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Highly-Charged Radioactive Molecules: Amplifying Sensitivity for New Physics

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One necessary extension to the Standard Model of Particle Physics (SM) is one which describes the behavior of the early universe that leads to the matter-antimatter asymmetry which we observe today. It is commonly assumed that any explanation of this matter-antimatter imbalance must rely on the violation of the combined symmetry of charge conjugation (C) and parity (P) that is presently, however, considered to be too weak in the SM. Thus, identifying a new source of CP violation is of critical importance. CP-violating effects, particularly those that originate within the atomic nucleus, can be investigated by combining precision techniques from atomic, molecular, and optical physics with rare isotopes produced at accelerator facilities such as TRIUMF in Canada. In searches for CP-violating nuclear Schiff moments, for example, molecular systems offer a sensitivity advantage of 3-4 orders of magnitude which can be further increased by up to a factor of 1000 when a radioactive, octupole-deformed nucleus is incorporated into the molecule. Among these radionuclides, the short-lived protactinium isotope ^{229}Pa is thought to exhibit the highest sensitivity, once a suitable molecule has been identified. Recently, triply charged protactinium-monofluoride PaF^{3+} has been proposed as a highly attractive probe, which is isoelectronic to the well studied case of neutral RaF. Experimentally, forming such 'highly charged'molecules remains a significant challenge, also because all other Pa isotopes are radioactive, complicating the development of the necessary techniques. In this talk, we present the experimental formation of stable, doubly-charged cerium monofluoride CeF^{2+} which is identified as an intriguing surrogate to PaF^{3+} with a very similar molecular structure. Specific sensitivities of CeF^{2+} to new physics also position the system as an interesting probe for disentangling sources of symmetry-violating behavior inside the nucleus.

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