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Antiprotonic Atom X-ray Spectroscopy with Quantum Sensors

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From dark matter and dark energy, to neutrino oscillations and the lack of antimatter in the universe, there is growing evidence that the Standard Model is incomplete. Tests of Quantum Electrodynamics (QED) with few-electron systems offer a promising avenue for looking for new physics, as QED is the best understood quantum field theory and extremely precise predictions can be obtained for few-electron systems. Unfortunately, despite decades of effort, QED is poorly tested in the regime of strong coulomb fields, precisely the region where new exotic physics may be most visible. I will present a new paradigm for probing higher-order QED effects using spectroscopy of Rydberg states in exotic atoms, where orders of magnitude stronger field strengths can be achieved while nuclear uncertainties may be neglected [1]. Such tests are now possible due to the advent of quantum sensing detectors and new facilities providing low-energy intense beams of exotic particles for precision physics. First measurements have been successfully conducted at J-PARC with muonic atoms [2], but antiprotonic atoms offer the highest sensitivity to strong-field QED. I will present an overview of the PAX project, now funded by an ERC starting grant, that aims to develop a new experiment for antiprotonic atom x-ray spectroscopy with a large-area transition edge sensor (TES) x-ray detector at CERN. The PAX platform can also be used to study nuclear interactions and properties, and possible synergies with existing AD experiments will be presented.

[1] N. Paul et al, Physical Review Letters 126, 173001 (2021)
[2] T. Okumura et al, Physical Review Letters 30, 173001 (2023)

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