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Accessing higher-order nuclear magnetization moments with muonic atoms

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Little is known about the distribution of magnetization inside the nucleus. While nuclear charge distributions may be well understood through techniques like electron scattering, muonic atom spectroscopy, and precision measurements of atomic isotope shifts, nuclear magnetization distributions are much harder to probe.

We highlight and exploit a property of heavy muonic atoms that enables the determination of higher-order magnetization moments of the nucleus. Contrary to the electronic wave functions in usual atoms and ions, muonic wave functions are distinct for different states in the nuclear region. We show that measurements of hyperfine constants for several different states of muonic atoms give access to magnetization moments of the lowest $\langle R^2 \rangle$ and higher orders, $\langle R^4 \rangle$, $\langle R^6 \rangle$, etc. A measurement for an electronic system (H-like ion) gives additional information, though there is little, if any, benefit from a second electronic state. We demonstrate our approach in the nuclear single-particle model, and show how it may be used in a model-independent way. We demonstrate our approach using ^{209}Bi and ^{205}Tl, for which data are available for multiple muonic atom states and for H-like ions. We hope work stimulates new hyperfine measurements with muonic atoms, together with H-like ions, and provides a unique avenue for testing nuclear structure models and probing the neutron distribution.

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