PhD position in experimental nuclear physics

Development of an X-ray detection system for particle ID of superheavy nuclei

The synthesis and study of the heaviest nuclei in the region of superheavy elements (SHE) is still one of the major challenges of modern nuclear physics. Despite world-wide efforts and achievements throughout more than half a century, resulting in atomic number $Z = 118$ and isotopes of element oganesson as heaviest nuclear species synthesized so far, the envisaged "island of stability" of superheavy nuclei (SHN) has not yet been reached. The major ingredients for the stability and existence of those heavy systems are nuclear structure features, the so-called shell effects. Predictions of the various models on the market for closed proton and neutron shells point to numbers like 174 and 182 for the closed neutron shell and 114, 120 and 126 for the respective number of protons.

Experimental studies of the nuclear structure of the already known nuclei as well as the synthesis of new isotopes are essential for the progress of the field. Complex instrumentation at heavy ion accelerator facilities like the new linear accelerator facility SPIRAL2 at GANIL are the key ingredients to allow these investigations. So far, those SHN are produced in heavy ion fusion reactions, where the reaction products are separated from the primary beam by an effective ion-optical separator and then studied by a comprehensive detection system for particles and photons, including alpha-, gamma-, fission fragment and conversion electron spectroscopy.

The identification of the studied nuclei in atomic charge Z and nuclear mass A, typically based on decay features of known nuclei, e.g. by alpha spectroscopy of subsequent decay chain members, face severe limitations for hitherto unknown nuclei. The separator-spectrometer set-up S^3 at GANIL-Spiral2 is equipped with mass spectroscopic capabilities sufficient to resolve the mass A of SHN. At its focal plane the comprehensive detection system SIRIUS consists of an efficient silicon detection array for particle (reaction products, alphas, fission fragments, e^- and light charged particles). It will be accompanied by an array of large volume (typical dimensions: $(10\times10\times9)\ cm^3$) germanium detectors for gamma spectroscopy. To establish the atomic charge of the species of interest, characteristic X-rays can be used, whose energies are, however, at and below the energy detection threshold of those large volume germanium detectors. To provide the means for an efficient X-ray spectroscopy, the development and implementation of a photon detection system with lower energy threshold and enhanced efficiency for X-ray energies in the range from $\approx$15 keV to $\approx$100 keV is the major task of the Ph.D. thesis work.

On the instrumental side, our group has recently achieved experience in the use of so-called Low-Energy Photon Spectrometers (LEPS) which provide the specifications required for X-ray spectroscopy, consisting of small volume (thickness $\approx$ 1cm) Ge crystals with a thin (0.5 mm carbon) entrance window. An array with similar features will be needed at the S^3 focal plane. The development of such a system, its integration in the SIRIUS set-up as well as its in-beam test and use for SHN decay spectroscopy will be the main tasks of the Ph.D. thesis.

On the physics side our group pursues and is involved in the spectroscopic studies of very heavy and superheavy nuclei on site at GANIL-SPIRAL2 as well as in activities at international accelerator laboratories like Argonne National Laboratory (ANL), Argonne, U.S.A., Flerov Laboratory of Nuclear Reactions of the Joint Institute for Nuclear Research (FLNR-JINR), Dubna, Russia, Helmholtzzentrum for Heavy Ion Research GSI, Darmstadt, Germany, Japanese Atomic Energy Agency (JAEA), Tokai, Japan and others. The subjects of our research comprise spectroscopic studies of heavy and superheavy nuclei produced in fusion reactions as well as the investigation of alternative reaction schemes to produce exotic heavy nuclear systems like the exchange of nucleons between projectile and target in heavy-ion collisions, so-called multi-nucleon transfer (MNT) reactions. A Ph.D. thesis work is presently being performed on a recent experiment, studying MNT in the reaction $^{238}U+^{238}U$ at GANIL-SPIRAL2. A possible continuation at GANIL-SPIRAL2 or elsewhere depends on the outcome of this present thesis work. Concerning gamma and decay spectroscopy, we have an accepted experiment at ANL to study the doubly magic nucleus ^{252}Fm by in-beam gamma spectroscopy at the separator-gamma-detection array combination FMA+GRETINA, scheduled to run in October 2021. The decay of ^{254}Lr and its decay products to study the region around ^{252}Fm, employing the competing alpha and electron capture (beta) decay modes is envisaged to be studied also at ANL or elsewhere. These activities in which the Ph.D. student will be involved, are efficient preparatory studies for the experiment campaigns planned at S^3 which is scheduled to come online in 2024. This Ph.D. thesis work is a major ingredient for the preparation of the detection instrumentation needed for the S^3 operation.

Expected skills:

Team work capabilities
English
Computer coding (C++, ...)

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