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Living at the edge of stability: The role of continuum and three-nucleon forces

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Nuclear structure at and reactions at the dripline is a challenging undertaking. In order to give reliable predictions for future experiments and describing the exotic phenomena that occurs as we move beyond the valley of stability we need a theory that properly accounts for; (i) the effects of three nucleon forces, (ii) the presence of open decay channels and particle continuum, and (iii) many-nucleon correlations. We aim to fill this gap by using interactions from chiral effective field theory together with a schematic potential that accounts for the effects of three-nucleon forces, a Berggren basis that treats bound and continuum states on equal footing, and coupled-cluster theory to properly account for many-nucleon correlations. We apply this approach to the computation of binding energies, radii and excited states in the neutron rich oxygen [1] and calcium isotopes [2]. We show that effects of three-nucleon forces are essential in placing the dripline at ^{24}O and for explaining the shell closure in ^{48}Ca. We find a weak shell closure in ^{54}Ca, assign spin and parities to several unknown levels in oxygen and calcium isotopes, and in particular we find due to continuum coupling the level ordering of the states in the *gds* shell are reversed compared to the naïve shell model picture as we move towards ^{60}Ca. We also note that a saturation of total binding sets in around ^{60}Ca, indicating that the ^{60}Ca is either a very weakly bound or unbound nucleus. By computing overlap functions we have also extended our approach to compute reaction observables, and we present results for low-energy elastic proton scattering on calcium isotopes. The results are promising and open up new possibilities to perform predictive and microscopic structure and reaction calculations towards the dripline.

[1] G. Hagen, M. Hjorth-Jensen, G. R. Jansen, R. Machleidt, and T. Papenbrock, Phys. Rev. Lett. (2012), arXiv:1204.3612v1
[2] G. Hagen, M. Hjorth-Jensen, G. R. Jansen, R. Machleidt, and T. Papenbrock, arXiv:1202.2839v1 (2012)