1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title:

Interactions of ions with elementary particles

1.1. Project goals

- Investigation of collisions involving trapped ions and other charged particles, such as electrons, protons, positrons or antiprotons, quantitative description of such collisions in terms of cross sections
- Finding possible applications of such collisions in atomic physics and spectroscopy, matter-antimatter studies, nuclear physics, etc.

1.2. Outline

The project will be focused on application of trapped ions in experimental studying interaction between particles at atomic and sub-atomic levels. In particular, various types of positive and negative ions (for example Ca^+, I^-, etc.) will be used as targets in collisional experiments and other types of studies involving elementary particles.

The studies will cover electron-ion interactions, which will be run at the National Laboratory FAMO in Toruń, which will be the core part of the project.

Additionally, experiments with antiproton-ion/atom interaction will be run at CERN in cooperation with AEgIS project. These studies will involve the collisions, as well as studies on antiprotonic atoms formed via laser-assisted ion-antiproton interactions. Moreover this is possible to extend the range of studies to positively charged projectiles such as protons or positrons.

The successful candidate will be involved in the experimental studies run by the group of FAMO laboratory in cooperation with CERN. The tasks will involve designing and setting up the apparatus and integrating it with the AEgIS experiment ant CERN. The design stage will involve numerical analysis of the dynamics of the set of trapped ions and the charged projectiles in the electromagnetic fields produced in the experimental system in various operation conditions.

Running the experiments will require measurements of cross sections for the

collisional processes of interest, including analysis of the obtained data.

The work will require extensive travelling between Toruń and Geneva, including stays at CERN for periods of several weeks or months.

1.3. Work plan

- Introduction into techniques and methodology used in ion trap experiments (ion trapping, cooling schemes, vacuum preparation, operating the detectors, pulsed electronics driving the potentials used for experiments),
- Development of experimental setup (design, numerical analysis and simulations, setting up and testing elements of the apparatus)
- Experimental study on ion interactions (determination of cross sections, data analysis and interpretation)

1.4. Literature *(max. 10 listed, as a suggestion for a PhD candidate)*

- *Ł. Kłosowski et al.„ Experimental method for determination of the integral cross-section for electron impact ionization of ions with optical control of the target's initial quantum state", J. Electron. Spectrosc. Relat. Vol. 260, 147239 p. 1-8, (2022)*
- *Ł. Kłosowski et al., Attraction between trapped ions and beams of electrons, AIP Advances 10, 015028 (2020)*
- *Ł. Kłosowski et al., Measurement of electron-calcium ionization integral cross section using an ion trap with a low-energy, pulsed electron gun, J. Electron Spectroscopy and Related Phenomena 228, 13–19, (2018)*
- *AEgIS Collaboration, Exploring the WEP with a pulsed cold beam of antihydrogen, Class.Quant.Grav. 29, 184009 (2012)*
- *AEgIS Collaboration, Proposed antimatter gravity measurement with an antihydrogen beam Nucl.Instrum.Meth.B 266, 351-356 (2008)*
- *F.G. Major et al., Charged Particle Traps, Physics and Techniques of Charged Particle Field Confinement, Springer, (2005)*

1.5. Required initial knowledge and skills of the PhD candidate

- MSc in physics, chemistry, engineering or related field,
- knowledge in optics, electronics, quantum mechanics, atomic and molecular physics, laser spectroscopy and numerical methods at the level equivalent to basic university courses,
- programming skills in at least one programming language,
- teamwork skills and high motivation for research work,
- good English, sufficient for reading literature and preparing publications

1.6. Expected development of the PhD candidate's knowledge and skills

The PhD student will gain knowledge of:

- vacuum technology
- ion trapping
- charged particle beams
- various types of spectroscopy
- advanced numerical simulations