HK 17: Structure and Dynamics of Nuclei VI

Time: Tuesday 15:45–17:15 Location: HS 2 Physik

Group Report HK 17.1 Tue 15:45 HS 2 Physik

Experiments with exotic nuclei at the FRS Ion Catcher — •Kriti Mahajan for the Super-FRS Experiment-Collaboration — Justus-Liebig Universität Gießen, Germany — Helmholtz Research Academy Hesse for FAIR (HFHF), Campus Gießen, Germany

At GSI Darmstadt exotic nuclei can be produced at relativistic energies by projectile fragmentation or fission and separated in the fragment separator FRS. Then at FRS Ion Catcher, the beam is thermalized inside the cryogenic stopping cell (CSC) and transmitted to the multiple reflection time-of-flight mass spectrometer (MR-TOF-MS), which features a high resolving power of up to 1,000,000, short cycle times of a few ten milliseconds and mass accuracies down to a few 10^{-8}.

At FRS-IC, several masses have been measured so far across the nuclear chart. Direct mass measurements of neutron-deficient nuclides around $N = Z$ below ^{100}Sn and neutron-rich nuclides along $N = 126$ below ^{208}Pb have been performed and shed light on the nuclear structure in these regions. Additionally, broadband mass measurements of fission fragments from a ^{252}Cf spontaneous fission source reveal evidence for shape phase transitions in the $N \sim 90$, $Z = 56 - 63$ region, and provide direct determination of independent isotopic fission yields (IIFYs). Recently, proof-of-principle experiments were performed focused in the multi-nucleon transfer reactions and study of radioactive molecules driven by the hunt to explore fundamental laws of nature.

An overview of the setup, recent experimental highlights, technical advances and upcoming experiments in FAIR Phase-0 will be reported.

HK 17.2 Tue 16:15 HS 2 Physik

Correlation experiments in fission induced by quasi-monochromatic photons* — •Vincent Wende[1], Dimiter Balabanski[4], Joachim Enders[1], Sean W. Finch[2], Alf Göök[3], Calvin R. Howell[2], Annabel Ibel[1], Forrest Q.L. Friesen[2], Ronald C. Malone[7], Maximilian Meier[1], Andreas Oberstedt[4], Stephan Oberstedt[5], Marius Peck[1], Norbert Pietralla[1], Anthony P.D. Ramirez[6], Jack A. Silano[6], Gerhart Steinhilber[1], Anton P. Tonchev[6], and Werner Tornow[2] — [1]Institut für Kernphysik, Fachbereich Physik, TU Darmstadt, Darmstadt, Germany — [2]Triangle Universities Nuclear Laboratory, Duke University, Durham, NC, USA — [3]Uppsala Universitet, Uppsala, Sweden — [4]ELI-NP, IFIN-HH, Magurele, Romania — [5]EC-JRC Geel, Belgium — [6]Lawrence Livermore National Laboratory, Livermore, CA, USA — [7]U.S. Naval Academy, Annapolis, MD, USA

Describing the nuclear fission process requires high-precision data from experiments. We present results of an experimental campaign at the High-Intensity γ-Ray Source at TUNL, investigating the fission of actinides using linearly-polarized quasi-monochromatic photon beams between 6.2 and 13 MeV in the entrance channel. Mass, total kinetic energy and angular distributions of fission fragments have been measured simultaneously using a position-sensitive twin Frisch-grid ionization chamber.
*Work supported by DFG, GRK 2891 Nuclear Photonics (project-ID 499256822).

HK 17.3 Tue 16:30 HS 2 Physik

Microscopic description of collective inertias for fission — •Nithish Kumar Covalam Vijayakumar[1,2], Gabriel Martínez-Pinedo[2,1], Luis Robledo[3], and Samuel Andrea Giuliani[3] — [1]Institut für Kernphysik, Technische Universität Darmstadt, Darmstadt, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [3]Universidad Autónoma de Madrid, Madrid, Spain

The theoretical description of nuclear fission is a challenging quantum many body problem since it involves quantum tunneling of the nuclei through fission barriers. This tunneling is very sensitive to the collective inertia along the fission path. In most of the fission calculations, the collective inertia is evaluated using cranking approximation which neglects the dynamical residual effects. In this work, we are developing a scheme to compute collective inertias using finite amplitude method - quasiparticle random phase approximation (FAM-QRPA) which also takes into account the consistent treatment of dynamical effects. FAM-QRPA code is currently being developed using the finite range Gogny energy density functionals and axial symmetry preserving Hartree-Fock-Bogoliubov framework. The completed FAM-QRPA code will be then used to study the role of collective inertia in fission probabilities and the role of fission in r-process nucleosynthesis. Once the code is developed, it can also be used to study electromagnetic response of nuclei. This work is supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) Project-ID 499256822 GRK 2891 'Nuclear Photonics'.

HK 17.4 Tue 16:45 HS 2 Physik

Search for the Double Alpha Decay of Ra-224 at GSI: Final Sensitivity Estimation — •Heinrich Wilsenach — The Hebrew University of Jerusalem, Jerusalem, Israel

Double alpha decay is a predicted decay mode when the atomic nucleus decays via the simultaneous emission of two α-particles. A recent theoretical publication by Mercier *et al.* (PRL 127, 012501 (2021)) has renewed interest in this topic, which was first discussed in the late 1970s. The work proposes an experimentally achievable estimate for the branching ratio of about 10^{-8}. In the last 2 years, three experiments have been performed to search for the double alpha decay of trans-lead isotopes: at GSI (2022), at the ISOLDE facility (CERN, 2023), and at MSU (2024).

In this talk, we will focus on the double alpha experiment performed at the FRS Ion Catcher (FRC-IC) to observe the decay of ^{224}Ra. To reduce the random coincidence detection rate, an offline ^{228}Th source was used at FRS-IC to produce a beam of Ra^{2+} ions. Since the two α-particles are predicted to be emitted in opposite directions with the branching ratio of 10^{-8}, two face-to-face silicon strip detectors were employed to detect all alphas and betas from the known decay transitions in the ^{224}Ra decay chain. A large dataset of 10^9 ^{224}Ra events gives an expected number of signal events of 90 double alpha decays.

The final stage of data analysis is the main focus of this talk. We present the consistent processing of the entire combined dataset and the final evaluation of the detection setup sensitivity.

HK 17.5 Tue 17:00 HS 2 Physik

Measurement of masses of fission products and isotopic yields from a ^{252}Cf spontaneous fission source at the FRS Ion Catcher — •Meetika Narang for the FRS Ion Catcher-Collaboration — University of Groningen, Netherlands — GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany.

Masses of neutron-rich nuclei and the nuclear fission process are essential for understanding nuclear structure far from stability and the abundance of elements synthesized through the r-process.

At the FRS Ion Catcher (FRS-IC) at GSI, fission fragments are produced via spontaneous fission (SF) from a ^{252}Cf source mounted inside a gas-filled Cryogenic Stopping Cell (CSC). These fragments are thermalized and stopped within the CSC. Their masses and IIFYs are then measured with a Multiple-Reflection Time-Of-Flight Mass Spectrometer (MR-TOF-MS). The MR-TOF-MS resolves isobars, incorporating several novel and unique concepts, even with limited statistics. Its broadband nature ensures minimal relative systematic uncertainties among fission products. Extracting IIFYs includes isotope-dependent efficiency corrections for all the components of FRS-IC.

In this talk, I will present our results, including high-accuracy mass measurements representing the first direct mass measurements in the N = 90 and Z = 56-62 region. Additionally, I will discuss our IIFY results, which cover several tens of fission products, extending to the high-mass fission peak and yields as low as 10^{-5}. Future experiments aim to broaden these results to cover a wider range of Z and N values, lower fission yields, and other spontaneously-fissioning actinides.