Deformations of atomic nuclei studied with Coulomb excitation

- perspectives and experimental needs

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Amongst many different and complementary techniques used to study nuclear structure, Coulomb excitation brings substantial and unique information detailing nuclear deformation. This technique allows for selective excitation of low-lying states and results in a direct measure of the non-diagonal and diagonal electromagnetic matrix elements including their signs. Based on this experimental information about various moments describing nuclear deformation can be extracted for each state, independently of nuclear models, using the quadrupole sum rules method [1,2]. The method is particularly useful for attributing shape parameters to low-lying 0^+ states.

The study of low-energy electromagnetic structure of atomic nuclei with Coulomb excitation has been a long standing task of our group. One of the main topic of our recent studies performed at HIL was focused around transitional region of nuclear chart (A~100, Z~40,50), where shape instabilities are relatively common and may lead to coexisting nuclear shapes. Most of the even-even nuclei in this region are also traditionally considered as the best examples of vibrational nuclei. However, the recent results [3-7] seriously contradict this simple interpretation. Moreover, triaxiality is expected to play an important role in this mass region, as evidenced by our Coulomb excitation studies of shape-coexisting structures in ^{96,98,100}Mo [8,9].

A detailed Coulomb excitation studies are surprisingly scarce and critically needed in this region of nuclear chart to move towards a resolution of the most fundamental question “What is the nature and origin of low-energy collectivity in these nuclei ?”. The aim of the future projects is to perform an extensive multi-step Coulomb excitation studies to extract a rich and complete set of reduced diagonal and non-diagonal matrix elements in stable nuclei. In the multistep Coulomb excitation experiments, when several levels are populated, a number of matrix elements affect the Coulomb-excitation cross section in a complex way. The contribution from various excitation paths vary with the scattering angle of projectile and atomic number of the used beam-ions. The differential measurements of the Coulomb-excitation cross-section make it possible to disentangle them and gain the sensitivity to the subtle higher-order effects, such as relative signs of the electromagnetic matrix elements and spectroscopic quadrupole moments. Combining such a rich Coulomb excitation data sets will consequently yield shape parameters, including triaxiality, and even opens a possibilities to describe their softnesses.

To summarize, future detailed and comprehensive Coulomb excitation studies require: (i) various beam ions differing with atomic number, (ii) a new, dedicated experimental set-up equipped with a particle detectors covered broad angular range. In the presentation perspectives of Coulomb excitation studies will be discussed and experimental needs.

[1] K. Kumar Phys. Rev. Lett. 28 249–53 (1972)
[2] D. Cline Annu. Rev. Nucl. Part. Sci. 36, 683–716 (1986)
[3] P E Garrett, J. L. Wood, S. W. Yates Phys. Scr. 93 063001 (2018).
[4] P. E. Garrett and J. L. Wood, J. Phys. G: Nucl. Part. Phys. 37, 064028 (2010).
[5] P. E. Garrett and J. L. Wood, J . Phys. G: Nucl. Part. Phys. 37, 069701 (2010).
[6] J. Srebrny et al., Nucl. Phys. A766 25 (2006).
[7] W. Urban et al., Phys. Rev. C 87, 031304(R) (2013).
[8] M. Zielinska et al, Nucl. Phys. A712 (2002).
[9] K. Wrzosek et al, Phys. Rev. C 86, 064305 (2012).