Precision Spectroscopy of Antiprotonic Atoms for Probing Strong-Field QED

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Precision measurements in quantum systems are critical for testing the boundaries of the Standard Model and exploring new physics [1]. Such investigations depend on a precise understanding of quantum electrodynamics (QED), one of the fundamentally best-understood theories. While bound-state QED (BSQED) predictions have been validated to high precision (parts per 10^{12}) in simple systems like hydrogen [2], its predictions for high-Z atoms in strong Coulomb fields remain largely untested beyond first-order interactions. This limitation arises from experimental challenges and fundamental theoretical uncertainties related to nuclear effects [3].

PAX is a new experiment designed to test strong-field BSQED up to second-order through x-ray spectroscopy of antiprotonic atoms. These exotic systems exhibit Coulomb fields two to seven orders of magnitude stronger than those in their highly charged ion counterparts, amplifying QED effects and making them more accessible to measurement [4]. Our aim is to measure Rydberg transitions in gaseous targets using a novel Transition Edge Sensor x-ray detector, enabling high-precision measurements with a large solid angle and intrinsic resolution of ~50 eV (FWHM) in the 50–250 keV range, achieving an accuracy of 10^{-5}–10^{-6}. The PAX strategy will effectively eliminate uncertainties from the nucleus, allowing direct and purely QED-focused measurements.

First prototype detector tests for PAX are being conducted in the TELMAX zone at ELENA, CERN. I will present the current status of the test beam, and prospects for the next phases of the experiment.

ANTIPROTONIC ATOM X-RAY SPECTROSCOPY

References

[1] C. Delaunay, JP. KArr, T. Kitahara, J. Koelemeij, Y. Soreq, and J. Zupan, *Physical review letters* **130**, 12 (2023).
[2] H. Fleurbaey, *et al.* , *Physical review letters* **120**, 183001 (2018).
[3] P. Indelicato, *Journal of Physics B: Atomic, Molecular and Optical Physics* **52**, 232001 (2019).
[4] N. Paul, *et al.*, *Physical Review Letters* **126**, 17300 (2021).