Nowadays in modern science one of the still unsolved problems, is the significant imbalance between matter and antimatter present in the known Universe. Based on the Big Bang theory physicists predicted that in the early stages of the Universe an equal amount of matter and antimatter was produced. However, due to not known reasons all the antimatter annihilated, as the Universe started to cool down. Therefore today we observe the dominance of matter in the Universe. One of the potential reasons of the described imbalance can arise form the difference in the properties of matter and antimatter, which can manifest itself in fundamental symmetries violation. The research that will be devoted to the project has purely epistemological nature and concern the development of new experimental methods of fundamental symmetry investigations, including CP symmetry. The proposed studies will be conducted in the framework of HADES collaboration which operates it spectrometer detector at GSI Helmholtz Institute for Heavy Ion Research in Darmstadt. The main goal of HADES collaboration is exploring baryonic matter at zero (vacuum) and moderate temperatures. HADES performs measurements with pion-nucleon, nucleon-nucleon and heavy ion collisions. One of the research pillars of HADES are studies of the baryon resonance production in the elementary collisions and their electromagnetic decays. The latter provides an insight in their structure in vacuum and is a crucial baseline to study hot and dense baryonic matter which properties are explored by means of rare penetrating probes like dielectrons (e^+e^- pairs) or kaons.

In the view of proposed studies HADES has recently performed a measurement with proton-proton collisions at energy of 4.5 GeV, collecting sufficient statistics (total integrated luminosity of $\sim$ 5 pb^{-1}) to study the high e^+e^- invariant mass region, beyond 1 GeV/c^2. This region is very crucial to investigate the so-called $\rho - a_1$ mixing effect. In vacuum the spontaneous chiral symmetry breaking effect is responsible for the mass generation. ρ and a_1 are chiral parity partners in the SU(2) flavour symmetry with a large, around 500 MeV, mass difference. As it has been predicted by theorists, in hot and dense nuclear matter masses of the chiral partners are practically the same. This phenomenon is known as chiral symmetry restoration and will be investigated with heavy-ion reactions with HADES and the future CBM experiment at the FAIR facility. To understand such in-medium effects, reference spectra from elementary p+p collisions need to be subtracted. Our recently collected data for p+p at 4.5 GeV will serve as the reference and baseline to study the upcoming heavy-ion reactions.

The acquired statistics will also allow us to study production cross sections and rare decays (branching ratio $\sim 10^{-4}$) of light mesons η, η', ω or $f_1(1285)$. Especially with the Dalitz decays ($\eta^{(')} \to e^+e^-\gamma$, $\omega \to e^+e^-\pi^0$) we could study electromagnetic structure of mesons and test the Vector Meson Dominance model which provides very intuitive explanation of hadron-photon interaction. Very important aspect of these studies is looking for the effects beyond the Standard Model physics. Our interest is to investigate the CP violation in the $\eta^{(')} \to e^+e^-\pi^+\pi^-$ decays. This effect has been studied by various experimental groups, however, up to now, the sensitivity to the CP violation is still not at the level to be observed. The collected HADES data for p+p at 4.5 GeV could also contribute to these studies. Moreover based on the Resonance Chiral Theory it has been shown that existence of recently observed (but not yet confirmed) an axion-like boson, could be investigated in rare axio-hadronic $\eta^{(')} \to \pi^+\pi^-X(17) \to \pi^+\pi^-e^+e^-$ decays. This analysis is along the lines of the CP-violation studies with the recent HADES data and could significantly contribute to searches of the $X(17)$ boson.

Proposed light meson studies have an extremely important contribution to the development of modern experimental and theoretical physics, especially in the view of investigations of the mechanism through which our Universe is existing. Moreover the prominent results and excellent detector performance led to decision of using the HADES spectrometer also with the future FAIR accelerator facility, currently under construction in Darmstadt. HADES is currently the only experiment in world which measures rare penetrating probes like dilectrons at moderate temperatures and large baryonic potential by means of a pion, proton, and heavy ion beams in energy range $\sqrt{s}$ = 1–4 GeV.Therefore the results of proposed project could significantly contribute to plan new future experiments which will be performed at FAIR facility.