Fully aligned high-spin states in $^{86}\text{Zr}$


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The evolution of collectivity in the light Zr isotopes has recently been studied [1] indicating collective rotation as the dominant mode for isotopes below $N = 45$. For nuclei with $N > 44$ an almost disappearance of rotational collectivity and the occurrence of strong competition between intruder $g_{9/2}$ neutron and $g_{9/2}$ proton excitations have been found. To study these multi-quasiparticle excitations and to search for a possible onset of rotational collectivity at very high spins, an in-beam investigation of the transitional ($N = 46$) even-even $^{86}\text{Zr}$ has been performed via the $^{58}\text{Ni}(^{32}\text{S},4p)$ reaction at 135 MeV using the early implementation of GAMMASPHERE (36 Compton-suppressed Ge detectors) combined with the $4\pi$ charged-particle detector system MICROBALL (95 CsI(Tl) scintillation detectors). The yrast positive- and negative-parity sequences have been extended up to a 30$^+$ level at 20.553 MeV and a 27$^-$ level at 16.631 MeV, respectively. The new transitions in the positive-parity yrast sequence show a third "backbend" at 26$^+$, just above the highest previously known state [2].

Calculations with the configuration-dependent shell-correction method [3] using a cranked Nilsson potential have shown that the highest spins are built (relative to an $^{80}\text{Zr}_{40}$ core) from the six $g_{9/2}$ neutrons and at most four protons excited from the $p_{1/2}$, $p_{3/2}$, $f_{5/2}$ subshells to the $g_{9/2}$ subshell at a small deformation. In this framework states up to 24$^+$ can be obtained by generation of two holes in the $f_{5/2}$ proton subshell. The observed "backbend" at 26$^+$ might be caused by the excitation of two additional protons across the $Z = 40$ shell gap which represents a rather drastic structural change. The 30$^+$ and 27$^-$ states are the highest possible fully-aligned states based on four holes in the $N = 3$ proton shell leading to terminations in both positive- and negative-parity sequences. Higher spins could be built by promotion of one neutron from the $g_{9/2}$ to the $g_{7/2}$ subshell but with a quite high energy cost. None have been observed.

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References: