ 91–97 are taken from Ref. [2], and those for ^{99}Zr are extracted from the IBFM calculations of Refs. [8,9] (open symbols), and Ref. [1] (filled symbols).

Earlier IBFM calculations for ^{97}Sr and ^{99}Zr [8,9] reproduced the discussed properties reasonably well using much different sets of parameters [no prediction for $\mu(7/2_1^+)$ was reported], and, unlike the calculations of Ref. [1], their ground-state wave functions are dominated by the $\nu s_{1/2}$ component, and the $3/2_1^+$ state highly mixed with dominant $\nu d_{3/2}$ and $\nu g_{7/2}$ components [8,9]. Figure 1 also displays the single-particle energies relative to the energy of the $\nu d_{5/2}$ orbital, with the IBFM input energies from both Refs. [1] and [9] for ^{99}Zr. From these latter calculations, one would conclude that there are no drastic deviations in the single-particle energies. Thus, given the evidence of the nature of the ground state, and ambiguities in the IBFM parameter sets, the conclusions of Ref. [1] may not be on firm footing.

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