There are four types of fundamental forces in nature: gravity, electromagnetism, the strong and the weak interaction. While we are familiar with the first two interactions from our daily lives, the remaining two are directly observed in investigations of elementary particles and atomic nuclei. In atomic nuclei the strong interactions between the protons and neutrons, and the electromagnetic interaction between the protons play a primary role. Protons, having a positive charge, repel each other and the atomic nuclei are held together by the (typically attractive) strong interaction. While we know a lot about the nature of the electromagnetic interaction, we have only approximations for the strong force. It is known, that that the strong force arises from the interactions between the quarks and gluons that make up the neutrons and protons. Currently there exist many models of this force and new ones are constantly being constructed. In recent years much attention has been brought to models derived from the, so called, chiral effective field theory. Within this theory, the observable properties of nucleons are described using auxiliary quantum fields of particles that exist in nature. An advantage of nuclear forces constructed in this way is their connection to the fundamental theory describing the interaction of quarks and gluons – quantum chromodynamics. What's more, chiral effective field theory allows not only the derivation of two nucleon iterations but also a consistent derivation of many body forces – interactions which involve many nucleons that cannot be expressed as a sequence of two nucleon interactions.

The aim of this project is a systematic description of nucleon reactions within the three nucleon system and the structure of atomic nuclei with the use of the newest models (using the, so called, semi-local regularization) of nuclear interactions. We plan to perform calculations of observables for such reactions as elastic nucleon deuteron scattering and nucleon induced deuteron disintegration into a proton and neutron. As part of the project we will also use electromagnetic currents consistent with the nuclear interactions in order to investigate the photodisintegration of ^{2}H, ^{3}H and ^{3}He nuclei leading to different output channels. Muon capture processes will also be analyzed on these nuclei, they are particularly interesting because, apart from the strong force, weak interactions play there an important role. Some groups participating in the project will focus on calculations of the energy levels of atomic nuclei using the same two and three nucleon interaction models. In order to achieve this, first a unitary transformation of the Hamiltonian will be performed. Next, so called, the no-core shell model or the coupled cluster model will be used to find the energy levels of the nuclei. During the investigations, results obtained for nuclear reactions and nuclear structure will be used together to determine the values of the free parameters in the theory. These results will be then be utilized to verify the validity of the nuclear forces and current operators derived from chiral effective field theory by performing a comparison with experimental data.

Scientists from 10 research institutions from Poland, Germany, USA, Japan, France and Canada are engaged in the project. They create a team of experts in areas such as chiral effective field theory, nuclear reactions involving few nucleons, nuclear reactions involving electromagnetic probes and nuclear structure. During the realization of the project, many of the numerical calculations will be carried out using powerful supercomputers.