Exploring physics of the Standard Model with proton-proton collisions at 13 TeV

To investigate the fundamental processes of nature and learn what the world is made of and what holds it together, the ATLAS scientists have built a detector of unprecedented size and complexity. The detector is used to study proton-proton collisions at the Large Hadron Collider (LHC), the most powerful particle accelerator in the world. The 46 m long and 25 m high ATLAS detector is one of the most elaborate particle physics experiments ever designed, and is the product of a worldwide effort of over 3000 scientists from 174 institutions in 38 countries. The participation of Polish groups in ATLAS dates back to 1990, the very commencement of the experiment.

The first running period of the Large Hadron Collider provided proton-proton collisions with centre of mass energies up to 8 TeV (8 teraelectronvolts), allowing the scientists to probe the structure of matter at scales of the order of 10^{-13} m, and was successfully concluded in early 2013. In June 2015 the accelerator started up again, this time at 13 TeV — almost twice its previous energy and with higher luminosities than ever before. This new energy frontier will allow researchers to probe new boundaries in our understanding of the fundamental structure of matter. During the first running period the Standard Model of particle physics - the theory that explains the fundamental particles and the forces between them - has tenured supreme. Undoubtedly, the highlight of the first running period was the discovery by the ATLAS and CMS experiments of a Higgs boson, a particle with a mass of 125 GeV. The Higgs is the simplest manifestation of the Brout-Englert-Higgs mechanism that gives particles mass. It was the last component of the Standard Model to be experimentally verified. Increasing the energy of the LHC will increase the chance of creating Higgs bosons in collisions, which means greater opportunity for researchers to measure properties of the Higgs precisely and to probe its very rare decays. High-energy collisions could also detect small, subtle differences between what the boson looks like in experiments and what the Standard Model predicts. The Standard Model has worked beautifully and has predicted what experiments have shown so far about the basic building blocks of matter, but the theory does not yet answer all fundamental questions and searches for phenomena beyond the Standard Model are continuously pursued.

The scientific programme of ATLAS, based on the excellent capabilities of the ATLAS apparatus, includes the study of an ample spectrum of topics. The recently upgraded detector is ready to explore the new energy frontier of the Large Hadron Collider. The Polish groups are actively participating in this effort.

Within this project, the investigators from the Institute of Nuclear Physics Polish Academy of Sciences, the Faculty of Physics and Applied Computer Science of the AGH University of Science and Technology, closely collaborating with the group from the Institute of Physics of the Jagiellonian University, plan to focus on the verification of the Standard Model in a new energy regime, available since 2015. The following physics topics are foreseen. The first is the precision measurement of processes with W and Z bosons, the massive carriers of the weak force, which are responsible for radioactive decays. These bosons also couple to the Higgs boson. W and Z bosons are produced at a large rate in proton-proton collisions at the Large Hadron Collider. With these measurements, the electro-weak sector of the Standard Model will be probed at a new energy. The second topic will focus on the study of the production and properties of the heaviest elementary particle, the top quark. The top quark is believed to play a special role in our quest for new physics. The measurement of its properties is an excellent test-bed for probing the strong-force sector of the Standard Model. We hope to find new physics here. For the study of the rare processes described above, which typically involve high momentum transfers, it is necessary to understand the dominant processes, namely low momentum transfer interactions. The planned measurements of low-momentum transfer processes are also crucial for a good understanding of the performance of the upgraded ATLAS detector as well as for verifying the ability of the Monte Carlo event generators to describe the data at the new collision energy. These studies will be complemented by our contributions to data preparation and reconstruction, in particular by providing the precise description of the detector geometry and optimisation and development of data analysis tools, adjusted to new data-taking conditions, as well as validation of the Monte Carlo event generators. The investigators of this project are also responsible for the operations and performance advancement of these detector components, which were developed, produced and tested by collaborating institutions from Poland.