How doubly-magic is the nucleus $^{78}_{28}\mathrm{Ni}_{50}$?

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Doubly-magic nuclei play an important role in nuclear structure theory as testbeds for shell model calculations. Data on neutron-rich nuclei in the regions of doubly-magic nuclei as $^{78}_{28}\mathrm{Ni}_{50}$ and $^{132}_{50}\mathrm{Sn}_{82}$ have a decisive influence on nucleosynthesis calculations. They comprise the longer-lived waiting-point nuclei determining the duration of the r-process as well as the matter flow through the abundance maxima related to the magic neutron numbers [1].

Remaining deficiencies in the calculation of isotopic abundances have been interpreted by our group as signatures of nuclear structure near the neutron drip-line. Pronounced abundance troughs prior to the maxima have their origin in an overestimation of the neutron shell strength far from stability in global mass models such as FRDM and ETFSI-1.

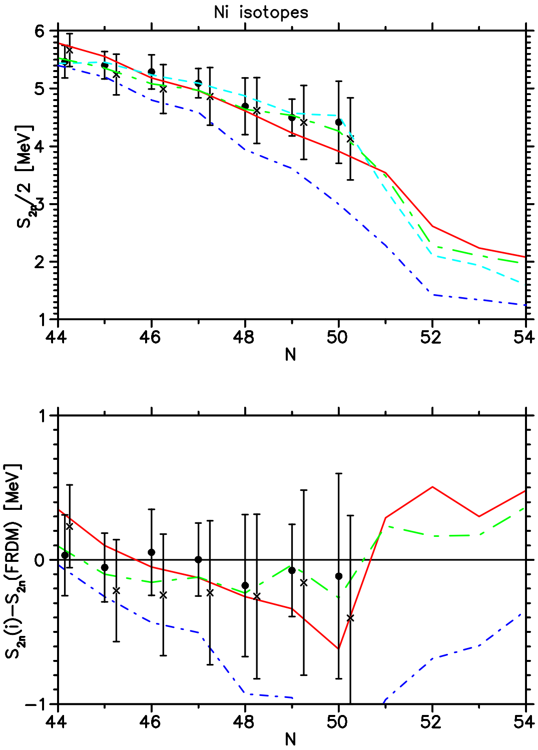

Figure 1: The two-neutron separation energies (S_{2n}) across the shell gap at N=50 for Ni-isotopes (upper part) and the differences to the FRDM model (lower paret). Experimental values: crosses from 1995 mass evaluation [2] and circles from 2003 evaluation [3]. Theoretical masses: FRDM: cyan, ETFSI-1: green, ETFSI-Q: blue, HFB-2: red

A weakening ("quenching") of spherical shells with increasing isospin, resulting in a gradual setting in of collectivity has been predicted by HFB calculations for the spherical shells at N= 50, 82 and 126, and is well established in the meantime for the lower neutron-magic numbers.

Only recently, first decay data on the very neutron-rich doubly-magic nuclei $^{78}_{28}\mathrm{Ni}_{50}$ could be obtained at MSU [4]. It is of interest to determine the mutual influence of the proton and neutron magic numbers far from stability. The shell strength can be derived from the difference of the two-neutron separation energies S_{2n} prior and behind a magic neutron number. As an example, Fig. 1 displays the S_{2n} values for Ni isotopes.

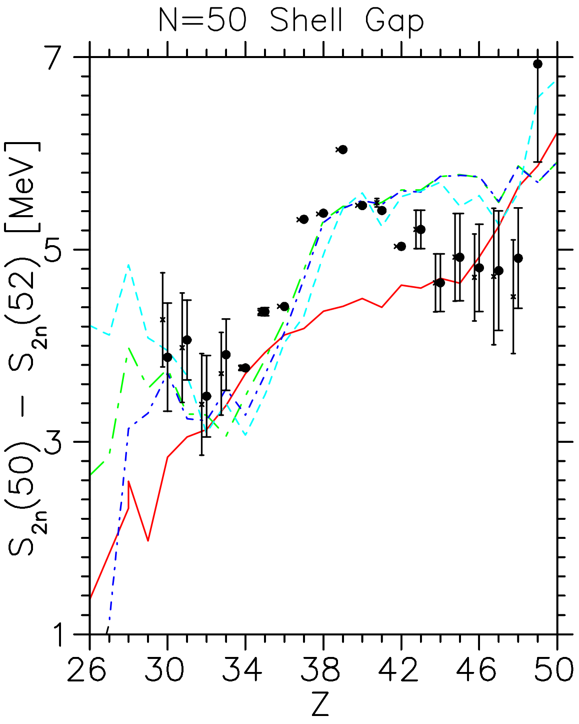

Figure 2: The N=50 shell gap as a function of Z. Experimental values from the 2003 mass evaluation [2] (black and red circles) are compared to the 1995 ones [3] (crosses and black circles). [Same colour coding for the mass models as in Fig. 1.]

In Fig. 2 the N=50 shell gap over a wide Z range is shown. The maximum corresponds to $^{90}_{40}\mathrm{Zr}_{50}$, where the subshell closure at Z=40 reinforces the N=50 magic number. Most global mass models predict a local maximum for ^{78}Ni. However, so far below Z=30, i.e. ^{80}Zn, experimental masses have not been determined, so that this prediction cannot be verified. Direct mass measurements at MSU or the FRS-ESR of the GSI will in future extend the range of experimental masses in this region to more neutron-rich isotopes.

References

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