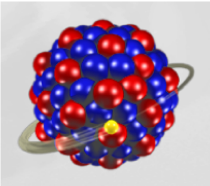
PhD PROPOSAL



Fundamental tests through precision spectroscopy of muonic and antiprotonic atoms

High-precision studies of the quantum structure of atomic systems allow to probe a multitude of fundamental physics questions, from quantum electrodynamics to astrophysics, to tests of the standard model and studies of nuclei. Our group is pioneering a new domain of atomic spectroscopy by applying quantum sensing x-ray detectors to study exotic atoms. An exotic atom is formed when a heavier, negatively-charged particle like a muon (μ-) or an antiproton replaces the electron on the atomic orbitals. Due to their larger mass, these particles lie much closer to the nucleus (e.g. ~207 times closer for the μ-), and thus probe higher Coulomb fields than their electronic counterparts. A special region of transitions in these systems can be found between high-n circular Rydberg states, where nuclear contributions to the transition energies vanish while the QED contributions remain large, providing a unique opportunity to cleanly probe strong-field QED [1]. Antiprotonic atoms offer access to the strongest field QED conditions, and low-energy antiproton beams amenable to precision physics are now available at the Extra Low Energy Antiproton (ELENA) facility at CERN.

We are developing a new experiment called PAX (antiProtonic Atom X-ray spectroscopy), funded by an ERC Starting grant, to perform high precision x-ray spectroscopy of antiprotonic atoms at CERN to probe strongest-field QED. The student will work on building the magnetic, gas-filled trap that will be used to trap the antiprotons. The student will also participate in proof-of-principal studies with antiprotons and solid targets at CERN using a protype transition edge sensing x-ray microcalorimeter detector developed by the NIST (USA).

The student will also gain experience in the context of a new, complementary experimental collaboration, QUARTET (QUAntum inteRacTions with Exotic aToms) to study the structure of light nuclei via muonic atom spectroscopy. The student will participate in experimental campaigns at the Paul Scherrer Institute, and based on her/his experience develop tools and technical solutions to make these detectors compatible with antimatter beams.

[1] N. Paul, G. Bian, T. Azuma, S. Okada, and P. Indelicato, Phys. Rev. Lett. **126**, 173001 (2021).

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