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# Collectivity in neutron-rich Co and Mn isotopes going towards $N = 40$

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In the recent years a large effort has been devoted to the study of shell evolution in neutron-rich nuclei. These studies have been possible thanks to the improvements in experimental techniques, as state-of-the-art detector arrays combined with stable and radioactive beam facilities, that have boosted these studies through regions that were unaccessible before. In the last decade, for example, a large experimental an theoretical effort has been devoted to the study of the sub-shell closure $N = 40$ and the evolution of the magic number $N = 50$ for the Ni isotopic chain. Meanwhile the $N = 50$ $^{78}$Ni excited states represent still nowadays an experimental challenge, the evolution of the sub-shell closure at $N = 40$, when taking away protons from the Ni core, has been thoroughly studied. I fact, it has been measured that, by removing protons from the $f_{7/2}$ shell below $^{68}$Ni, the $N = 40$ subshell gap vanishes and a new region with large quadrupole deformation develops, as is the case for $^{66}$Fe and $^{64}$Cr [1,2]. A large theoretical effort within the shell-model framework has been done to describe this development of deformation and it has been shown that only by the inclusion of the neutron orbital beyond $N = 50$, $d_{5/2}$ the deformation can be reproduced in this so called new island of inversion [3,4]. In this work we have studied the low-lying excited states in the neutron-rich Co (one proton hole respect to Ni) where the coexistence of both collective (one proton $f_{7/2}$ hole coupled to the Fe core) and single-particle states (one proton $f_{7/2}$ hole coupled to the Ni core) are present [5,6]. We have also studied the excited states in neutron-rich Mn isotopes (three proton holes respect to Ni). The lifetimes of the excited states in $^{63,65}$Co as well as $^{59,61}$Mn have been measured employing the Recoil-Distance-Doppler-Shift method. The nuclei of interest were populated employing a multinucleon transfer reaction with a $^{64}$Ni beam impinging onto a $^{238}$U target, taking advantage of the state-of-art AGATA demostrator [7] to measure the $\gamma$ rays. The experimental $B(E2)$ values have been compared with large-scale shell-model calculations, which lead us to draw some conclusions on the role of the $d_{5/2}$ and $g_{9/2}$ neutron orbitals in driving collectivity below $^{68}$Ni.

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