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Competition between core excited and single-particle proton and neutron states out of 78Ni studied via lifetime measurements.

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In the vicinity of ^{78}Ni the quadrupole collectivity is expected to be large because the orbits close to the Fermi level allow the realization of a quasi-SU(3) symmetry, having orbits with Δj =2 Δl = 2 quasi-degenerated. As a consequence the quadrupole interaction produces a shape transition in which highly correlated many-particles -holes configurations gain binding energy and become as bound as the spherical states. These intruder deformed bands often appear at low excitation energy in the magic nuclei and also ^{78}Ni is expected to show such features.
Potential energy surface calculated for ^{78}Ni [1] shows a spherical minimum which is very flat. This interesting pattern is predicted also for the first 2^+ state, reflecting a particular fluctuation. This fluctuation is much narrower in the lighter Nickel isotopes such as ^{68}Ni, where the E2 excitation from the ground state goes to very high 2^+ states. The overlap probabilities with the closed shell are predicted to be 60%, 53%, and 75% for ^{56,68,78}Ni, respectively in [1].
On the other hand, recent large scale shell model calculations [2] predict a ground state of doubly magic 65% character, but the first 2^+ excited state at 2.88 MeV belongs to the (prolate) deformed band based in the intruder second 0^+ state at 2.65 MeV. The B(E2) for the decay to the g.s. is B(E2: 2^+_2–> 0^+) = 32 e2 fm4 These calculations give a second 2^+ of 1p-1h nature at 3.15 MeV, connected to the ground state with B(E2) = 110 e^2 fm^4.

The neighboring odd-even nuclei are expected to present a relatively simple structure, at least for the lowest lying states, and as consequence such nuclei constitute a unique test bench for the effective interactions and the nuclear degrees of freedom. However, as a consequence of the presence of intruder configurations in even-even nuclei, it is of fundamental importance to characterize the states of the odd-even nuclei in terms of their single particle character versus a core-excited character.

The nucleus ^{79}Cu can be exploited to probe the proton excitations outside ^{78}Ni, provided that the character of the states is understood. Calculations reported in [3] show that indeed the lowest lying states are predicted to have very different microscopic structure. The 5/2$^-$ g.s and the 3/2$^-$ first excited correspond mainly to a proton in the $f_{5/2}$ and $p_{3/2}$, respectively, while the first 1/2$^-$ state has a more mixed character, with an occupancy near 50% for both $p_{1/2}$ (single particle configuration) and $f_{5/2}$ (core coupled configuration). We propose here to study the structure of the excited states via lifetime measurement. Most of the states of interest are predicted to have a lifetime in the ps range that is accessible with plunger techniques.

It would be very interesting to study the nucleus ^{79}Ni to probe the neutron excitations along the N=51, however this nucleus is not at reach. Instead ^{81}Zn will be the most exotic N=51 isotope that will be accessible for in-beam experiments. This nucleus [4] is expected to present different states corresponding to a 1/2$^+$ states of dominating single particle $s_{1/2}$ character, two 5/2$^+$ states, one corresponds to a core-coupled configuration and the other having a neutron $d_{5/2}$ single-particle character. Lifetime measurement will be able to disentangle the character of such states.

[1] Y. Tsunoda et al. PRC 89, 031301(R) (2014)
[2] F. Nowacki et al. PRL 117, 272501 (2016)
[3] L. Olivier et al. PRL 119, 192501 (2017)
[4] C.M. Shand et al. PLB 773 492–497 (2017)

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