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Beta decay is the most common decay mode among radioactive nuclei. Isotopes with excess of neutrons decay by beta minus transition in which the mass number remains the same but the atomic number is increased by one. The new nucleus is often created in an excited state and typically emits gamma rays after the transition. Such a deexcitation method is typical for nuclides close to the stable ones. The beta decay energy generally grows with a neutron excess. At some point the energies of the excited states populated in the beta decay may excess the neutron separation energy (a minimal amount of energy needed to remove one neutron from the nucleus), and deexcitation may proceed through neutron emission rather than gamma ray. This phenomenon, discovered in 1939, is called a beta-delayed neutron emission. Although the delayed neutrons amount to just about 1% of all neutrons in the nuclear reactor, they are absolutely crucial in controlling the reaction. Since they are emitted with delay of seconds to minutes, we are able to keep reactor in a critical state with help of mechanical tools.

Delayed neutrons are also important in understanding the astrophysical supernova type II explosions. During these cosmological events many of the heavier than iron elements are created. The normal burning processes in the stars may create only lighter elements. The other are created in series of neutron capture and beta decay events. In the case of supernovae explosion, a vast amount of neutrons allows to start a rapid neutron capture process, that last a couple of seconds, but during which a very neutron-rich nuclides are created and most of them are delayed neutron emitters. In order to accurately model this process we need to take into account the delayed neutrons that change the final elements yield and length of the process in time.

Even though we are aware of phenomenon of delayed neutron emission for almost 80 years, our knowledge is far from being complete. For example so far we measured only about a half of all of the delayed neutron emitter created in the uranium fission process (there should be about 270 of them). Together with light nuclides that do not appear in nuclear reactors we have some information on about 200 cases of delayed neutron emission. We know even less about the energy of the emitted neutrons – the energy spectra were measured for about 20 cases so far. As a consequence of that there is incompatibility of partial data (for individual nuclides) with those gathered in the so-called integration experiments where a global properties of fission materials were measured. In order to solve that mystery we need new experimental data as well as verification of the existing ones. The data for the astrophysics are more difficult to obtain, we learned just recently to produce isotopes appearing during these processes. The more neutron-rich nuclides we measure the more we will known about the origin of the elements on Earth and why some of them are common while other are very rare.

In our project we would like to focus on experimental studies of new, unknown before neutron emitters and on measurement of unknown delayed neutrons energy spectra. Such experiments are possible in large international nuclear physics facilities such as RIKEN (Japan), CERN (Switzerland) or ORNL (USA). These laboratories are equipped with detectors suitable for the our experiments but we would like also to build our own spectrometer, which should fill in the gaps of the existing systems. Thanks to the possibilities of extensive tests in our own laboratory we should be able also to develop new experimental methods that are going to be useful with other detectors as well.

The experimental studies are possible only in these cases where we know how to produce certain nuclide. There are many exotic ones that are beyond our current capabilities. In these cases, particularly important in astrophysics, the nuclear physics theory is crucial in predicting needed properties. We would like to further develop one of such models, and thanks to the new experimental data we should be able to understand which factors are crucial for proper description of this phenomenon.