PhD position in theoretical nuclear physics

Study of reaction mechanisms for the synthesis of super-heavy elements

One of the main questions in nuclear physics is why is there a finite number of nuclides, and, in particular, what are the heaviest possible nuclear objects in the region of super-heavy elements (SHE)? This limited number is related to their stability, as it is well known. Consequently, challenging research programmes are devoted to the study of very exotic nuclide at the limit of stability where new properties may appear and where one might have direct access to the specific features of nuclear matter being responsible for their existence. These limits are located at the edges the chart Segrè in regions extreme proton-neutron ratios (proton/neutron driplines) and at highest masses *A* and atomic numbers *Z*.

The so-called super-heavy nuclei (SHN) are expected to exist beyond the liquid drop limit of existence defined by a vanishing fission barrier thanks to the quantum mechanical shell effects. These nuclei are particularly interesting because they are at the limit between few body and large n-body physics: magic proton and neutron numbers, *Z* and *N*, are replaced by a magic region or island extended in *Z* and *N*.

Synthesis of these very and super-heavy nuclei by fusion-evaporation reactions is an experimental challenge due to the extremely low cross-sections. Modelling the complete reaction in order to guide the experiments is also a difficult challenge because models developed for lighter nuclei cannot be simply extrapolated. Fusion reactions are hindered with respect to what is observed with light nuclei because of the very strong Coulomb interaction being enhanced by the strong repulsion created by the large number of positive charges (protons) in the system. Due to its competition with the attractive strong (nuclear) force in a highly dynamic regime. The predictive power of the models is low although the origin of the hindrance phenomenon is qualitatively well understood. Quantitative ambiguities are large enough to observe few orders of magnitude differences in the fusion probabilities calculated by different models. A small change of the cross-section could result in many months being required to successfully perform experiments.

In such a context, the main purpose of the theoretical researches performed at GANIL on the synthesis of SHE is aimed to find ways to assess the models in order to improve their predictive power. One way is based on uncertainty analysis that is very new in theoretical nuclear physics. Standardised methods as well as state-of-the-art data analysis methods such as Bayesian analysis are used. Moreover, a special effort will be put on designing specific experiments dedicated to study the reaction mechanisms that could help to constrain the so-called fusion hindrance.

This thesis is done in collaboration with the experimental group in GANIL as well as laboratories in Japan, China and Poland. Depending on the skill of the student, the thesis will be more oriented towards formal developments in statistical physics or towards the experiments at the new facility Spiral2. Participation in experiments is an option.

Expected skills:
English, computer programming

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