2018 HGF – GSI – OCPC – Programme

For the involvement of postdocs in bilateral collaboration projects

Part A:
Title of the project:
Experiments with thermalized exotic nuclei for nuclear astrophysics
Helmholtz Centre and institute:
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Description of the project :
The origin of the heavy elements beyond iron in our Universe is still an open question and has triggered many nuclear physics studies. The relevant nuclear physics inputs are masses, capture cross sections, half-lives and beta-delayed particle emission probabilities of the nuclides. Although the precise determination of these properties is a great challenge, enormous progress has been made in recent decades, which has contributed significantly to both nuclear structure and astrophysical nucleosynthesis studies. The FRS Ion Catcher experiment at GSI enables determination of many of these properties in precision experiments with projectile and fission fragments. The fragments are produced at relativistic energies in the target at the entrance to the fragment separator (FRS), spatially separated and energy-bunched in the FRS, and slowed-down and thermalized in a cryogenic stopping cell (CSC). A versatile RFQ beamline and diagnostics unit and a high-performance multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS) enable a variety of

experiments, including high-precision mass measurements, isomer measurements and mass-selected decay spectroscopy. At the same time the FRS Ion Catcher serves as a test facility for the Low-Energy Branch of the Super-FRS at FAIR.

In this project one focus shall be measurements of properties of neutron-rich exotic isotopes. These provide important input for nuclear astrophysics models of nucleosynthesis via the rapid neutron capture process (r-process), nuclear physics models, and nuclear reactor operation. Of these, single- and multi-neutron emission probabilities (Pxn, where x stands for the number of emitted neutrons) are the scarcest.

A novel, original and relatively simple method to measure Pxn of neutron-rich isotopes will be used at the FRS Ion Catcher. We will generate a pure ensemble of neutron-rich nuclei via the FRS; contain them in the CSC for a controllable duration, during which they may decay, and extract the precursor and the recoil nuclei to the MR-TOF-MS, where they are identified and counted. We determine the precursor's Pxn from the ratios between the recoils amounts. In addition, we simultaneously measure the masses and the precursor's Q-values from the MR-TOF-MS spectra, and the precursor's half-life from the recoils to precursor ratios.

The method is independent of existing approaches (that mostly rely on neutron coincidence detection), effectively background-free, and practically immune to systematic errors. Further, our method's efficiency is independent of the number of emitted neutrons, making it the method of choice for multi-neutron emitting isotopes.

Several beam-time proposals for the FRS Ion Catcher have been approved (incl. the one for the Pxn measurements) for FAIR Phase-0 at GSI in 2018/19. Experiments and developments for FAIR will continue until the full start of FAIR, when the different components will be installed in the Low-Energy Branch of the Super-FRS. The proposed project will strengthen the collaboration on nuclear astrophysics between GSI/FAIR and the Chinese collaboration partners and pave the way for a rich and state-of-the-art nuclear astrophysics program at the future Chinese accelerator facility HIAF.

Description of existing or sought Chinese collaboration partner institute:
We are looking for Chinese partners with strong interest in nuclear astrophysics, especially in mass measurements and beta-delayed neutron emission probabilities. One of the potential partners for this program is the School of Physics and Nuclear Engineering at the Beihang University (BUAA) in Bejing. With BUAA we have a collaboration for more than 10 years that includes common experiments for the isochronous mass measurements in the ESR at GSI and detector developments at the University of Giessen. BUAA participates in numerous ongoing and future experiments at the Fragment Separator FRS at GSI, such as investigations of the tensor force, charge-changing cross section, and detector developments. Therefore, the GSI/FAIR-BUAA collaboration on nuclear astrophysics will expand the current collaboration to a new research field. Candidates from other institutions are also highly welcome if the institutions would like to collaborate on experiments with the FRS Ion Catcher at GSI. The establishment of a stronger collaboration between GSI/FAIR and Chinese partners for nuclear astrophysics will give benefits to both parties due to large synergies between GSI/FAIR and HIAF.
Required qualification of the post-doc:
• PhD in experimental nuclear physics • Experience with data analyses, detectors and electronics in nuclear physics • Language requirement: fluent in English

Part B:
Documents to be provided by the post-doc:
• Detailed description of the interest in joining the project (motivation letter) • Curriculum vitae (CV) • copies of degrees as a proof of education qualification • List of publications (if any) • 2 letters of recommendation

Part C:
Additional requirements to be fulfilled by the post-doc:
• Very good command of the English language • Strong ability to work independently and in a team