The aim of the project is: (i) to exploit the method of electron irradiation for precise tuning of Fermi level in the range between bulk conduction band through bulk band gap to bulk valence band of three-dimensional topological insulators (TIs); (ii) to identify physical phenomena characteristic for topological insulators, which have so far been heavily hampered by the presence of charge carriers with high concentration in the volume of the material, and to investigate them versus Fermi level position.

Topological phases build a novel category of phases with quantum order which goes beyond the well-known Landau symmetry breaking theory that successfully describes phases connected with different states of matter, magnetic order, or even superconductivity or superfluidity. Topological insulators constitute one of topological phases - they possess gapped bulk states and gapless (metallic) Dirac boundary states simultaneously. Such surface states in three-dimensional topological insulators or edge states in two-dimensional TIs originate from band inversion (being a consequence of strong spin-orbit coupling) in bulk, and are topologically protected by time reversal symmetry of the respective materials. Due to this protection, the spins of Dirac electrons from the boundary states are tightly locked with their momentum, and therefore experience no backscattering even in the presence of defects or impurities, which is beneficial for low-dissipation transport and spintronic applications.

At the Faculty of Physics University of Warsaw research will be performed with use of ESR (Electron Spin Resonance) spectrometer. This technique is a powerful tool for investigation of numerous phenomena, starting from standard application connected with investigations of spin properties of localized defect centers, through delocalized conduction electrons (both exploiting spin resonance phenomenon), ending at investigations of electron transport properties utilizing resonant or non-resonant changes of the cavity quality factor induced by changes of the sample conductivity. Well-established methods for measurement and analysis of ferromagnetic resonances also exist. More recently, ESR spectrometers were applied for spin pumping experiments. Thus, one experimental technique covers a wide variety of the physical phenomena that could be observed for topological insulators.

The project aims at deeper understanding of topological insulators and development of method for precise tuning the Fermi level with electron-beam irradiation. These materials are important for theoretical understanding of the formation of different topological phases, and they have direct implications for proposed devices in publications. Despite initial difficulties researchers worldwide indeed believe that topological insulators with their topologically protected conduction are a path towards realizing practical quantum computers, spintronic devices or multifunctional topological transistors (using, e.g. magnetic interfaces with topological insulators, such as magneto-electric junctions). Realization of these ideas would have wide impact on every area that uses technological achievements, that means actually all possible areas of everyday life.