PhD position in theoretical nuclear physics

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

Description:
One of the main activities in nuclear physics is the study of the properties of the exotic nuclei up to the limits of the nuclear chart, in regions with extreme proton-neutron ratios (proton/neutron driplines) and at the 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: the magic proton and neutron numbers, Z and N, are replaced by a magic region or island extended in Z and N.

The 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, as models developed for lighter nuclei cannot simply be extrapolated. Fusion reactions are hindered compared to what is observed with light nuclei, because the very strong Coulomb interaction is enhanced by the strong repulsion caused by the large number of positive charges (protons) in the system in competition with the attractive strong (nuclear) force in a highly dynamic regime. The predictive power of the models needs to be improved, although the origin of the hindrance phenomenon is qualitatively well understood. The quantitative ambiguities are large enough to observe a few orders of magnitude differences in the fusion probabilities calculated by different models. A small change in the cross-section could result in many months being required to perform successful experiments.

At GANIL, in collaboration with other institutes, we have developed a model that describes all the three steps of the reaction to synthesise super-heavy nuclei. Future developments will focus on finding ways to assess the models in order to improve their predictive power, including the design of dedicated experiments to constrain the so-called fusion hindrance. Of course, a careful uncertainty analysis, which is new in theoretical nuclear physics, will be necessary to assess the different ideas. Standard methods as well as state-of-the-art data analysis methods such as Bayesian analysis may be used.

This PhD work will be done in collaboration with the experimental group at GANIL and a research team in Warsaw (Poland). Depending on the skills of the student, the thesis will be more oriented towards formal developments or towards the experiments at the new Spiral2 facility. Participation in experiments is possible.

Expected skills:
English, computer programming

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