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MR-TOF-MS at the FRS: Instrumental Advances, Mass Measurements and Spatial Isomer Separation for Decay Spectroscopy

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At the FRS Ion Catcher experiment at GSI, projectile and fission fragments are produced at relativistic energies with the FRS, separated in-flight, range-focused, slowed-down and thermalized in a cryogenic stopping cell and are transmitted to a multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS). The MR-TOF-MS is used to perform direct mass measurements of exotic nuclei, to provide an isobarically and isomerically clean beam for further experiments, and as a versatile diagnostics device to verify the particle identification of the FRS and analyze the ions emerging from the CSC.

The MR-TOF-MS consists of an RFQ for ion cooling and transmission, an injection RF trap for ion bunching, a coaxial isochronous TOF analyzer, as well as a TOF detector for mass measurement and a Bradbury-Nielsen Gate for mass separation. Several novel principles have been implemented to further enhance the performance and versatility of the MR-TOF-MS, including a post-analyzer reflector. Thus extremely high resolution can be obtained as well as very short flight times. Mass resolving powers up to 600,000 (FWHM) at 50% transmission efficiency, ion capacities of more than a million ions per second and cycle frequencies as high as 400 Hz have been achieved.

Recently, the kinetic energy of the ions in the time-of-flight section of the MR-TOF-MS has been increased, yielding a mass resolving power of 220,000 at mass 133 u after only 4.6 ms. A novel RF quadrupole-based ion beam switchyard has been developed that allows merging and splitting of ion beams as well as transport of ion beams into different directions. It efficiently connects a test and reference ion source and an auxiliary detector to the system.

Mass measurements of uranium projectile and fission fragments produced at the FRS at 1000 MeV/u have been performed at mass resolving powers up to 400,000. For several nuclides, the mass was measured directly for the first time, among them the nuclides 213-Rn, 218-Rn and 217-At with half-lives of 19.5 ms, 35 ms and 32.3 ms, respectively. Mass determination with as few as 27 detected ions at ion rates of five ions per hour has been demonstrated, and mass measurement accuracies down to 0.2 ppm have been achieved. The excitation energy of several isomers and isomeric ratios were determined using mass spectrometry. For the first time, an isomeric beam was prepared using an MR-TOF-MS. This work opens up new perspectives for decay experiments with isomers.

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