2026 Helmholtz – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project:	High-Precision Mass Measurements and Nuclear Structure Studies of Neutron-Rich Exotic Nuclei at the FRS Ion Catcher and Super-FRS at FAIR
GSI Division & Group:	NUSTAR – FRS/Super-FRS Experiments (Thermalized Exotic Nuclei)
Project leader/supervisor:	Dr. Timo Dickel
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Description of the project (max. 1 page):

The NuSTAR (Nuclear Structure, Astrophysics and Reactions) collaboration at FAIR exploits exotic nuclei far from the valley of stability to address fundamental open questions in nuclear physics and astrophysics. The Fragment Separator (FRS) at GSI is the world's premier in-flight separator for relativistic heavy ions, and its successor – the Superconducting Fragment Separator (Super-FRS) at FAIR – is entering its commissioning phase targeting Early Science operations from 2027. The Super-FRS is characterised by large-acceptance superconducting magnets and three experimental branches (Ring, High-Energy, and Low-Energy), enabling unprecedented access to isotopes across the entire nuclear chart up to uranium.

This project focuses on **high-precision nuclear mass measurements and spectroscopy of neutron-rich exotic nuclei** using the FRS Ion Catcher (FRS-IC) facility. The FRS-IC combines the FRS with a Cryogenic Stopping Cell (CSC) and a high-performance Multiple-Reflection Time-of-Flight Mass Spectrometer (MR-TOF-MS). Unlike the companion GSI05 project which targets multinucleon transfer (MNT) reaction mechanisms and CSC hardware development, this project focuses on the physics programme of precision mass measurements in key nuclear structure regions: in particular the N=82 and N=126 shell closures and the third r-process abundance peak, directly relevant to understanding element synthesis in neutron star mergers and core-collapse supernovae.

Concretely, the postdoctoral researcher will: (1) carry out and analyse broadband mass measurement campaigns of neutron-rich nuclei produced via uranium projectile fission and fragmentation at the FRS, with resolving power $m/\Delta m > 10^6$; (2) exploit the unique isobar and isomer separation capability of the MR-TOF-MS to identify and characterise shape-phase transitions and nuclear isomers in the $N \approx 90$ and actinide regions; (3) contribute to the detector commissioning and beam tests of the Super-FRS Low-Energy Branch in the context of FAIR Phase-0 and Early Science preparation; and (4) develop and benchmark physics simulations for future Super-FRS experiments.

Recent highlights from the group include the first observation of MNT isotope beams at the FRS Ion Catcher (2025), broadband mass measurements probing the shape-phase transition near N=90, and fission isomer studies with advanced detection systems. The postdoc will build on these results

and contribute to the emerging Super-FRS era at FAIR.

Description of existing or sought Chinese collaboration partner institute (max. half page):

The primary Chinese partner is the **Institute of Modern Physics (IMP), Chinese Academy of Sciences, Lanzhou**. IMP operates the Heavy Ion Research Facility in Lanzhou (HIRFL) and is constructing the High Intensity heavy-ion Accelerator Facility (HIAF), which will be the Chinese counterpart to FAIR for exotic beam physics in the relativistic energy regime. IMP groups have extensive experience in in-flight separation, isochronous mass spectrometry (IMS), and time-of-flight mass measurements of exotic nuclei – expertise directly complementary to the MR-TOF-MS programme at the FRS Ion Catcher.

An additional sought partner is **Peking University**, with its groups active in nuclear astrophysics simulations and nuclear reaction network calculations for the r-process, providing direct theoretical context for the mass measurement results. Exchange visits, joint beamtime proposals, and co-authored publications between GSI/FAIR and IMP/HIAF are foreseen within the existing bilateral framework between the Helmholtz Association and the Chinese Academy of Sciences.

Required qualification of the postdoc:

- PhD in experimental nuclear physics
- Experience with exotic beam facilities and in-flight separation techniques
- Hands-on experience with mass spectrometry or time-of-flight detector systems
- Additional skills in data analysis frameworks (C++, ROOT, Python) and simulation tools (MOCADI, LISE++)
- Experience with or interest in nuclear astrophysics and r-process nucleosynthesis is an advantage
- Language requirement: good command of written and spoken English