Muonic Atoms

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The QUARTET collaboration aims to improve the accuracy of absolute nuclear charge radii of light nuclei from Li to Ne by about one order of magnitude using high-precision X-ray spectroscopy of muonic atoms. Metallic Magnetic Calorimeters (MMC) operated at temperature around 20 mK are used because of the demonstrated high energy resolution and large dynamic range, as well as a reliable and stable energy calibration.

After the first experiment at the PiE3 beamline at the Paul Scherrer Institute (PSI) in 2023, which showed the suitability of MMCs for the high-precision X-ray spectroscopy of muonic atoms, two data taking campaigns have been performed in 2024 and 2025 for the measurement of different stable Li-, Be-, B-, O-isotopes as well as proof-of-principle measurements of C-isotopes. In addition, a short measurement for the determination of the chemical composition of a prehistoric human tooth was carried out, showing the outstanding performance of MMCs with respect to conventional detectors. While for the first experiments an already available detector system could be used, a new MMC array had to be developed for achieving high quantum efficiency for x-rays emitted in muonic oxygen and heavier elements, covering the energy range up to 200 keV. This new detector system will be also used for the three weeks beamtime in 2026.

The optimization of the MMC array as well as the non-trivial integration of the detector system at the PiE3 beamline will be discussed. The data acquisition system will be shortly introduced in order to discuss the data reduction and, in particular, the suppression of background events. The importance of the energy calibration will be discussed, before presenting the spectra obtained for muonic Li, with a precise isotope shift determination, and Be. As special highlight, the chemical composition of the prehistoric human tooth will be shown.