# Proton shell closures in proton–rich heavy nuclei

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Magic numbers are a key feature of any finite Fermion system as they provide crucial clues on the underlying mean field. The study of shell closures is thus very interesting in exotic nuclei. One wants to know how the shell closures develop when moving towards the driplines. It is now well–established for neutron–rich $N=20$ and $N=28$ isotones that the neutron shells fade away. This gives rise to a transient regime of pronounced low-lying collecive states and finally to stable ground-state deformation [1]. There are hints from the systematics of $2^+$ and $4^+$ excitation energies in Cd and Pd isotopes that also the $N=50$ and $N=82$ shells are weakened when going towards neutron–rich nuclei [2]. All these examples concern a weakening of neutron shells. The situation seems to be different for protons. For light nuclei there is no indication that the proton shell closures fade away towards the proton drip line. But the analysis of recent mass measurements [3] shows a substantial weakening of the two–proton shell gap

$$\delta_{2\mathrm{p}}(Z,N) = E(Z-2,N) - 2E(Z,N) + E(Z+2,N)$$

for very proton-rich Pb isotopes. It is speculated whether this is related to a weakening of the $Z=82$ shell [4]. This contribution looks at this problem from a theoretical perspective.

As tool we take self-consistent mean-field models which are nowadays well developed and provide a pertinent picture of the nuclear properties throughout the whole mass table. We consider two different models, the Skyrme-Hartree-Fock approach (SHF) and the relativistic mean-field model (RMF). We take one typical parametrisation for each model, SkI3 for the SHF and NL3 for the RMF, see e.g. [5]. SHF as well as RMF produce single–proton spectra in Pb with a well developed magic gap at $Z=82$ for all isotopes up to the dripline. This is confirmed by the systematics of the shell-correction energies extracted from self-consistent calculations [6]. The $\delta_{2\mathrm{p}}$ are presented in Fig. 1. The upper panel shows $\delta_{2\mathrm{p}}$ for spherical calculations in Pb as well as in its $Z\pm2$ neighbours Po and Hg. The theoretical results give an almost constantly large $\delta_{2\mathrm{p}}$ along the whole isotopic chain, in compliance with the large spectral gap and shell-correction energy. But the results for $\delta_{2\mathrm{p}}$ are clearly at variance with the data. This changes dramatically when allowing for ground–state deformation, see the lower panel. While the ground states of Pb isotopes stay spherical, the ground states of proton-rich Hg and Po isotopes become deformed. They thus gain energy which significantly reduces the extremely sensitive double difference $\delta_{2\mathrm{p}}$. The findings are consistent with the currently available data which confirm deformation softness in these heavy proton-rich isotopes, see e.g. [7] and references therein. Important for our purpose is: (i) $^{180-190}$Hg have oblate deformed ground states, (ii) data on excitation spectra and charge radii for Pb isotopes are consistent with spherical ground states, and (iii) proton-rich Po isotopes show an increased collectivity.

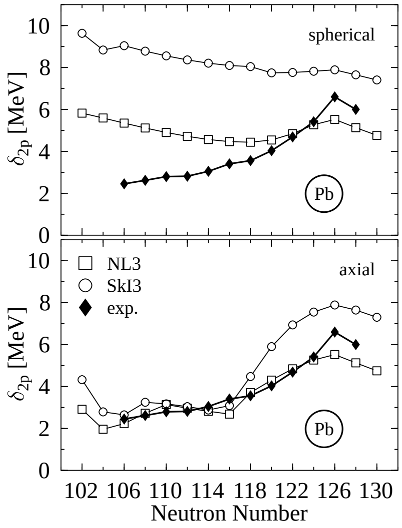

Figure 1: Two–proton shell gap $\delta_{2p}$ for Pb isotopes calculated with SHF (force SkI3) and RMF (force NL3) and compared with experimental data. Upper panel: from spherical configurations of all nuclei. Lower panel: allowing for ground-state deformations.

In summary the observed weakening of $\delta_{2\mathrm{p}}$ around $Z=82$ is caused by the increased collectivity of the Hg and Po isotopes, and not by a quenching of the $Z=82$ shell. Large values of $\delta_{2\mathrm{p}}$ are a sufficient, but not a necessary indicator for a shell closure. This example shows that a thorough analysis of magic shells requires a simultanous consideration of various signals, e.g. the $\delta_{2\mathrm{p}}$ together with energy and strength of low-lying $2^+$ and $4^+$ states, possibly complemented by $\alpha$-decay hindrance factors [8]. True proton-shell quenching, however, is expected for the next magic proton number in the realm of superheavy elements [9].

## References

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