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E2 Coulex measurements in ^{79,81}Zn to understand nuclear intruder states and shell evolution

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Introduction

Recent work [Delafosse] has pointed out that the physics around the N=50 shell closure close to ^{78}Ni may be driven by the effects of ρ-meson exchange potential. On the one hand, this is causing a reduction of the N=50 gap going towards Z=32, inducing a sudden increase of across-shell quadrupole coherence in ^{84}Ge. On the other hand, this short-range interaction could be the responsible of the observed lowering in energy of the $\nu s_{1/2}$ shell above N=50, which is separated from the ground-state $\nu d_{5/2}$ by only 200 keV in ^{83}Ge. Indeed, by looking at the $\nu s_{1/2}$ energy trend in N=51 isotones, one may be tempted to hypothesize that the $\nu s_{1/2}$ shell becomes ground state already in ^{81}Zn. A ^{81}Zn beta-decay measurement found a very small feeding to the $5/2^-$ ^{81}Ga ground state, further hinting at a possible $1/2^+$ spin-parity assignment for ^{81}Zn ground state [Paziy]. Recent theoretical calculations made for ^{78}Ni do predict degenerate $\nu d_{5/2}$ and $\nu s_{1/2}$ shells at Z=38 [Taniuchi].

Coulex measurement to detect the ^{81}Zn ground state

If the $5/2^+$ states and $1/2^+$ states are very close in energy in ^{81}Zn (<100 keV), it may be very difficult to identify which is the ground state, even with particle transfer gated by γ rays. Here we propose to use Coulomb excitation at relativistic energies with high-resolution γ-ray spectroscopy to investigate the matter. If 81Zn has a "normal"$5/2^+$ ground state, one would expect to observe a multiplet of five Coulomb-excited states, from $1/2^+$ to $9/2^+$, which will be the coupling of the ^{80}Zn 2^+ state to the unpaired neutron in the $\nu d_{5/2}$ shell. On the contrary, if ^{81}Zn has a $1/2^+$ ground state, the multiplet will be composed of only two states. The energies of all these states will be within few hundred keV of the 2^+ of ^{80}Zn (1456 keV), and they will share the B(E2) of ^{80}Zn, in a weak-coupling approximation. However, the measured Coulex cross sections will be enhanced for the case of $1/2^+$ ground state, due to the spin factor. Shell-model calculations with the JUN45 interactions give the B(E2) distribution among the states of ^{81}Zn reported in Tab. 1, and the corresponding Coulex cross sections have also been calculated with Dweiko.

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In conclusion, the proposed measurement will allow one to probe the spin of the ^{81}Zn ground state by measuring the multiplet populated by the Coulex reaction.

Experimental considerations:

We consider the use of a ^{81}Zn beam of 200 pps, and a ^{208}Pb target of 1 g/cm^2. We consider a γ-ray detection efficiency of 5% (no addback and high γ-ray energies). Using the cross section quoted above, this would imply the number of counts reported it Tab. 1 in each peak in a 5-day measurement. A 15% error on the measured B(E2) is foreseen on the biggest peaks, while 20-25% error for the smallest ones.

Coulex of isomeric intruder states in ^{79}Zn

Shape coexistence in the ^{78}Ni region has been reported in Refs. [Gottardo, Yang] in ^{80}Ge and ^{79}Zn. The shape-coexisting $1/2^+$ state in ^{79}Zn has also the peculiarity of being a long-lived isomer (seconds). The wave function of this isomeric level has been investigated through g-factor measurement with LASER spectroscopy. It is an N=50 intruder level with a $(\nu g_{9/2}){-}1-(\nu s_{1/2})^1$ configuration. Contamination of the wave function from the other known intruder $(\nu g_{9/2})^{-1}-(\nu d_{5/2})^1$ state is possible, though limited [Yang]. The same state was previously observed in a 78Zn(d,p)^{79}Zn transfer measurement at ISOLDE [Orlandi], and indeed the transferred angular momentum was compatible with an s wave. The measurement in Ref. [Yang] not only determines the intruder $(\nu g_{9/2}){-}1-(\nu s_{1/2})^1$ nature of the state, but also shows a large isomer shift of the $1/2^+$ isomer with respect to the $9/2^+$ ground state. In their paper, Yang et al. suggest this is due to a large quadrupole deformation with β=0.22, against the β≈0.14 value of the ground state [Yang]. This result was obtained by assuming an axial deformation and that the mean radius of the wave function of this intruder state follows the standard 1.2·A$^{1/3}$ fm rule (5.1 fm for ^{79}Zn). However, since the g factor clearly points out a major $\nu s_{1/2}$ component in the wave function, the <r^2> of the $1/2^+$ isomer may actually be 10-15% larger

[Bonnard2], justifying the measured isomeric shift even with an almost spherical shape.
In [Bonnard1, Bonnard2] it is shown how the s-wave function radius may be even larger than what was previously thought, having implication in shell formation. Indeed, the rapid decrease of the $\nu s_{1/2}$ energy in N=51 isotones leading to a possible $1/2^+$ ground state in ^{79}Ni, has been attributed to the coupling to the continuum of the $\nu s_{1/2}$ shell and to an increase in nuclear diffusivity [Hagen, Nowacki, Delafosse].
The understanding of how the $\nu s_{1/2}$ determine shape coexistence can thus help to infer important information on the neutron shell structure at N=50. More specifically, ^{79}Zn may represent a very particular case of coexistence between the slightly deformed ground state shape and a similarly spherical intruder shape but with a large radius.
The proposed Coulomb excitation measurement will help to understand the nature of the shape coexistence of the intruder $1/2^+$ isomer: a (almost) spherical larger $\nu s_{1/2}$ intruder state as suggested by recent calculations on s shell in this region, or a more deformed configuration (likely involving at least some $\nu d_{5/2}$ components) as suggested in Ref. [Yang]. The measured energies and transitional quadrupole moments will help, also in comparison with theoretical calculations, to verify if the large measured isomer shift is due to a large radius or to a large deformation. The levels populated by the Coulex reaction will already be indicative of the wave function we want to probe. Another important observable we will get from coulomb excitation are B(E2) values from $3/2^+$ and $5/2^+$ states coming from the coupling of the intruder states with the 2^+ of the ^{78}Zn core. The B(E2) value of the 2^+ of the ^{78}Zn core is 8 Wu↓. In the case of an almost spherical, s-wave state, we will observe slightly larger (5-10%) reduced E2 matrix elements in the band built on the intruder-state, due to the isomer shift of the $1/2^+$ state (since B(E2) $\propto\langle r^2 \rangle^2$). On the contrary, if the deformation is the large one claimed in Ref. [Yang], β=0.22, B(E2) values will be much larger, several times the 8 Wu↓ value of the ^{78}Zn core. The combination of the energy and B(E2) measurements with the coulex reaction will thus provide an unambiguous characterization of the shape coexistence in this region, also helping to understand the role played by the $\nu s_{1/2}$ in the N=50 gap stability and size going towards ^{78}Ni.

Experimental details for Coulex of ^{79}Zn
We consider the use of a ^{79}Zn beam of 5*10^3 pps, and a ^{208}Pb target of 1 g/cm^2. We consider a γ-ray detection efficiency of 5% (no addback and possibly high γ-ray energies). The isomeric ratio for the $1/2^+$ isomer is known from a previous decay study at EURICA [Delattre]. Using an isomeric ratio of 10% and the cross section deduced from the B(E2) values quoted above, 100 mbarn to be conservative, this would imply 1200 counts in γ-ray peaks in a 2-day measurement. A 15% error on the measured B(E2) is foreseen.

Bibliography

[Bonnard1] J. Bonnard, A. Zucker, S. Lenzi, Phys. Rev. Lett. 116, 212501 (2016)
[Bonnard2] J. Bonnard and A. Zucker, arXiv:1606.03345 (2016)
[Gottardo] A. Gottardo et al., Phys. Rev. Lett. 116, 182501 (2016)
[Yang] X.F. Yang et al., Phys. Rev. Lett. 116, 182502 (2016)
[Hagen] G. Hagen et al.,Phys. Rev. Lett. 117, 172501 (2016)
[Delafosse] C. Delafosse et al., Phys. Rev. Lett. 121, 192502 (2018)
[Delattre] M.C. Delattre, PhD thesis IPN Orsay (2016)
[Nowacki] F. Nowacki et al., Phys. Rev. Lett. 117, 272501 (2016)
[Taniuchi] Taniuchi et al., to be published in Nature (2019)

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