PROPOSITION SUJET DE THÈSE

« Shape evolution in neutron-rich nuclei studied by low energy Coulomb excitation »

SCIENTIFIC PROBLEMATICS

One of the most fundamental properties of the atomic nucleus is its shape, which is governed by the interplay of macroscopic, liquid-drop like properties of the nuclear matter and microscopic shell effects, which reflect the underlying nuclear interaction. In some cases, configurations corresponding to different shapes may coexist at similar excitation energies, which results in the wave functions of these states mixing. Experimental observables such as quadrupole moments and the electromagnetic transition rates between states are closely related to the nuclear shape. The experimental determination of these observables, therefore, represents a stringent test for theoretical models.

We have an on-going 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). 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 is sparse, while direct information of the shape is practically non-existing.

In recent years our group has performed several experiments to study neutron-rich nuclei in the mass A~100 region via Coulomb excitation. In these scattering experiments a particle detector array is employed for the detection of radioactive projectiles and recoiling target nuclei. Coincident gamma-rays from the de-excitation process are detected by an array high-resolution Ge detectors, which allows to determine the Coulomb excitation yield for each excited state and as function of the particle scattering angle. With these data it is possible to extract nuclear electro-magnetic matrix elements, and in particular quadrupole moments, which are a direct measure of the nuclear shape.

For the thesis work an experiment on ^{100}Zr is planned. The beam is provided by the ATLAS-CARIBU facility at Argonne National Laboratory (ANL), which is currently the only facility world-wide able to deliver beams of such refractory elements. The programme advisory committee has already accepted the experiment with high priority. The CARIBU facility is currently being upgraded with a new ion source, including a higher yield ^{252}Cf source, and should deliver higher intensity beams with less (isobaric) contaminants from mid 2016. We expect the ^{100}Zr experiment to be scheduled in 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.

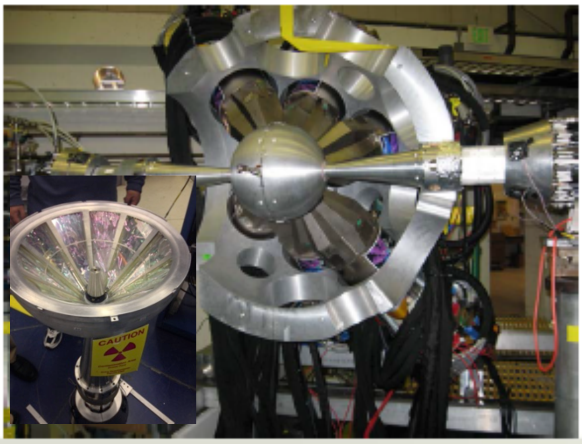

Figure 1 : Photo of the high resolution Ge spectrometer used at Argonne National Laboratory; in the insert the particle detector inside the scattering chamber is shown.

DESCRIPTION OF THE WORKING GROUP

The PhD candidate will be working in IRFU/ SPhN/LENA[1], a group of ~20 researchers, post-docs and PhD students. In our group we are interested in several aspects of nuclear structure

[1] Additionnel information about LENA

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 electromagnetic properties of atomic nuclei. 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 (Coulomb excitation analysis, Doppler-shift and fast timing techniques, etc.) and be supported by the technical divisions from IRFU.

The PhD supervisor (directeur de these) has been spokesperson of many projects at international accelerator facilities, e.g., ISOLDE-CERN; LNL, Italy; ANL, USA and 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, for example by analysing data obtained in previous experiments. In parallel, the candidate will be strongly involved in the preparation of the experiment at ANL. As most of the analysis codes already exist it should be possible to complete 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, scintillators, 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 a medium-size international collaboration, in particular with colleagues from the US national laboratories in Argonne and Oakridge. As a consequence several students may analyse the obtained data in parallel. The preparation and execution of the experiment may require an extended stay at ANL, Chicago area, USA (4-6 weeks).

CONTACTS

Wolfram Korten ; w.korten.at.cea.fr

PROPOSITION SUJET DE THÈSE

« Shape evolution in neutron-rich nuclei studied by low energy Coulomb excitation »

SCIENTIFIC PROBLEMATICS

One of the most fundamental properties of the atomic nucleus is its shape, which is governed by the interplay of macroscopic, liquid-drop like properties of the nuclear matter and microscopic shell effects, which reflect the underlying nuclear interaction. In some cases, configurations corresponding to different shapes may coexist at similar excitation energies, which results in the wave functions of these states mixing. Experimental observables such as quadrupole moments and the electromagnetic transition rates between states are closely related to the nuclear shape. The experimental determination of these observables, therefore, represents a stringent test for theoretical models.

We have an on-going 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). 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 is sparse, while direct information of the shape is practically non-existing.

In recent years our group has performed several experiments to study neutron-rich nuclei in the mass A~100 region via Coulomb excitation. In these scattering experiments a particle detector array is employed for the detection of radioactive projectiles and recoiling target nuclei. Coincident gamma-rays from the de-excitation process are detected by an array high-resolution Ge detectors, which allows to determine the Coulomb excitation yield for each excited state and as function of the particle scattering angle. With these data it is possible to extract nuclear electro-magnetic matrix elements, and in particular quadrupole moments, which are a direct measure of the nuclear shape.

For the thesis work an experiment on ^{100}Zr is planned. The beam is provided by the ATLAS-CARIBU facility at Argonne National Laboratory (ANL), which is currently the only facility world-wide able to deliver beams of such refractory elements. The programme advisory committee has already accepted the experiment with high priority. The CARIBU facility is currently being upgraded with a new ion source, including a higher yield ^{252}Cf source, and should deliver higher intensity beams with less (isobaric) contaminants from mid 2016. We expect the ^{100}Zr experiment to be scheduled in 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.

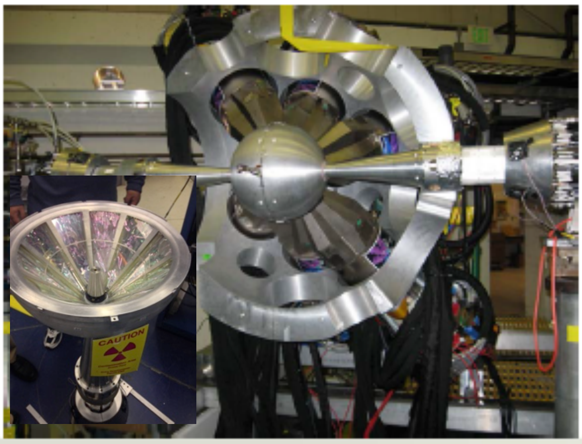

Figure 1 : Photo of the high resolution Ge spectrometer used at Argonne National Laboratory; in the insert the particle detector inside the scattering chamber is shown.

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

[2] Additionnel information about LENA

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 electromagnetic properties of atomic nuclei. 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 (Coulomb excitation analysis, Doppler-shift and fast timing techniques, etc.) and be supported by the technical divisions from IRFU.

The PhD supervisor (directeur de these) has been spokesperson of many projects at international accelerator facilities, e.g., ISOLDE-CERN; LNL, Italy; ANL, USA and 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, for example by analysing data obtained in previous experiments. In parallel, the candidate will be strongly involved in the preparation of the experiment at ANL. As most of the analysis codes already exist it should be possible to complete 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, scintillators, 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 a medium-size international collaboration, in particular with colleagues from the US national laboratories in Argonne and Oakridge. As a consequence several students may analyse the obtained data in parallel. The preparation and execution of the experiment may require an extended stay at ANL, Chicago area, USA (4-6 weeks).

CONTACTS

Wolfram Korten ; w.korten.at.cea.fr