Atomic nuclei are complex systems composed of protons and neutrons, which stand for excellent objects to probe quantum phenomena. Thus far, three thousand different ways that protons and neutrons can combine to form bound system have been identified. Presently – 100 years after the discovery of atomic nucleus – its structure is still not fully understood. Consistent theoretical description of nuclei, explaining the variety of observed nuclear effects, remains still to be firmly established. Nuclei with a large excess of either protons or neutrons are the best systems for testing nuclear model's predictions and consequently our understanding of interactions between nucleons. On the other hand, exotic nuclei are extremely unstable, making their experimental studies challenging. Nevertheless, their investigation provides access to probe the most surprising nuclear effects. Because the r-process nucleosynthesis is inextricably linked to the details of the structure of exotic nuclei, an understanding of properties of nuclei involved in this process is necessary to explain how the matter in the universe was created. Reconstruction of the r-process path and determination of its astrophysical site bring together nuclear physicists, astronomers and astrophysicists.

The principal goal of the research project is to obtain new experimental information on beta-decay properties of neutron-rich indium isotopes, ^{134}In and ^{135}In ($Z = 49$), containing 19 neutrons more than the heaviest stable indium isotope. In the chart of nuclides, these two nuclei are located right after $N = 82$ shell, whose special nature, called magic, was evident in dynamics of the rapid-neutron capture process (so called r-process). This process, occurring during explosive astrophysical conditions – like neutron star merger, is considered to be responsible for the creation of about half of the nuclei that are heavier than iron. The r-process involves multiple neutron captures repeated until beta decay occurs. As a consequence, atomic number increases and neutron capture sequence proceeds for next isotopic chain, which is again terminated by beta decay and so on. Determination of the quantities characterising beta decays of neutron-rich nuclei is crucial for r-process modelling. In the case of studied indium isotopes, the neutron excess is so extreme, that emission of beta-delayed neutrons can occur. The quantitative knowledge about beta-delayed single-, two- or more neutron emissions have a significant impact on the r-process modelling. Moreover, the tendency of the nucleus to emit a few beta-delayed neutrons reveals important information about its structure.

The purpose of this project is to not only provide new astrophysically relevant data on ^{135}In and ^{134}In beta decays, but also aims at gaining deeper insight into nuclear structure of involved isotopes. Analysis of radiation emitted in studied decays allows us to investigate excited states in tin isotopes ($Z = 50$), from ^{132}Sn to ^{135}Sn. Owing to special properties of $Z = 50$ and $N = 82$ nuclear shells (called magic), these isotopes constitute simple systems, relevant for the nuclear shell-model description. Systematic studies of tin isotopes are a reliable way to investigate whether and in what manner neutron excess affects the effective nucleon-nucleon interactions. Reconstruction of the r-process path and its consequences require information on properties of more neutron-rich systems which are nowadays beyond experimental access, yet even extrapolation of their properties from accessible ones is immensely helpful. Only after understanding of nuclear properties of nuclides attainable presently, we will be able to validate theoretical predictions for more exotic nuclei.

Experimental data constituting the basis for our project were collected in measurements performed at CERN-ISOLDE facility, which is one of the world-leading laboratories for experimental nuclear research. Indium isotopes were produced in uranium fission. High-purity beams of ^{135}In and ^{134}In ions were obtained by using resonance ionization laser ion source and electromagnetic separation.