Understanding matter is one of the most exciting challenges in science. We know that matter is composed of atoms that in turn consist in a group of electrons around a nucleus. The nucleus is a complex quantum many-body system formed by neutrons and protons. Both neutrons and protons are built with quarks, which are fundamental particles as the electrons. Nuclear physics is devoted to the study of the properties of matter at the level of protons and neutrons. It is known, that depending on the combination formed by them, the resulting nuclei will behave in different ways. In particular, a vast majority of the known and predicted nuclei are unstable due to their excess (or deficit) of neutrons. When this happens, a neutron converts into a proton (or a proton into a neutron) to compensate this instability, undergoing the so-called beta decay. This process transforms not only one nucleus into another, but at the same time one chemical species into another.

The abundance of the different chemical species in the solar system is the result of a number of processes in the framework of nuclear astrophysics. In these processes, very unstable nuclei are created, and they decay approaching gradually the stability. The decay properties of such exotic nuclei shape the abundance distribution observed.

The aim of this work is to study the radioactive decays of very exotic nuclei in order to test and improve our understanding of the nuclear structure. Properties of nuclei far from stability are valuable information to compare with predictions of theoretical nuclear models, based on the behavior close to the stability. The decay information obtained from the experiments of this project will be of significance for nuclear astrophysics studies, helping to shed light on the origin of the elements in the universe.

Exotic nuclei are seldom observed in our environment, since they decay very fast. In order to study their properties, we need to produce them by means of different nuclear reactions. Nowadays production techniques are able to provide very unstable nuclei, which may emit a lot of high energy photons, and even protons or neutrons, to become more stable. In particular, the observation of proton emission has started a new era in nuclear physics studies, opening the possibility of improving our knowledge on the internal structure of nuclei in the limits of bounded systems. The nuclei of interest for this project will be studied at high-level international accelerator laboratories, where such exotic nuclear species can be produced.

The way to observe all radiations emitted in the microscopic nuclear world is to develop powerful eyes- that we call detectors- devoted to the detection of the photons, charge particles and neutrons emitted by the nuclei in their path to stability. As we move deeper and deeper in the details of nuclear structure, we need more sophisticated detection systems. The challenging studies of very unstable nuclei that will be performed in this work, will employ advanced nuclear instrumentation. In particular, the detection of emitted protons demands, since the beginning of the 21st century, a different approach with respect to traditional experiments. For this reason, a photographic technique was developed at the University of Warsaw, in order to register the trajectories of the protons. Such a powerful strategy will be used in this project to study the decays of neutron-deficient nuclei. In addition, improvements of this photographic technique will be investigated in this project aiming at enhancing the sensitivity for future challenging experiments.

The measurements carried out in this project will be analyzed with the help of algorithms and Monte Carlo simulations in order to extract the nuclear structure information of interest. The results will allow to better understand the behavior of unstable nuclei, to test the robustness of the present theoretical nuclear models and to improve the nucleosynthesis calculations in the amazing path to understand the composition of the universe.