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Reviving muonic atom spectroscopy to extract absolute nuclear charge radii in rare and radioactive targets

The knowledge of absolute nuclear charge radii has a significant scientific impact, from testing nuclear theories to beyond standard model physics. The absolute charge radii of almost all stable isotopes were extracted till the late 1990s, using the muonic atom spectroscopy method. In this method, a negatively charged muon beam is shot on target, the muon stops and is captured at a high principle quantum number. From there on, the muon will cascade down to the ground state of the atom, emitting muonic x rays at the later stage of the cascade. Due to the heavy mass of the muon, there is a large overlap between the low-lying muonic states and the nuclear charge distribution making the muonic 2p-1s x rays highly sensitive to the nuclear properties, such as the charge radius. However, to stop and capture the muon directly in the target, tenths to hundreds of milligrams of target material are typically needed, limiting past muonic measurements to stable or abundant targets. Since then, we have developed a method in which muon captures in microgram targets are realized through subsequent transfers of the muon in a high pressure H_2/D_2 gas, and thus we have extended the muonic measurements to radioactive and rare isotopes across the nuclear chart. In this contribution, an overview of the experiment and the current stage of charge radii extraction of isotopes spanning from Si to Cm will be discussed, highlighting the experimental and theoretical principles and challenges in that process.

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