Beta decay is one of the fundamental processes undergone by unstable atomic nuclei. It is one of the most prevalent transformations, taking place among naturally occurring radioactive isotopes on Earth, and yet it remains mysterious and largely unexplored.

The history of research into beta decay dates back to the late 18th century when the pioneering work of Ernst Rutherford laid the foundations for our understanding of this phenomenon. Subsequent studies revealed that beta decay involves the conversion of one nucleon into another – a proton into a neutron with the emission of a positron (beta-plus decay) or a neutron into a proton with the emission of an electron (beta-minus decay). Over time, it was observed that beta decay could be accompanied by the emission of delayed particles, most commonly protons or neutrons. They are emitted when the nucleus formed after beta decay is in an excited state with an energy higher than the binding energy of this particle. Beta decay also turned out to be a crucial element in the formation of elements heavier than iron, setting the boundaries for proton and neutron capture processes.

This project focuses on investigating the beta decay properties of nuclei around 132Sn and 70Ni. These are highly neutron-rich nuclei, meaning they have more neutrons than stable nuclei of the same element. In both regions, these nuclei undergo beta-minus decay, which may be accompanied by the emission of delayed neutrons. Until recently, it was believed that if the nucleus after beta decay reaches an energy level higher than the neutron separation energy, the particle will be emitted immediately. Recent research has shown that a non-neglected competing process is the emission of gamma radiation from these states. This is quite surprising and calls into question the understanding of the process of neutron emission from neutron-unbound states. Understanding the mechanism of neutron emission and neutron-gamma competition is one of the main goals of the project.

Studying such exotic nuclei is only possible in a few of the world's most advanced laboratories. The challenge lies in both producing such exotic nuclei and detecting them. For nuclei around 132Sn, the ISOLDE laboratory at CERN provides unique capabilities. By combining a high-energy proton beam, a mass separator, and selective laser ionization techniques, very clean beams of the nuclei of interest can be achieved. The nuclei 68-70Co will be measured at the Facility for Rare Isotope Beams laboratory at Michigan State University in the USA, one of the most advanced nuclear physics laboratories in the world.

In our investigations, we will use a somewhat niche but exceptional detection technique known as total absorption spectroscopy. Total absorption spectroscopy involves the use of large scintillation crystals designed to surround the measured sample from all sides. The key feature of this technique is its very high efficiency in detecting gamma radiation, allowing even very subtle effects and weak gamma transitions to be observed and measured.

It is expected that the proposed project will fill in the missing information about the beta decay of nuclei around 132Sn and 70Ni, helping us better understand the mechanism of beta delayed neutron emission.