

The survival of the matter in the Universe remains a deep and profound puzzle, considering the far too small measured asymmetry between matter and antimatter in the weak interaction processes. No indications for similar asymmetries in gravitational, electromagnetic and strong interactions were ever observed. Electromagnetic interaction, is responsible for the existence of atoms, molecules, and living organisms. Then why stars exist, why do we exist? Why the Universe exists? Are there other particles and forces responsible for the survival of matter against antimatter up to our time? Today there are no indications of such new candidates. Moreover, thus far, our experiments were not even sufficiently precise to prove whether, within the Standard Model theory, the electromagnetic interaction describes properly the annihilation into light of electrons and positrons, the lightest charge constituents of matter and antimatter.

We propose to perform a dedicated table-top high precision experiment, using innovative photon detector technologies, to measure the light produced in the electron-positron (and in particular in positronium) annihilations to test, with unprecedented precision the Standard Model predictions, or, alternatively, to uncover an asymmetries between matter and antimatter in the electromagnetic sector, which would represent a revolution in understanding the Universe and our own existence.

The proposed investigation relies on unique features of the positronium atom which, being an electron-positron system bound by electromagnetic interaction, is simultaneously an atom and its own anti-atom. The positronium, unlike the ordinary atoms is symmetric under the exchange of particles into anti-particles. This qualifies it as the ideal system to study symmetries between matter and antimatter in Nature.

We have designed and constructed at the Jagiellonian University in Poland a prototype of the first ever positron emission tomography scanner based on plastic scintillators. We have performed feasibility studies showing the capability of the prototype for measurements of the positronium decays into photons. We have collected first data and tested symmetry between matter and antimatter with a precision few times better than that achieved in the previous experiments (presented at few international conferences). The commissioning of the prototype demonstrated that the developed instrument enables to perform the proposed studies with significantly higher precision than achieved in the best previous experiments.

The main output of the project will be a deeper understanding of the matter in the Universe and of the electromagnetic interaction, responsible for the existence of atoms, molecules and humans. In the framework of this project we will test the symmetry between matter and antimatter in the electromagnetic interactions of the lightest constituents of matter (electron and positron) with precision by two orders of magnitude higher with respect to the best so far published experimental results.