Master and PhD studies in LHCb experiment at CERN

- **Search for exotic hadrons in LHCb**
  Master (dr Dmytro Melnichuk) or PhD (dr Dmytro Melnichuk, prof. Wojciech Wiślicki) thesis

  In traditional quark model strongly interacting particles (hadrons) are built from quark-antiquark pair (mesons) or three quarks (baryons). Particles which cannot be classified in these categories are called exotic hadrons. In quark model, after adding quark-antiquark pair to minimal meson and baryon configuration, tetraquarks and pentaquarks can be obtained. Besides multiquarks it is foreseen the existence of other exotic QCD states, namely hybrid meson and glueballs. Hybrid mesons are states with excited gluonic degree of freedom. Possible topic of the research can be the search for resonances decaying to $\chi_{b1}\pi^+\pi^-$ as possible candidates for beauty meson hybrids.

- **Bachelor, Master (dr Artur Ukleja) or PhD (dr Artur Ukleja, prof. Wojciech Wiślicki)** thesis

  - **Reconstruction of charm meson or hyperon decays and the search for CP violation using binned and unbinned model-independent techniques in the LHCb experiment**

  - **Search for difference of CP violation between $\Lambda_c \to pK^-K^+$ and $\Lambda_c \to p\pi^-\pi^+$ decays in the LHCb experiment**

  - **Estimation of the power of the binned and unbinned methods using to search for CP violation in the LHCb experiment**

  The CP transformation is a result of the assembly of two transformations: charge coupling (C) and spatial inversion (P). The identity of the physical properties of the systems before and after CP transformation means full symmetry between relativistic particles and antiparticles. The CP asymmetry was observed in the decays of strange (K) and beauty mesons ($B_{(s)}$). But so far it was not observed in charm mesons and baryons, where it is expected. The expected value of CP asymmetry for charm particles is 10^{-3} or less in the Standard Model (SM), a theory describing the interaction of elementary particles. The current sensitivity of searching for CP asymmetry, due to the activation of Large Hadron Collider (LHC), has approached the size of the SM predictions in the charm particle decays. This sensitivity can be improved by increasing the sample size of collected data and reducing systematic uncertainties. In addition the size of the CP violation in the SM is too small to explain the dominance of matter over antimatter observed in the Universe. This fact is the motivation to search sources of CP violation beyond the SM. Indirect searches are provided in the LHCb experiment at LHC. These indirect searches involve testing the SM predictions in very precise measurements of the decay in charm particles. Therefore, the planned measurements can provide important information on nature of CP asymmetry with much greater accuracy than previously studied. The finding of disagreement in predictions of the SM will indicate the existence of New Physics. The studies will be performed in the Dalitz plot in model-independent way.

- **Recontruction of the $B_s \to J/\psi\phi$ decay in the LHCb spectrometer**
  Bachelor (mgr Varvara Batozskaya) or master (dr Konrad Klimaszewski) thesis
  The $B_s \to J/\psi\phi$ decay is very sensitive decay to CP symmetry violation through angular distrubutions of the final state. The study includes the identification of the decay in the LHCb experiment using kinematic variables and the reconstruction of the J/ψ and ϕ mass. The analysis will be perform on LHCb data collected in 2011-2012 (Run I) and 2015-2018 (Run II).

- **Reconstruction and study of the inclusive $B_s \to J/\psi X$ decays**
  Bachelor (mgr Varvara Batozskaya) or master (dr Konrad Klimaszewski) thesis
  The study concerns the identification and reconstruction of the B_s meson decayin on J/ψ, where J/ψ decays into lepton pair, and any additional particles in the final state. The analysis will be perform on LHCb

simulated data. The aim of the study is to find selection criteria for these decays. This analysis is the introduction to the study of the CP symmetry violation in these decays where the X state can be a single meson of a pair of mesons.

- **Bachelor, Master (dr Wojciech Krzemień) or PhD (dr Wojciech Krzemień, prof. Wojciech Wiślicki) thesis**

  - **Testing CPT symmetry violation in neutral meson system D^0 from $B \to \mu D^* X$ decay**

  - **Testing CPT invariance in semileptonic decays of B mesons in the LHCb experiment**

  The aim of the project is the study of the possibility to measure CPT symmetry violation in neutral mesons sysytem D^0 originating from the $B \to \mu D^* X$ decay. The CPT symmetry is fundamental to all recognized quantum field theories describing interactions within the Standard Model. Therefore, the experimental search for its violation includes into the area of the so-called New Physics. Precise CPT tests can be carried out using neutral meson oscillations (quark-antiquark systems), one of the fascinating examples of the effects of quantum mechanics. As part of the work, the efficiency estimations and the study of the background decays will be carried out based on Monte Carlo simulations and experimental data. The work enables learning advanced methods of machine learning (e.g. neural networks, boosted decision trees, etc.) in one of the best experiments in the world, as well as developing knowledge of modern information technologies (`unit` testing, `git`, programming languages: `Python/C++14/C++17`).

- **Software development as part of the DIRAC distributed computing platform**
  Bachelor, Master (dr Wojciech Krzemień) or PhD (dr Wojciech Krzemień, prof. Wojciech Wiślicki) thesis
  The aim of the project is a participation in the development of software for logging pilots - distributed agents that provide information on possible errors during installation and configuration of the environment or during data processing. One of the tasks would be to add a module to interpret login information, and to add an interface to visualize the collected data. The project will be implemented in cooperation with a group of programmers from CERN in Geneva. The project allows to get knowledge about methods of distributed computing, technologies like `RabbitMQ`, `Tornado` or `ElasticSearch` as well as to develop your programming competences in `Python`.

- **Software development for reconstruction and data processing within the LHCb experiment**
  Bachelor, Master (dr Wojciech Krzemień) or PhD (dr Wojciech Krzemień, prof. Wojciech Wiślicki) thesis
  The LHCb will end data collection at the end of 2018. The next detector will be upgraded to prepare for operation during Phase III. The work also includes the software development and improvement of data reconstruction and processing to take full advantage of the parallel processing capabilities. As part of the project, students will participate in the software modernization and development of data processing. The work enables learning advanced programming techniques in one of the best experiments in the world, as well as developing knowledge of modern information technologies (`unit` testing, `git`, programming languages: `Python/C++14/C++17`).