Contribution ID: **74** Type: **not specified**

Muonic atoms reveal the structure of deformed nuclei

Tuesday 27 August 2024 17:30 (2 hours)

Keywords: muonic atoms; nuclear structure; hyperfine structure

The study of exotic atoms, such as muonic hydrogen-like ions [1-3], provides an intriguing way to probe the internal structure of their atomic nuclei. In this work, we use nuclear structure simulations to accurately calculate the hyperfine splitting of muonic hydrogen-like ions, focusing in particular on the incorporation of finite volume corrections, such as Bohr-Weisskopf and Breit-Rosenthal, due to the penetration of the muon wavefunction into the nuclear electric charge and magnetic dipole densities [3-5]. These corrections are essential for refining our understanding of the nuclear magnetic and quadrupole moments.

The simulations leverage a modified Skyrme-Hartree-Fock-based model integrated with Bardeen-Cooper-Schrieffer (BCS) and Hartree-Two-Delta-Approximation (HTDA) corrections. This model is particularly effective in representing highly deformed nuclei [6] and focuses extensively on the isotopes $^{161,163}Dy^{65+}$ and other lanthanides, including $^{159}Tb^{64+}$. Additionally, this model is coupled with an adapted Dirac-Fock method for computing the muonic wavefunction within the derived nuclear magnetic and electric potential. The methodology is scalable and can be extended to multielectron ions by analyzing the hyperfine anomaly across various isotopes.

Our findings reveal that while the discrepancy in hyperfine constants between two given finite size models is modest (approximately 1%) for both electronic and muonic penetrative wavefunctions, $s^{1/2}$ and $p^{1/2}$, the proximity of the muon to the nucleus results in an amplification of the absolute difference by two orders of magnitude (approximately $\times 100$), thus facilitating a more precise discrimination between theoretical models.

Our study aims to align theoretical predictions of muonic hydrogen-like ions with experimental data to validate our models and verify fundamental nuclear physics principles. This crucial comparative analysis not only tests the accuracy of nuclear structure predictions but also confirms the utility of muonic ions as effective nuclear probes. Moreover, the approach can be generalized across various nuclear models, serving as a benchmark for further investigations. The anticipated outcomes of this research will significantly enhance our understanding of the deformation and complex structures of lanthanides, thereby advancing the broader field of nuclear physics and refining theoretical frameworks for describing exotic atoms and highly deformed nuclei.

Indico rendering error

```
Could not include image: [429] Error fetching image
```

[1.] B. M. Roberts, P. G. Ranclaud, and J. S. M. Ginges, Bohr-Weisskopf Effect: From Hydrogenlike-Ion Experiments to Heavy-Atom Calculations of the Hyperfine Structure, Phys. Rev. A 105, (2022).
[2.] T. Okumura et al., Deexcitation Dynamics of Muonic Atoms Revealed by High-Precision Spectroscopy of Electronic K X Rays, Phys. Rev. Lett. 127, (2021).
[3.] E. V. Tkalya and A. V. Nikolaev, Magnetic Hyperfine Structure of the Ground-State Doublet in Highly Charged Ions Th89+87+229 and the Bohr-Weisskopf Effect, Phys. Rev. C 94, (2016).
[4.] F. F. Karpeshin and M. B. Trzhaskovskaya, The Theory of the Bohr–Weisskopf Effect in the Hyperfine Structure, Nuclear Physics A 941, 66 (2015).

[5.] A. Pálffy, Nuclear Effects in Atomic Transitions, Contemporary Physics 51, 471 (2010).
[6.] L. Bonneau, N. Minkov, D. D. Duc, P. Quentin, and J. Bartel, Effect of Core Polarization on Magnetic Dipole Moments in Deformed Odd-Mass Nuclei, Phys. Rev. C 91, (2015).

Authors: JANKOVIC, Denis (Institut de Physique et Chimie des Materiaux de Strasbourg (FR) / Karlsruhe Institute of Technology (DE)); Mr HARTMANN, Jean-Gabriel (Institut de Physique et Chimie des Materiaux de Strasbourg (FR)); Prof. HERVIEUX, Paul-Antoine (Institut de Physique et Chimie des Materiaux de Strasbourg (FR))

Co-authors: Dr MOLIQUE, Hervé (IPHC Strasbourg); Prof. BARTEL, Johann (IPHC Strasbourg); Dr BONNEAU, Ludovic (Laboratoire de Physique des 2 infinis (LP2i) Bordeaux, UMR 5797, Université de Bordeaux, CNRS, Gradignan, France)

Presenter: JANKOVIC, Denis (Institut de Physique et Chimie des Materiaux de Strasbourg (FR) / Karlsruhe Institute of Technology (DE))

Session Classification: Poster