PROPOSITION SUJET DE THÈSE

« Shape evolution in neutron-rich nuclei »

SCIENTIFIC PROBLEMATICS

We propose a project to study the evolution of nuclear shapes in exotic nuclei, far from the valley of stability, specifically in neutron-rich nuclei in the isotopic chains from Zr (Z=40) to Pd (Z=46), which can be produced as fission products. Usually, nuclear shapes are slowly evolving from spherical shapes around closed-shell or (doubly-) magic nuclei to elongated (prolate) shapes in nuclei with very many valence nucleons. The nuclei of interest, however, show rapidly evolving patterns of excited states, which can be interpreted as rapid variations of the nuclear shape, including the rare observation of oblate (disk-like) and triaxial shapes. So far the known properties for these nuclei are (mainly) limited to excitation energies. Information on the nuclear collectivity, which can be deduced from the lifetime of the excited states, are sparse, while direct information of the shape is practically non existing.

In 2011, we performed a pilot experiment at GANIL measuring lifetimes of neutron-rich nuclei produced as fission fragments and identified by the VAMOS spectrometer. This experiment validated the experimental technique, but can now be strongly improved by using superior gamma-ray spectrometers as well as higher efficiency for particle detection and the possibility of higher data rates. The combination of the AGATA Ge detector array and the FATIMA LaBr detector array is worldwide unique allowing to measure lifetimes in an unprecedented wide range using Doppler shift techniques and the excellent energy resolution of AGATA for (sub-) ps timing and direct timing from the excellent timing resolution of the LaBr detectors.

The new experiment has been accepted by the GANIL PAC and should be scheduled with high priority in early 2017. The expected results will allow a validation of the predictions of state-of-the-art nuclear structure calculations, such as beyond mean field calculations or large valence shell model calculations. They will also serve as important input to the analysis of the future Coulomb excitation experiments which depending on their exact timing may become part of the PhD project.

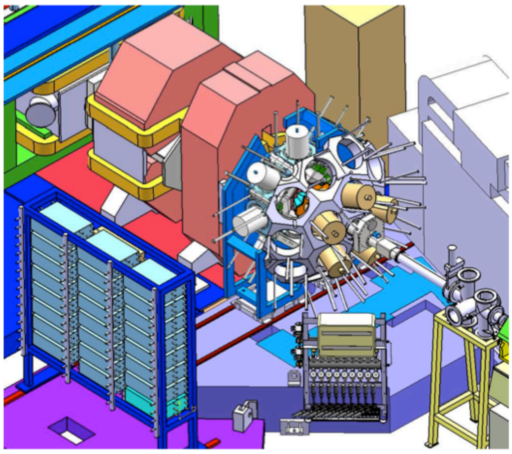

Figure 1 : Artistic view of the installation of the gamma-ray tracking spectrometer AGATA at GANIL[1].

DESCRIPTION OF THE WORKING GROUP

The PhD candidate will be working in IRFU/ SPhN/LENA[2], a group of ~20 researchers, post-docs and PhD students. In our group we are interested in several aspects of nuclear structure physics, such as the evolution of the nuclear shell, structure and nuclear shapes in exotic nuclei and the study of the heaviest elements. The group has extensive expertise in measuring nuclear lifetimes and the electromagnetic excitation of nuclei. We are also strongly involved in the construction of the gamma-ray spectrometers AGATA and FATIMA and has strong links with theory groups. The candidate will thus be working in a very fruitful environment combining expertise on different detection techniques (gas, scintillation and semiconductor detectors) and analysis methods (Doppler-shift and fast timing techniques, Coulomb excitation analysis, etc.) and be supported by the technical divisions from IRFU.

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[1] Communiqué de presse sur AGATA au GANIL
[2] Information supplémentaire sur LENA

The PhD supervisor (directeur de these) has been spokesperson of many projects at international accelerator facilities, e.g., ISOLDE-CERN; LNL, Italy; ANL, USA et RIKEN, Japan), which gives the PhD candidate the chance to participate in other experiments and to extend his knowledge in nuclear structure physics.

WORK SCHEME AND PLANNING

During the first year or already during a "stage" for the master thesis, the candidate should become familiar with the experimental techniques: The gamma rays emitted by the fission fragments will be detected with the Ge detectors of AGATA and the LaBr3 detectors of FATIMA. The excellent energy resolution of AGATA allows to characterise the nucleus and to measure lifetimes in the (sub-) ps regime using Doppler-shift techniques[3], while the excellent timing resolution of the $LaBr_3$ detectors will allow a direct measuring of longer lifetimes (tenths of ps to several ns).

The candidate will be strongly involved in the preparation of the experiment, which should take place in the last trimester of 2016 or early 2017. As most of the analysis codes already exist it should be possible to perform the data analysis in the second year. The interpretation of the results in collaboration with colleagues from CEA Bruyeres-le-Chatel as well as their publication and the preparation of the manuscript are planned for the third year.

During the PhD thesis the candidate will also participate in other experiments of the group. He/she will be expected to present the results at collaboration meetings and conferences.

FORMATION ET REQUIRED COMPETENCES

The most important point is a strong interest in nuclear structure physics together with a liking for experimental works and detection systems. A dedicated nuclear physics course, e.g., on the master M2 level as well as a prolonged interim or master thesis is strongly recommended. Some notions of computer programming (C, C++) or analysis routine ("Root") would be advantageous.

ACQUIRED COMPETENCES

The candidate will acquire a profound knowledge in experimental nuclear structure physics and will also have a solid understanding and the ability to exploit theoretical models used in contemporary nuclear structure physics. The candidate will also evolve into scientific maturity by working in international collaborations, being familiar with large-scale instrumentation and by acquiring expertise in using modern data analysis tools (C++, Root) commonly used in subatomic physics. At the end of the thesis he/she will be able to conduct research independently.

The thesis work will also offer the candidate a solid basis for a career not only in basic research, but also in industry due to the acquired competence in exploiting different detector concepts (gaseous, szintillators, semi-conductors) in particular, but not limited to, nuclear radiation and radioactivity. in addition he/she will be trained in analysing scientific problems and in team building.

COLLABORATION/PARTNERS

The experiment will be performed in close collaboration with colleagues from CSNSM in view of their expertise on the plunger device and the Doppler-shift analysis techniques. More generally, the experiment will take place in an international collaboration and several students may analyse the data in parallel. The preparation and execution of the experiment will demand prolonged stays at GANIL, Caen, while collaboration meetings could also be organised outside of France.

CONTACTS

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[3] The Recoil Distance Doppler Shift (RDDS)) will be applied using a mechanical "plunger apparatus" that separates the gamma ray emission into components with different Doppler shifts.