Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: Institut des NanoSciences de Paris
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Institut des NanoSciences, Sorbonne Université Campus Pierre et Marie Curie
4 Place Jussieu, 75005 Paris
GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

Thesis possibility after internship: YES
Funding: YES If YES, which type of funding:Initiative Physique des Infinis

Test of quantum electrodynamics in heavy highly charged ions

This internship will be centered into two experiments that will take place next spring 2021 at the GSI Helmholtz center in Darmstadt, Germany. Both experiments study ions stored in a ring for testing quantum electrodynamics (QED) in strong Coulomb field (the field of the highly charged ion). In this regime, perturbative methods cannot be used for theoretical predictions and contributions of the vacuum polarization of the electron self-energy has to be calculated to all orders. At present, the most advanced calculations of bound states QED are limited to the two-loop contributions only and have not been tested yet in the simplest atoms (hydrogenlike and heliumlike).

In both experiments, QED contributions will be investigated in hydrogenlike uranium (Z =92, one bound electron only) and heliumlike uranium (two bound electrons) by high-accuracy X-ray spectroscopy of photons from the de-excitation of ions in storage rings. In one case, the Lamb shift of the fundamental level of hydrogenlike uranium will be measured from the energy of Lyman α (2p $\rightarrow$ 1s transitions of ~ 70 keV) by two state-of-the-art magnetic microcalorimeters detectors. In the other case, the 1s2p $^3P_2 \rightarrow$ 1s2s $^3S_1$ transition (of 4.5 keV) will be measured with two twin crystal Bragg spectrometers equipped with two large X-ray CCD cameras.

Both experiments have as aim to reach an accuracy of 0.1–1 eV to be sensitive to two-loop QED contributions and test, for the first time, the most advanced predictions of all-orders QED. In the case of heliumlike uranium, the electron-electron interaction will be also studied in the strong Coulomb regime.

The internship will consist on the preparation of the experiments, the participation to the data acquisition at the accelerator facility during the measurement campaign in March-April 2021.

The remaining months of the internship will be dedicated to the data analysis, for which Bayesian data analysis methods will be employed. Possibly, the student could work on the development of such methods, based on the code NestedFit (https://github.com/martinit18/nested_fit).

Techniques involved: highly charged ions, ion accelerators, x-ray spectroscopy, Bayesian methods

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: NO Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: NO