Resummations of Quantum Chromodynamics in application to precision description of electroweak processes at the LHC

The main goal of the present project is obtaining the most accurate theoretical predictions for processes at the Large Hadron Collider (LHC) in which there are produced the heaviest known quarks: top and bottom and also the bosons mediating in weak and electromagnetic interactions: $W^{\pm}$, Z^{0} and highly energetic photons.

The most important goal of particle physics is a search for a deeper structure of matter and the origin of the fundamental forces. These hypothetical phenomena are usually called "New Physics" and they could possibly result in new kinds of fundamental particles that might be produced and detected at the Large Hadron Collider. Hence the main mission of the experiments at the Large Hadron Collider after the discovery of the Higgs boson, is to search for the effects of "New Physics". This is a goal of the highest scientific importance because finding traces of New Physics in at the fundamental level may answer key questions of the origin of matter, the nature of elementary interactions (e.g. hint on possible grand unification of elementary forces), and important cosmological questions, like one about the origin of dark matter in the Universe.

After the first six years of the LHC operation and reaching in the last years the proton-proton collision energy 13 TeV, close to the maximal planned value of 14 TeV, it is clear that a possible future discovery of New Physics at the LHC is most likely by finding rare processes with New Particles or by finding deviations from the Standard Model predictions in precision measurements. In the coming years the LHC experiments are going to accumulate almost ten times more data than they have collected so far. This will result in excellent experimental precision of measurements and for the optimal use of physics potential of the LHC, it is necessary to improve the precision of theoretical predictions.

For most of the important processes at the LHC the uncertainty of theory predictions comes predominantly from unknown effects of the strong interactions that govern both the structure of colliding proton beams and affect the rates of particle production processes. This uncertainty may be reduced by systematic calculations of the corrections due to radiation and quantum effects of virtual gluons and quarks in Quantum Chromodynamics (QCD), and by independent measuring and theoretically constraining the proton structure.

In this project we shall apply two complementary approaches to reduce theoretical uncertainty of predictions for production of heavy quarks and electroweak bosons at the LHC. (i) The quantum corrections due to virtual gluons and gluon radiation will be resummed to all orders in the strong coupling constant using a strong field-theoretical technique of the soft gluon resummation. In many important cases this method was found to provide most accurate predictions for particle production rates and kinematic distributions. In the current project recent extension of this method will be explored, to a new class of particle scattering processes — with three particles in the final state. (ii) In the description of the proton structure in electroweak boson production processes effects of the transverse momentum of quarks and gluons will be taken into account, that are neglected in the standard collinear approximation. One expects that the inclusion of the transverse momentum into the analysis will lead to a better theoretical description of the kinematic distributions of electroweak bosons produced at the LHC. Moreover, the new data from the Large Hadron Collider will be used to a more accurate determination of the transverse momentum distribution of gluons and quarks in the proton, hence to better understanding of the proton structure.