Blahoslav Rataj

How to open the way for neutrons to searches to study the secrets of dark matter and antimatter disappearance

Scientists at the European Spallation Source (ESS) in Sweden are designing a new research facility. The ESS will provide the highest number of neutrons produced per second for various experiments in the World. The neutrons produced at the ESS will enter a moderator, where they are slowed down before they reach beamports to beamlines. The beamlines deliver neutrons to experiments and modify their properties. The focus of my master's project was on delivering neutrons from the moderator into the High-Intensity Baryon Extraction and Measurement (HIBEAM) experiment by creating a computer geometric model of the proposed ANNI beamline. An integral part of the project was also to conduct simulations using the computer geometric model to estimate how the ANNI beamline was efficient to block high-energy (fast) neutrons before they reach HIBEAM. In addition, the effectiveness of the proposed shielding against fast neutrons for the ANNI beamline was tested in the simulations to keep the level of radiation safe for the ESS personnel. All of these studies of the ANNI beamline are important in order to achieve the experimental goals of HIBEAM.

Specifically, HIBEAM will study rare oscillations of the neutrons into sterile neutrons which do not interact with electromagnetic, weak, or strong force. These forces are fundamental forces that we use to describe particles and their interactions around us. The sterile neutrons may come from a hidden world of particles. Therefore, they are assumed to be one of the dark matter candidates. The dark matter corresponds to a significant fraction of particles present in the Universe whose origin is unknown. These particles should interact with the ordinary world of particles via gravity to explain the observations, for example, of galaxies and clusters of galaxies that feel the additional gravitational force from an unknown source to keep their form. Although no experimental evidence exists, the sterile neutrons can be part of the mirror world of particles. These would be duplicates of the ordinary world neutrons that we know. However, the interaction between the ordinary and mirror world neutrons would be possible only via gravity. If the hypothesis about the existence of the mirror world of particles is correct, it would have implications on, for example, observed ultra-high-energy cosmic rays hitting the Earth atmosphere.

In addition, HIBEAM may also observe oscillations of neutrons into antineutrons. This is unlikely, but such a process can help to explain another important question of modern cosmology: why the ratio of matter over antimatter became asymmetric in the early times of the Universe such that most of the antimatter disappeared from the Universe. The NNBAR experiment, which will be constructed based on the experience gained in the HIBEAM experiment, should observe the oscillations of neutrons into antineutrons due to a significant increase of the experimental sensitivity in comparison to the similar experiment already conducted at the Institut Laue-Langevin (ILL) in France.