Structure Beyond the Neutron Dripline

Testing a physical system under extreme conditions is one of the methods often employed to obtain a better understanding and deeper insight into its organisation and structure. In the case of the nucleus, one such approach is to investigate isotopes that have very different neutron-to-proton rations (N/Z) than in stable nuclei. Light neutron-rich isotopes exhibit the most asymmetric N/Z ratios and are the most accessible experimentally. Those lying beyond the limits of binding, which undergo spontaneous neutron emission and exist only as very short-lived resonances, provide some of the most stringent tests of nuclear structure models.

The present thesis will focus on the exploration of such unbound neutron-rich nuclei in the region below doubly-magic ^{24}O and the recently observed unbound systems $^{25,26}O$. In terms of the evolution of the single-particle orbits, the O isotopes exhibit magicity at N=14 and 16. When protons are removed, as shown in the case of the C isotopes, the N=14 gap is predicted to disappear and the $\nu s_{1/2}$ and $\nu d_{5/2}$ single-particle orbitals become degenerate. Such behavior is believed to be at the origin of the formation of the s-wave halo neutron configuration in ^{22}C, rather than the naïve shell model d-wave valence neutron occupation. Moreover, spectroscopy of ^{21}C, performed within the context of an earlier thesis in the group, indicates that the physical $5/2^+$ and $1/2^+$ levels are inverted. As in the case of $^{25,26}O$ isotopes, measurements beyond N=16 are critically important in establishing the behaviour of the $\nu d_{3/2}$ single-particle orbital.

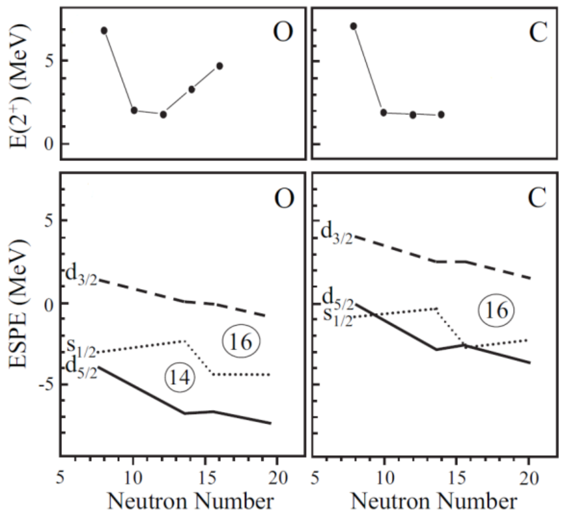

***Figure**: Effective single-particle energies (ESPE) for the sd-shell orbitals across the O and C isotopic chains as computed using the WBT shell model interaction in the psd-model space.*

The thesis work will have two main components:

- Exploit data obtained within an experiment carried out using the SAMURAI-NeuLAND-NEBULA setup at the RIBF, RIKEN (Japan) to search for excited states in ^{22}C, including the all-important 2^+ level which will provide a measure of the persistence or otherwise of the N=16 gap below ^{24}O.

- Investigate the production and spectroscopy of unbound nuclei in this region using (n,p)-type charge exchange reactions. This work will exploit data obtained in an early phase experiment with the SAMURAI+NEBULA setup.

The analysis work requires a capacity to adapt to the manipulation of large and complex sets of data obtained with a wide range of detectors, including charged particle detectors (gas based and scintillator), fast neutron detectors, a gamma-ray array and the SAMURAI spectrometer itself. This will require the use of the ROOT analysis software incorporated into a locally developed framework Nptool. Additionally, expertise will be gained in simulations, which are vital to interpreting the measurements, using GEANT4 and related codes, as also incorporated in Nptool.

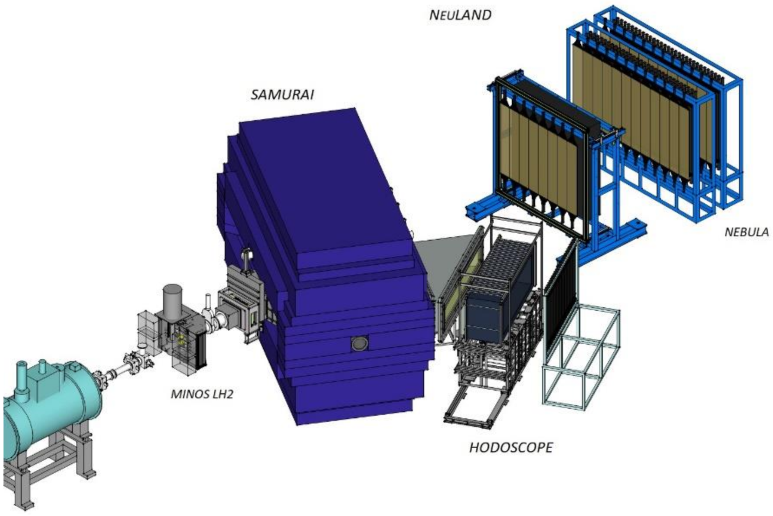

***Figure**: Schematic view of the SAMURAI-NeuLAND-NEBULA-Plus setup at the RIBF-RIKEN (Japan)*

In addition to the data analysis work and interpretation of the results in the light of theoretical modelling, the student will gain significant hands on training through their involvement in the group's ongoing experiments at the RIBF using the newly commissioned NEBULA-Plus neutron array as well as the commissioning and experiments with the STRASSE liquid-H_2 target silicon-vertex array, which will also be coupled to the SAMURAI setup. This training will also include the use of the state-of-the-art FASTER digital electronics and acquisition system developed at LPC.

The student will also have the possibility to participate in international schools and conferences in the field, such as the *EUROSchool on Exotic Beams*[1] and the *Direct Reactions with Radioactive Beams* conference[2].

Permanent members of the Nuclear Structure group:

*Lynda Achouri, Franck Delaunay, Freddy Flavigny, Julien Gibelin, Adrien Matta, Miguel Marqués,
Nigel Orr (Head of Group)*

[1] https://indico.fys.kuleuven.be/event/84/
[2] https://indico.gsi.de/event/17568/