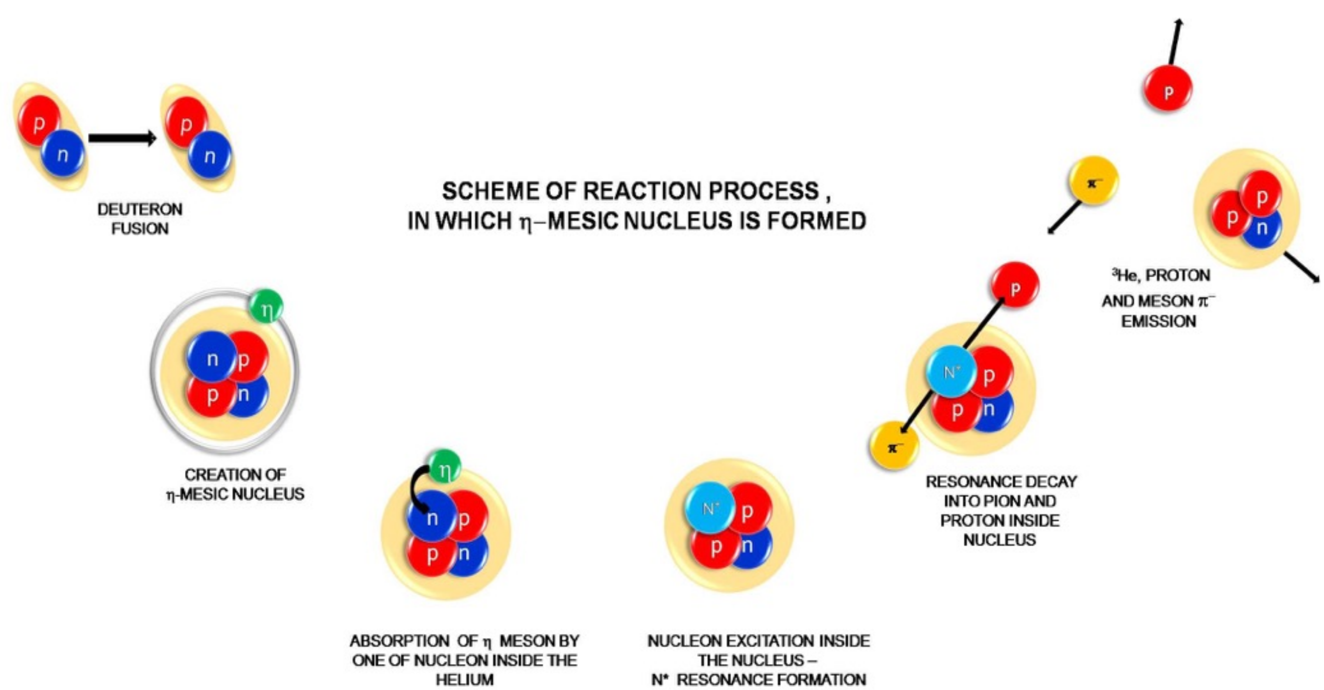
The scientific aim of our research is experimental confirmation of the existence of mesic-nucleus: a new kind of nuclear matter consisting of nucleons and mesons. Nucleons are components of atomic nucleus while mesons are particles composed of quark and anti-quark (matter and antimatter). A mesic nucleus would be a system of nucleus and meson bound via *strong* interaction. Analogously electron and nucleus form a system bound via *electromagnetic* interaction, and Earth and Moon form a system bound via *gravitational* force.

The existence of such mesonic matter was postulated over thirty years ago, however, till now it was not confirmed experimentally. Such system may be created for example in the deuteron-deuteron or proton-deuteron fusions. Fusion of protons and deuterons is one of the basic nuclear processes which leads to the synthesis of helium inside the Sun. At large energies, such process may lead to the production of the helium associated with the η meson. The η meson is the best candidate for the creation of the mesic nucleus because it interacts with nucleons stronger than other mesons. In addition the η meson is electrically neutral, therefore η-mesic system cannot be formed by the *electromagnetic* interaction and hence it can be bound only by the *strong* forces.

Presently the production mechanism of such a system is not known. One of the hypothesis postulates that reaction proceeds via scheme presented in the picture below. According to this hypothesis the η-mesic nucleus is produced in deuteron-deuteron fusion reaction. Such reaction leads to the formation of helium nuclei interacting with the η meson via *strong* interaction. Next the η meson might be absorbed by one of the nucleons inside helium causing its excitation. The excited nucleon can emit its energy for example by the emission of the π meson. As a result of such decay of the hypothetical mesic-nucleus the ^{3}He, proton, and meson π are emitted and can be measured in the detector.

This year we have completed analysis of the experiment devoted to the search for the η-^{4}He bound state produced via deuteron-deuteron fusion. We have observed a signal which indicates existence of the η-^{4}He bound state. However the life-time of this state is unexpectedly short. It amounts approximately to the life-time of the excited nucleon. This interesting observation is at present a subject of interpretation of few theoretical groups.



It is interesting to note that ^3He is larger and interacts stronger with the η meson than ^4He, though ^4He comprises more nucleons than ^3He. This indicates that it is more probable that η meson can form a mesic nucleus with ^3He than with ^4He. Therefore, it is worth to search for the η-^3He bound state.

Our research group has developed a method giving a chances to discover the η-^3He bound state. In 2014 we performed measurements using proton beam from COSY synchrotron and the WASA detector installed in the Research Center Juelich in Germany – one of the best research centers in the Europe and in the World. Based on the new data, in addition to the mechanism depicted in the above figure, for the first time, we will be able to verify new hypotheses: e.g disintegration of the η-^3He bound state via decay of the η meson while it is still "orbiting" around the nucleus. The main advantage of the used experimental setup is a possibility of continuous changing of beam energy and simultaneous registration of all particles taking part in the reaction. Moreover, we have collected significantly higher statistics in comparison to previous experiments. The existence of the bound system should manifest itself as an increase of the number of events in the energy range corresponding to its production – for the energy lower than the sum of η meson and helium masses. Therefore, the main task of our research is determination and analysis of the excitation functions for the eight reactions for which we expect the formation of the mesic nuclei.

The search for new kind of nuclear matter is a very exciting experimental challenge. But the confirmation of the existence of a mesic nucleus would be interesting on its own account, and in addition it would allow for better understanding of mesons structure and their interactions with nucleons.