”We are currently in the midst of a second quantum revolution. While the first revolution gave us laws for understanding physical reality at very small scales, the second revolution will take these rules and develop new technologies”. Rightfully so, quantum theory is the primary way of our understanding and formal description of Nature. Moreover, it constitutes a perfectly empirically confirmed formal construction. The phenomenon of quantum correlations, especially entanglement, is believed to be most amazing and eluding the schemes of classical thinking. Conceptual efforts to grapple this 'spooky actions for separated distance systems' began with the fundamental work of Einsten, Podolski and Rosen and continue until this day. Yet, today we possess the knowledge that quantum correlations - still remaining a great mystery – can be controlled and realized experimentally. It allows us to perform nontrivial tasks such as secure quantum communication or quantum computation. We can also investigate fascinating, complex condensed matter systems, constituting from fundamental “bricks” of the universe – bosons and fermions. Let us mention here Bose-Einstein condensate, topological insulators or the superconductivity phenomenon. It seems that to describe these systems we can use the notion of quantum correlations. However, quantum correlations in such cases, especially for fermionic systems are poorly understood.

That’s why, the main task of this project is to analyze the role and feature of quantum correlations (such as entanglement) in systems build from fermions. We will use the formalism of, the so-called, fermionic linear optics, fermionic Gaussian states and Majorana fermions to describe some fundamental problems related to the nature of quantum correlations (“amount” of quantumness in fermionic systems), possible applications of fermions to perform quantum computation or reasons why fermionic states (as other states in the universe) typically evolve towards equilibrium situation.