PhD position in experimental nuclear physics

Laser spectroscopy of neutron-deficient lanthanides for a study of the N = 82 nuclear shell closure

Nuclei with “magic” numbers of protons and/or neutrons have played an essential role in shaping the modern understanding of nuclear structure. They have helped establish the shell model of the atomic nucleus and constrain the underlying interaction, by studying the systematics of nuclear properties of magic or almost-magic nuclei, while changing the number of nucleons. The trends of the electromagnetic properties of nuclear ground states have played a particularly useful role, since they allow observing both macroscopic tendencies (charge radii), as well as probe single-particle structure (magnetic dipole moments) and the development of correlations (electric quadrupole moments). All these properties can be determined by performing laser-spectroscopy experiments.

The ground-state electromagnetic properties of lanthanides below N = 82 are almost completely unknown, with the few experimental charge radii in the europium isotopic chain (Z = 63) showing enhancement with the removal of neutrons ([1] and Fig. 1). The evolution of this feature with the number of protons would shed light on the onset of ground-state deformation towards the proton dripline and the proton-neutron interaction.

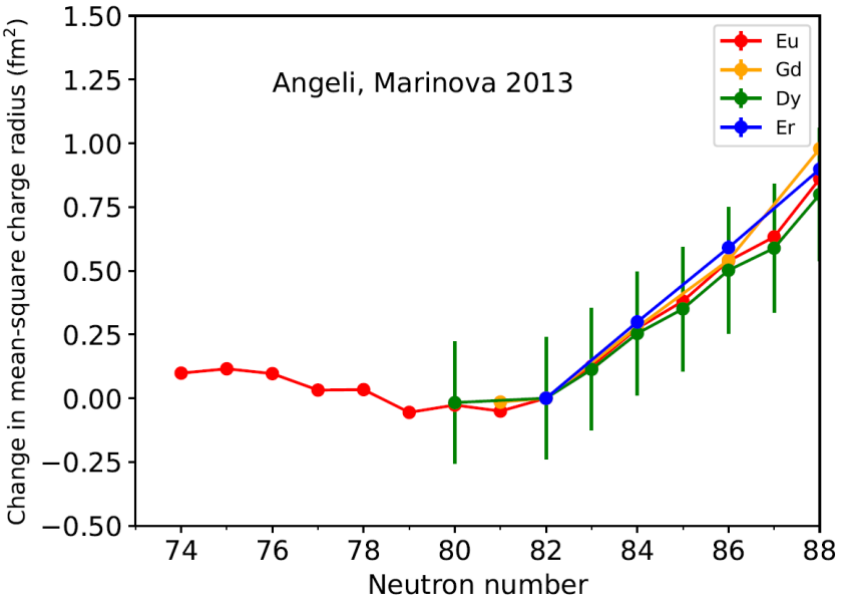


Figure 1 – Differences in mean-square charge radii with respect to N = 82 for different lanthanide isotopic chains

This thesis project thus aims to study the evolution of nuclear structure across the N = 82 shell closure by performing laser spectroscopy of very neutron-deficient lanthanide isotopes (erbium, dysprosium, gadolinium). Measurements of charge radii showing the global trend of the nuclear size will be complemented by measurements of magnetic and quadrupole moments, giving insight into the microscopic origin of these trends.

The experiments will be performed at GANIL-SPIRAL2 using the S^3 Low Energy Branch (S^3-LEB) [2], exploiting the first beams produced by the Super Separator Spectrometer (S^3) of SPIRAL2. The radioactive nuclei will be stopped in the gas cell of S^3-LEB, neutralized and extracted by gas flow in a supersonic jet. In this environment, wavelength-tunable lasers will be used to perform laser-spectroscopy measurements. The S^3-LEB setup is operational at the focal plane of S^3.

In parallel with these developments, a new experimental setup called FRIENDS^3 (Fast Radioactive Ion Extraction and Neutralization Device for S3) has been commissioned at GANIL for off-line developments of the S^3-LEB gas cell [3,4]. The key tests and designs of a future version of the S^3-LEB gas cell, more adequate for studying short-lived and rare isotopes, will take place at GANIL as part of the PhD project, ensuring a continuity of activities during periods without radioactive ion beams.

Bibliography

[1] X. F. Yang et al., Prog. Part. Nucl. Phys.129, 104005 (2023)

[2] A. Ajayakumar et al., NIMB 539, 102-107 (2023)

[3] E. Morin et al., Nucl. Instr. Meth. B 573 166027 (2026)

[4] W. Dong et al., Nucl. Instr. Meth. B 579 166239 (2026)

Required skills

The thesis subject concerns experimental nuclear physics and instrumentation developments, consequently it will involve significant laboratory work. The candidate must show a particular interest in work with the specific instrumentation of the project, notably tunable lasers, low-energy ion-manipulation devices such as ion traps, as well as the dedicated detection and acquisition systems. An understanding of the basics of atomic and nuclear physics is desirable, as well as a good handle of numerical methods and of a programming language allowing the treatment, analysis and presentation of data.

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